Vision Sciences Society

Third Annual Meeting
May 9-14, 2003
Sarasota, Florida

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Tom Sanocki

Web Services
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Shauney Wilson

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David Knill  Tatiana Pasternak
Ken Nakayama  Tom Sanocki

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Patrick Cavanagh  Jack Loomis
Marvin Chun  Jitendra Malik
Heiner Deubel  Cathleen Moore
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Isabel Gauthier  Tony Norcia
Charles Gilbert  Alice O'Toole

Covers by Shinki Ando, Program by Shauney Wilson
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Program Summary

Friday

Poster Session – Municipal Auditorium
“Something For Everyone”
Authors Present: 5:00 – 8:00 pm

Texture, Motion: Temporal Factors, Spatial Vision: Orientation, Clinical, Space Perception, Search, Scene Perception, Perceptual Organization, Perceptual Learning, Perception and Action, Object Recognition, Motion 1: Integration & Disorders, Lightness/Shading, Face Perception, Eye Movement Cognitive, Color, Binocular Vision: Stereo, Binocular vision: Rivalry, Attention 1
Attending to Scenes – North Hall
What could over 1000 Internet users tell us about visual attention in natural...  
9:00 Parkhurst, Niebur
A dynamic computational model of goal-directed visual perception  
9:15 Hanker
Top-down control of visual attention in real world scenes  
9:30 Oliva, Torralba, Castelhano, Henderson
I WILL use the channel I want: flexible spatial scale processing  
9:45 Ogzen, Soeren, Schyns
Different rates of memory formation for scenes with positive and negative...  
10:00 Maljkovic, Martini
How opiate activity may determine spontaneous visual selection  
10:15 Vessel, Biederman, Cohen

Space Perception – North Hall
What is stored in the sensorimotor visual system: map or egocentric ...  
10:45 Bridgeman, Dawsonville, Bala, Thiem
Lost in virtual space: estimating state uncertainty  
11:00 Stankiewicz, McCabe, Kelly, Legge
The role of effort and intention in distance perception  
11:15 Witt, Proffitt, Epstein
The effects of restricted viewing conditions on egocentric distance judgments  
11:30 Creem-Regehr, Willenssen, Gooch, Thompson
Interactions of motion parallax and ground contact in specifying distance in...  
11:45 Ni, Braunstein, Andersen
Compression of distance judgments when viewing virtual environments...  
12:00 Thompson, Gooch, Willenssen, Creem-Regehr, Loomis, Beall

Visual STM – North Hall
Visual short-term memory capacity for orientations is lower for oriented...  
1:30 Atoyou, Cavanagh
Limitations of visual memory in spatial frequency discrimination  
1:45 Wright, Alston
Placing objects at different depths increases visual short-term memory...  
2:00 Xu, Nakayama
Task relevance of object features modulates the content of visual working...  
2:15 Drol, Hague, Triesch, Sullivan
Eye Movements are Cheaper than Memory: Evidence from a Scene...  
2:30 Gajewski, Henderson
Incidental memory in visual search: both targets and rejected distractors...  
2:45 Williams, Henderson, Zacks

Attention Mechanisms – North Hall
Competitive selection of superimposed stimuli moving through space  
3:15 Fallah, Stoner, Reynolds
Macaque area V4 neurons translate the attended features of a visual...  
3:30 mirabella, Samengo, Bertini, Kilavik, Frilli, Fanini, Chelazzi
The monkey’s lateral intraparietal area: parallel representations and...  
3:45 Gottlieb
Toward an embedded process metathesis of selective attention  
4:00 Lach, Vogel, Woodman, Hyun
Search for motion direction: pop-out and set-size dependencies explained...  
4:15 Burr, Veghese, Morrone, Baldassi
Perisaccadic V1 activity is not due to shifting visuo-spatial attention  
4:30 Vallines, Bodis-Wollner, Oezyurt, Rutschmann, Greenlee

Spatial Vision – South Hall
Adaptation to sine-wave gratings selectively reduces the sensory gain of the...  
9:00 Dao, Lu, Dosher
Origins of the nonlinearity near threshold  
9:15 Kontsevich, Tyler
Noise detection: bandwidth uncertainty and adjustable channels  
9:30 Taylor, Bennett, Sekuler
External noise yields a surprise: What template?  
9:45 Klein, Levi
Perception of ellipse orientation: data and bayesian model  
10:00 Dijkstra, Liu, Oomes
STICKS: Image-representation via non-local comparisons  
10:15 Balas, Siiva

Early Visual Processing – South Hall
Origins of size tuning in LGN neurons  
10:45 Torralba, Carandini
Linear and nonlinear orientation dynamics of receptive fields in cat area 17  
11:00 Repucci, Mechler, Victor
Orientation selectivity in V1 of alert monkeys  
11:15 Gur, Kagan, Snodderly
A new quantitative analysis of simple cell space-time receptive fields  
11:30 Westover, Anderson, DeAngelis
Transformation of perceptual activity into saccade-related activity in the...  
11:45 Sper, Spekreijse, Lamme
Chromatic tuning of binocular neurons in early visual cortex  
12:00 Petrou, Solomon, Forte, Krauskopf, Lennie

Multisensory Integration – South Hall
A biologically plausible model of cue combination  
1:30 Banks, Ernst
Learning to fuse unrelated cues  
1:45 Ernst, Jäkel
Visual cortex as a site of cross-modal integration  
2:00 Shams, Tanaka, Rees, Iwaki, Shimojo, Inui
Recalibration of audiovisual simultaneity by adaptation to a constant time lag  
2:15 Fujisaki, Shimojo, Kashano, Nishida
Kinesthetic Visual Capture Induced by Apparent Motion  
2:30 Somers, McNally
Multisensory integration in self-motion  
2:45 Sun, Campos, Chan, Zhang, Lee

Natural Images – South Hall
Ecological Statistics of Grouping by Similarity  
3:15 Fowlkes, Martin, Malik
Independent component analysis of natural time-varying images under the...  
3:30 Dastjerdi, Dong
No suppression, only dynamic decorrelation: saccadic effects on the visual...  
3:45 Dong, Simpson, Weyand
Extra-classical receptive field properties: Relation to natural scene...  
4:00 Zetzsche, Nuding
Effects of image structure on perceived contrast and cortical activity in...  
4:15 Olman, Ugrinov, Kersten
Textural statistics and surface perception  
4:30 Adelson

Poster Session – Municipal Auditorium
Authors Present: 5:00 – 7:00 pm
**Sunday**

**Binocular Vision – North Hall**
- Depth-dependent contrast gain-control  
  9:00  Aslin, Jacobs, Battaglia
- Motion prolongs perceptual dominance during binocular rivalry  
  9:15  Blake, Sobel
- Traveling waves of activity in V1 correlate with perceptual dominance during...  
  9:30  Lee, Blake, Heeger
- A dynamical hierarchy of rivalry stages in vision  
  9:45  Wilson
- Fractal statistics of perceptual switching time series.
  10:00  White, Gao, Zhou
- Stochastic resonance in bistable binocular rivalry.
  10:15  Kim, Grabovecky, Suzuki

**Lighting and Shading – South Hall**
- Lightness constancy in 4-month-old infants: The effect of a local luminance...
  9:00  Chien, Bronson-Castain
- The highest luminance anchoring rule in lightness perception: A...
  9:15  Rudd, Zemach
- fMRI of brightness perception.
  9:30  Cornelissen, Wade, Dougherty, Wandell
- Layered image representations and the perception of lightness.
  9:45  Anderson, Winawer
- How does the perception of shape interact with the perception of shiny...
  10:00  Hartung, Kersten
- Blackshot: An unexpected dimension of human sensitivity to contrast.
  10:15  Landy, Chubb, Econopouly

**Stereo – North Hall**
- Sensitivity to interocular delay in binocular V1 neurons.
  10:45  Cumming, Read
- Reduced binocular disparity selectivity of V4 neurons to anti-correlated...
  11:00  Tanabe, Fujita
- The cost of resolving stereo ambiguity.
  11:15  McKee, Farell, Vergnese
- The effect of absolute and relative disparity noise on stereocuity.
  11:30  Foulkes, Parker
- Disparity gradient between the target and its surroundings defines depth...
  11:45  Petroc, Glennerster
- Focus cues to display distance affect perceived depth from disparity.
  12:00  Watt, Akeley, Banks

**Eye Movements - Cognitive – South Hall**
- Flashing scenes and moving windows: An effect of initial scene gist on eye...
  10:45  Castelhano, Henderson
- Visual search: Gaze contingent displays and optimal search strategies.
  11:00  Geisler, Perry, Najemnik
- The accumulation of visual information driving the 1st saccade during visual...
  11:15  Caspi, Beutter, Eckstein
- Target tagging in visual search.
  11:30  Körner, Gilchrist
- Dynamic allocation of visual attention during the execution of sequences of...
  11:45  Gersch, Kovler, Dosher
- Saccadic decision-rate distributions reveal competition process.
  12:00  Beintema, Van Loan, Hooge, Van den Berg

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**Shape and Depth – North Hall**
- How image statistics drive shape-from-texture and shape-from-specularity.
  3:30  Fleming, Torralba, Dvor, Adelson
- Can we see the shape of a mirror?
  3:45  Swarese, Li, Penza
- The influence of object orientation and shading on pictorial relief of...
  4:00  Nefs, Koenderik, Kappers
- 3D shape-colour interactions in a real object similarity task.
  4:15  Ling, Hurlbert
- Depth and size scaling created by the differential perspective of ground plane...
  4:30  Rogers
- A new kind of global stereopsis: The ability to determine slant or occlusion,...
  4:45  Gillam, Grover
- Flexible patches for recovering surfaces from binocular disparity.
  5:00  Vuong, Domini, Caudek
- Slant anisotropy and tilt-dependent variations in stereo precision.
  5:15  Ghose, Hils, Landy, Banks

**Biological Motion – South Hall**
- Brain activity reflects perceptual learning of point-light biological motion.
  3:30  Grossman, Kim, Blake
- Biological motion perception is impaired in unilateral parietal patients.
  3:45  Battelli, Cavanaugh, Thornton
- Metric category spaces of biological motion.
  4:00  Giese, Thornton, Edelman
- Role of learning in biological motion recognition.
  4:15  Jastorff, Kourtzi, Giese
- Critical features for biological motion.
  4:30  Castile, Giese
- Gender and attractiveness from biological motion.
  4:45  Troje
- Inversion effects on the structural encoding and recognition of biological...
  5:00  Jokiich, Troje, Kress, Daum
- Walk with me: Self-relative gait speed judgments are influenced by observer...
  5:15  Jacobs, Shiffrar

**Poster Session – Municipal Auditorium**
Authors Present: 1:30 – 3:30 pm
- Surfaces, Space Perception, Object Recognition, Natural Images, Motion 3: Low-level, Time, Biological, Locomotion, Attention 3, Adaptation/Aftereffects

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  5:15  Jacobs, Shiffrar

**Keynote Speaker** – Ruediger Wehner,
“Multifaceted Vision: How Desert Ants navigate - Mini Brains, Mega Tasks, Smart Solutions”
6:00 pm, South Hall
Monday

**Face Perception 1 – North Hall**

Is there a relationship between the band of spatial frequencies critical for face...  
9:00  Boutet, Collin, Faubert  
Integration of low and high frequency information in facial recognition  
9:15  Ostrovsky, Sinha  
Face specific processing: role of local features in an affine metric  
9:30  Nakayama  
When misaligned faces are processed holistically  
9:45  Gauthier, Tanaka, Brown  
Invariance to contrast inversion when matching objects with face-like surface...  
10:00  Nederhouser, Mangini, Biederman, Okada  
Superstitious perceptions of a face revealed by non phase-locked gamma...  
10:15  Goffaux, Jacques, Mouraux, Gosselin, Schyns, Rossion

**Motion and Depth – South Hall**

Perception of binocular 3-D motion: visual direction is more important than...  
9:00  Harris, Dean  
Task-specific contribution of area MT to stereoscopic depth discrimination  
9:15  Ula, DeAngelis  
Is depth perception of stereo plaids predicted by intersection of constraints...  
9:30  Delicato, Qian  
Widespread cortical specializations for disparate lateral motion  
9:45  Tyler, Likova, Wade  
Analysing optic flow generated by locomotion through a natural environment  
10:00  Zanker, Zell  
Simultaneous computation of heading and depth in the presence of rotations...  
10:15  Royden, Picone

**Face Perception 2 – North Hall**

Neural responses to contextually defined faces  
10:45  Meyers, Cox, Sinha  
Isolating Face-Dependent and Face-Independent Processing of Expression...  
11:00  Ganel, Goshen-Gottstein, Goodale  
Normal object discrimination in a developmental prosopagnosic  
11:15  Duchaine, Nakayama, Barahimi, Stefansic, Shima, Kaszniak, Bonds, Casagrande  
Face classification following long-term visual deprivation  
11:30  Sinha  
Faces versus expertise: Early maturity of face recognition in children.  
11:45  McKone, Gilchrist  
Selective tuning of face perception  
12:00  Ng, Kaping, Anstis, Fine

**Cortical Organization – South Hall**

Spatial frequency preference maps of primate visual cortex revealed by...  
10:45  Xu, Boyd, Gallucci, Thomas, Emeric, Barahimi, Stefansic, Shima, Melzer, Allison, Bonds, Casagrande  
Cortical columns without a function  
11:00  Adams, Horton  
An fMRI method for identifying the sequential stages of processing in the...  
11:15  Tjan, Lestou, Bulthoff, Kourtzi  
The cortical magnification factor for area V4  
11:30  Motter  
Flexible retinotopy: Motion dependent position coding in visual cortex  
11:45  Whitney, Goltz, Goodale  
Monocular retinotopic mapping in amblyopic adults  
12:00  Conner, Schwartz, Odson, Mendola

**Business Meeting – South Hall**

12:15 – 1:15 pm

**Poster Session – Municipal Auditorium**

Authors Present: 2:30 – 4:30 pm  
Texture, Synesthesia, Search, Scene Perception, Perceptual Organization, Perceptual Learning, Memory, Eye Movement Cognitive, Color, Attention 4

**Contours – North Hall**

Learning to optimally detect image boundaries using brightness, color and...  
4:30  Martin, Fowlkes, Malik  
Modeling cortical mechanisms of border ownership coding  
4:45  Schuetze, Niebur, von der Heydt  
Interaction of Border ownership and transparency in monkey visual cortex  
5:00  Qu, von der Heydt  
Revisiting Ebenbreite  
5:15  Gerbino, Volcic  
The costs and benefits of grouping along a contour  
5:30  Vergese  
The efficiency of contour grouping  
5:45  Elder, Morgenstern, Tavone  
What limits thresholds for contours in noise --- contour response strength or...  
6:00  Norcia, Sampath  
Good continuation and relatability: Related but distinct principles  
6:15  Killman, Stapley, Garrigan  
Contour grouping: Is there something special about closed contours?  
6:30  Torsky, Geisler

**Visuo-motor Control – South Hall**

Illusory positional shifts affect both perception and action  
4:30  Ma-Wyatt, McGraw  
Look ahead fixations and visuo-motor planning  
4:45  Mennie, Hayhoe, Sullivan, Walthe  
Spatial memory use and coordination of eye, head, and hand movements.  
5:00  Hayhoe, Aivar, Novacovic  
Eye-centered remapping of remembered visual space in human parietal cortex  
5:15  Medendorp, Gotts, Vilis, Crawford  
Grasping and representational momentum  
5:30  Brouwer, Franz, Thornton  
Grasp effects of visual illusions: Dynamic or stationary?  
5:45  Franz, Scharnowski  
FMRI confirmation of a neurological dissociation between perceiving objects...  
6:00  Goodale, James, Culham, Humphrey, Milner  
When uncertainty matters: The selection of rapid goal-directed movements  
6:15  Trommershausen, Maloney, Landy

**Special Session**

Richard Gregory “Phenomenal Phenomena Classified” 7:00 pm, South Hall  
Video Demonstrations 7:15 pm, South Hall
Tuesday

Locomotion – North Hall

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<td>9:00</td>
<td>Enriquez, Andersen, Sauer</td>
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<td>Loomis, Beall</td>
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<td>Philbeck, O’Leary, Lew</td>
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<td>Warren, Di, Fajen</td>
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<td>10:00</td>
<td>Fink, Foo, Warren Jr.</td>
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<td>Legge, Mason, Brady, Giudice, Schlicht</td>
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Control of Eye Movements – North Hall

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<td>10:45</td>
<td>Stevenson, Mulligan, Cormack</td>
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<td>Liston, Chukoskie, Krauzlis</td>
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<td>Vishwanath, Kowler</td>
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<td>Connolly, Goodale, Goltz, Munoz</td>
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<td>DeAngelis, Wei, Angiakli</td>
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Poster Session – Municipal Auditorium

Authors Present: 2:30 – 4:30 pm

Temporal Processing, Perceptual Organization, Multimodal: Touch, Sound, & Integration, Motion 4: Shape & Depth, Letters/Reading, Face Perception, Depth/3D Shape, Depth & Motion, Attention 5

Attention 1 – North Hall

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<td>Hochstein, Sheiner</td>
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<td>Scholl, Nolte, Palhenu, Sussman</td>
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<td>Strayer, Drees, Johnston</td>
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<td>Dickinson, Chen, Zelinsky</td>
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<td>Carrasco, Giordano, McClure</td>
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<td>van Ee, van Dam, Brouwer, Korsten</td>
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Motion 1 – North Hall

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<td>Yeshurun, Levy</td>
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<td>Carlson, Schrater, He</td>
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<td>Verstraten, Kanai, Paffn, Gerbino</td>
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<td>Melcher, Morrone</td>
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Color – South Hall

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<tr>
<td>9:00</td>
<td>Troscianko, Baddeley, Parraga, Leonards, Troscianko</td>
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<td>Solomon, Peirce, Krauskopf, Lennie</td>
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<td>Shevell, Montier</td>
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<td>Teller, Civan, Bronson-Castain, Perceverza</td>
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Visual Cortical Coding – South Hall

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<tr>
<td>10:45</td>
<td>Braddick, O’Brien, Rees, Wattam-Bell, Atkinson, Turner</td>
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<td>Smith, Williams, Singh</td>
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<td>Samonds, Allison, Broan, Bonds</td>
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<td>Vanni, Dojat, Warring, Segebarth, Baller</td>
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Learning and Plasticity 1 – South Hall

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<td>Yu, Klein, Levi</td>
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<td>Gold</td>
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<td>Fiser, Aslin</td>
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<td>Bawelier, Green</td>
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<td>Eckstein, Pham, Shimozaki</td>
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<td>Tanaka, Miyauchi, Imauoka, Misaki, Matsumoto, Tashiro</td>
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Learning and Plasticity 2 – South Hall

<table>
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<tr>
<td>6:15</td>
<td>Sagi, Adini, Tsadyks, Wilkowsky</td>
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<td>Chun, Yi, Kelley, Marois</td>
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<td>Melnick, Nakauma, Stickgold</td>
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Learning and Plasticity 2 – South Hall

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**Wednesday**

### Attention/Switching – North Hall

**Sustained attention-related activity in primary visual cortex**
9:00  Silver, Ress, Hoeger

**Comparing the temporal dynamics of intra- and cross-modal attention...**
9:15  Lesmes, Lu, Dosher, Sperling

**Rapid visual search during slow attentional shifts**
9:30  Horowitz, Birnkrant, Wolfe

**The temporal dynamics of attention in a spatial cueing task revealed by...**
9:45  Chen, Eckstein, Shimozaki

**Detecting patterns of covert attention shifts in psychophysical tasks using...**
10:00  Hafed, Clark

**A linear cue combination framework for understanding selective attention**
10:15  Murray, Sekuler, Bennett

### Object Recognition – North Hall

**Integration of local features into global shapes: monkey and human fMRI...**
10:45  Kourtzi, Tolias, Altmann, Augath, Logothetis

**The rise and fall of visual priming**
11:00  Zago, Bar

**Classification-based approaches to the analysis of functional neuroimaging...**
11:15  O’Toole, Haxby, Abdi

**Reading word “airplane” is seeing object “airplane” in the right cerebral...**
11:30  Wang, Yen, Wang

**Object recognition by Dynamic Link Matching in biologically realistic time**
11:45  Zhu, von der Malsburg

**Object recognition by scene alignment**
12:00  Torralba, Oliva, Freeman

**fMRI studies of multi-modal semantic knowledge using artificial concepts**
12:15  James, Gauthier

### Temporal Factors – South Hall

**Perceptual binding of letters into words is low temporal resolution**
9:00  Holcombe

**Flash lag in depth**
9:15  Harris, Kopinska, Duke

**High temporal precision for perceiving event offsets**
9:30  Tadin, Lappin, Blake

**Attentive tracking can modulate the illusory misalignment of a flash**
9:45  Shim, Cavanagh

**Motion-biasing, not asynchronous feature binding, explains the feature-flash...**
10:00  Eaglesman, Sejnowski

**Distorting Time With Motion**
10:15  Arnold, Clifford, Johnston

### Motion 2 – South Hall

**Single neuron sensitivity for a fine motion discrimination task**
10:45  Purushothaman, Bradley

**Correlation between MT activity and behavioral judgment of visual speed in...**
11:00  Liu, Newsome

**Fourier motion energy analysis in macaque MT**
11:15  Krekelberg, Dobkins, Albright

**A neural substrate for illusory motion induced by static orientation: ...**
11:30  Bair, Movshon

**S-cone input into global motion processing**
11:45  Rappelisberg, Wuerger, Bertamini

**Infants integrate local motion**
12:00  Dobkins, Fine, Hsueh, Vitten

**Differential development of form and motion perception in monkeys**
12:15  Kiorpes, Movshon
Talks

Attending to Scenes

Saturday, May 10, 2003 9:00 – 10:30 am
North Hall

Moderator: Vera Maljkovic

9:00  Parkhurst, Niebur, TA1
9:15  Hamker, TA2
9:30  Oliva, Torralba, Castelhano, Henderson, TA3
9:45  Özgen, Sowden, Schyns, TA4
10:00 Maljkovic, Martini, TA5
10:15  Vessel, Biederman, Cohen, TA6

TA1
What could over 1000 Internet users tell us about visual attention in natural scenes? Derrick J Parkhurst (derrick.parkhurst@jhu.edu), Ernst Niebur; The Mind/Brain Institute, The Johns Hopkins University, USA – To study how visual attention is allocated in complex scenes under normal viewing conditions, we conducted a behavioral experiment on the Internet. Over 1000 participants used their web browser to view a series of natural and artificial scenes including landscapes, home interiors, city scenes and fractals, and were asked to select the five most interesting points in the image. Voluntary participation was solicited in science-oriented news groups and through popular Internet press articles. We found a high degree of variability in the reaction times (M=3.3s, SD=5.8s) but a surprisingly high degree of consistency in the selected locations. Their average nearest-neighbor distance was significantly less than that expected chance, indicating clustering. This distance was smallest for early selections and increased monotonically for later selections. An increase in the number of discrete clusters was also observed for later selections. We hypothesized that the greater similarity of chosen locations for early selections was due to the influence of bottom-up, stimulus-dependent factors while the greater diversity of selected locations for later locations was due to the influence of top-down, cognitive factors. To test this hypothesis, we compared the most salient locations in each natural scene, as determined by a purely stimulus-driven computational model of visual selective attention (Parkhurst, Law & Niebur, Vision Research 2002), to the selected locations. The salient locations are most strongly correlated with the first selections and this correlation declines with later selections. These results suggest that stimulus properties can influence attentional allocation even on a long time scale (many seconds) as in this experiment. Finally, we find that conducting behavioral experiments over the Internet with volunteer participants is technically feasible, practical and can provide a potentially large amount of useful experimental data.

Acknowledgment: Support: a NIH/NEI visual neuroscience training fellowship to DP and a NSF CAREER grant to EN
http://cnslab.nib.jhu.edu/~derrick/osc2003

TA2
A dynamic computational model of goal-directed visual perception Fred H Hamker (fred@klab.caltech.edu); Caltech, USA – Change blindness experiments suggest that we do not construct a fully elaborated representation of the external world. I present here a novel computational model to explain how higher cognitive processes influence early visual processing, in order to access the external world. Notably, within this model visual attention is not explicitly implemented, but rather emerges as a natural consequence of competitive interactions between brain regions (specifically, in this case, V4, IT, FEF and PFC).

It is proposed that visual areas first acquire information about the scene by processing visual stimuli in a parallel bottom-up manner and acquire a more detailed knowledge about an object of interest by feedback. Activity from the ventral pathway then converges onto premotor neurons to enforce behavioral decisions (in this case FEF movement cells), which in turn are fed back onto cells in the ventral pathway. This reentrant activity has the effect of implementing a spatially organized gain control of the item of interest. This model successfully replicates previously collected data from single-cell recordings in IT and V4 from a macaque visual search task (Chelazzi, Duncan, Miller, Desimone, J. Neurophysiol. 1998; Chelazzi et al., Cereb Cortex 2001). It predicts that the late target discrimination around 150ms after scene onset, often identified with conscious processing, is based on reentry from premotor neurons. The model is also consistent with other recordings in FEF (Schall, Philos Trans R Soc Lond B Biol Sci 2002). Moreover, by representing visual features as populations of active cells, whose activity is dynamically modulated in a parallel manner, this model offers an efficient solution to the problem of target localization within a cluttered visual display (e.g. natural scenes). Attention is not a prerequisite for object recognition but the dynamics resolve the ambiguities within active populations.

Acknowledgment: This work was supported by DFG HA2630/2-1 and in part by the ERC Program of the NSF (EEC-9402726).

TA3
Top-down control of visual attention in real world scenes Aude Oliva1 (aoliva@msu.edu), Antonio Torralba2, Monica S Castelhano3, John M Henderson1; 1Department of Psychology, Cognitive Science Program, Michigan State University, USA, 2Artificial Intelligence Laboratory, MIT, USA – During the first glance at a complex scene, attention of the observer is driven towards a particular region in the scene and the first saccade is programmed. Studies in scene recognition have acknowledged that significant structural and spatial layout information is extracted within a glance to form a semantic “gist” of the scene. Therefore, information included in the gist forms a visual context that is likely to modulate in a top-down manner where attention will land in a complex scene image. In this presentation, we extend a computational model of the gist that encodes the coarse spectral layout of a scene image to incorporate attentional guidance mechanisms and generate eye movements. The model uses the statistical correlations that exist between global scene structure (e.g. a street scene is in perspective) and object properties (e.g. location of pedestrian) to define a region of interest in the image that is relevant for solving a task (e.g., looking for people). Eye movements of 8 human observers were monitored, while instructed to search for a specific object (people) in 36 real world scenes. The region of interest scrutinized by observers and determined by the gist guidance schema overlap in more than 85% of the cases. Multiple fixation points (e.g. saccades) within the region of interest were generated by integrating a bottom-up saliency model with the top-down attentional guidance mechanism. Using a set of similarity metrics, we show that the locations of the multiple fixations of attention generated by the integrative model and by human observers
were very similar. The results validate the proposition that top-down information from visual context modulates early the saliency of image regions during the task of object detection.

http://www.msi.edu/~aolvta

TA4
I WILL use the channel I want: flexible spatial scale processing
Emre Özgen1 (e.ozgen@surrey.ac.uk), Paul T Sowden1, Philippe G Schyns2; 1University of Surrey, UK, 2University of Glasgow, UK – Spatial scale processing of natural stimuli (e.g. faces, scenes) can be flexible depending on type of categorization task and prior experience (Gosselin & Schyns, 2001, V. Res., 41, 2261-2271). We argue that attentional modulation of spatial frequency (SF) channels in early vision can account for such flexibility (Sowden, Özgen & Schyns, 2002, J. Vis., 2, 283a). Last year we reported evidence (Özgen, Sowden & Schyns, 2002, J. Vis., 2, 202a) suggesting that such early mechanisms may indeed be involved: we sensitised observers bottom-up to scenes with different SF content at separate retinal locations. Perception of hybrid images (those that contain both a low-pass and a high-pass scene of different categories) was orthogonal at different retinal locations.

Here we explored whether a top-down attentional process could also drive flexible scale use. In a sensitisation stage observers were required to categorise (highway or city) briefly presented low and high-pass filtered scenes that were combined with high and low-pass noise respectively. Prior to each stimulus a symbolic auditory cue (the words “coarse” and “fine”), expected to act top-down, signalled the SF bandwidth that would contain the scene on the next trial. In a subsequent test stage, unknown to observers, we interleaved hybrid images and continued cueing observers to expect a scene at one or the other scale. Orthogonal perceptions of hybrid images depending on the cues suggest that a top-down attentional process can also result in the flexible processing of spatial scale. Such evidence indicates that in contrast to the stimulus-determined attention to separate retinal locations. Perception of hybrid images (those that contain both a low-pass and a high-pass scene of different categories) was orthogonal at different retinal locations.

Acknowledgment: This work was supported by BBSRC Grant No’s 90/S13186, 17/S13185 awarded to Paul Sowden & Philippe Schyns.

TA5
Different rates of memory formation for scenes with positive and negative affective content
Vera Maljkovic1 (v-maljkovic@uchicago.edu), Paolo Martini2; 1The University of Chicago, USA, 2Harvard University, USA – PURPOSE. We have examined the rate of acquisition of information from briefly presented pictures rated to be of different emotional valences to establish the dynamics of perception and short term memory accumulation of emotional content in real-life scenes.

METHODS. Stimuli were color photographs with emotional valence ranging from extremely negative to extremely positive, drawn from the International Affective Picture System set. We used the RSVP procedure to present 8 pictures (different valences interspersed and counterbalanced across subjects) with durations per picture ranging from 13msec to 4sec. Following each 8-picture stream, subjects were shown 16 pictures singly (8 seen and 8 new), and asked to judge whether the given picture was present in the stream they just saw. 96 naïve subjects were tested, and their accuracy data were fitted with Weibull functions to compare the time to criterion performance and the rate of information acquisition for different valence categories.

RESULTS. Asymptotic performance in this task (~ 96% correct) is reached by 2sec of presentation per scene. Performance on both positive and negative stimuli reaches criterion significantly faster than performance on neutral stimuli, as expected given their higher arousal value. The rate of memory acquisition, however, is significantly different for negative and positive scenes. This is seen clearly by examining the derived hazard functions, which show a constant instantaneous rate of memory accumulation for positive and neutral scenes, but an accelerating function for negative scenes.

CONCLUSION. These results demonstrate that negatively tagged information is initially suppressed, but later processed more quickly than information with positive valence. We raise the possibility that human visual short-term memory is affected by a brief “freezing response,” followed by a preferential accelerated encoding of negatively tagged information.

Acknowledgment: NIH EY13155 & Univ. Chicago Soc. Sci. grant to V. Maljkovic

TA6
How opiate activity may determine spontaneous visual selection
Edward A Vessel1 (vessel@usc.edu), Irving Biederman2, Mark S Cohen3; 1University of Southern California, Program in Neuroscience, USA, 2University of Southern California, Department of Psychology, USA, 3University of California, Los Angeles, Brain Mapping Division, USA – People prefer some perceptual inputs to others, an effect readily manifested in visual fixations during free viewing. This preference may be based on the activity of a gradient of μ-opiate receptors (ligand = endomorphin) that, surprisingly, is found in the ventral cortical pathway for visual recognition. This gradient, discovered in the macaque, is sparse in V1 and increases in density through V2, V4, TEO, IT, and the parahippocampal cortex. The magnitude of endomorphin activity would determine perceptual and cognitive preference, resulting in a preference for patterns that are both richly interpretable (because they activate many associations in the opiate rich anterior regions of the ventral pathway) and novel. Repetition of a scene would result in less activity because of competitive interactions. Event related fMRI activity was recorded during the viewing of 1 s presentations of scenes that varied in their rated preference. The scenes were repeated 5 times over the course of the experiment. Highly preferred scenes produced greater BOLD activity than less preferred scenes in more anterior areas of the ventral pathway, such as the parahippocampal cortex, consistent with the endomorphin hypothesis. Both rated preference and parahippocampal activity consistently declined with repetition, further supporting the link between preference and endomorphin activity. The activity in more posterior areas was not closely associated with preference. For example, area LO showed no systematic modulation by preference nor a consistent decline in activity with repetition.

http://geon.usc.edu

Spatial Vision
Saturday, May 10, 2003
9:00 – 10:30 am
South Hall
Moderator: Allison Sekuler

9:00  Dao, Lu, Dosher, TA7
9:15  Kontsevich, Tyler, TA8
9:30  Taylor, Bennett, Sekuler, TA9
9:45  Klein, Levi, TA10
10:00 Dijkstra, Liu, Oomes, TA11
10:15  Balas, Sinha, TA12
Adaptation to sine-wave gratings selectively reduces the sensory gain of the adapted stimuli

Debbie Y' Dou (dda@usc.edu), Zhong-Liu Lu, Barbara A Dosher; Laboratory of Brain Processes (LOBES), University of Southern California, USA—Adapting to sinusoidal gratings selectively reduces contrast sensitivity to subsequent test stimuli (1). To investigate the perceptual processes underlying selective adaptation, we developed an external noise plus adaptation paradigm and a theoretical framework based on a noisy observer model. After adapting to a 45 deg, 2 Hz counter-flickering sine grating of 0.8 contrast, observers performed two-interval-forced-choice detection of Gabors of matched spatial frequency, tilted either at 45 or 135 deg, and embedded in one of six levels of external noise. Each session began with 2 min of adaptation, and test trials included 6 sec of re-adaptation and two 133 ms test intervals. The psychometric functions for tests of 45 deg without adaptation, and 135 deg with and without adaptation essentially overlapped. The tests of 45 deg after adaptation produced a 92.5% and a 90.8% threshold increase in the zero and highest external noise conditions. A contrast-gain control perceptual template model (cgPTM) was developed and tested. The cgPTM consists of a perceptual template, transducer non-linearity, contrast gain control, pre- and post gain control internal noises, and a decision structure. At the overall input and output level, the cgPTM is mathematically equivalent to an earlier version of the PTM that uses multiplicative noise in place of contrast gain control (2). In either framework, adaptation selectively reduces the gain of the perceptual template at the adapted spatial frequency and orientation without altering either pre- or post gain control (additive and multiplicative) noises, or changing transducer nonlinearity. The theoretical framework and the inferred mechanism of adaptation are fully consistent with the theory of adaptation proposed by Wilson & Humanksi (3). We conclude that adaptation selectively reduces the sensory gain to the adapted stimuli.


Acknowledgment: Supported by US AFOSR, NSF & NIMH.

Origins of the nonlinearity near threshold

Leonid L Kontsevich (lenny@ski.org), Christopher W Tyler; Smith-Kettlewell Eye Research Institute, USA—There is a long-standing controversy about the origin of nonlinear behavior of the visual system near detection threshold: whether it is due to a nonlinear transducer or it is due to uncertainty-related effects. Solving this problem is critical for interpreting the visual contrast sensitivity results, which constitute a substantial part of modern psychophysics. In the first experiment we show that presenting a test stimulus in an aperture surrounded by darker field has profound effect on the nonlinearity: for light Gaussian blobs the nonlinearity starts operating in positive contrast range while at zero contrast the transducer becomes effectively linear. In the second experiment we measured psychometric function for contrast detection of a monocularly-presented Gaussian blob superimposed on a pedestal presented either in the same or the other eye. We find that for monoptic stimulation the detectability corresponds to a linear transducer, whereas for dichoptic stimulation the transducer is accelerating with an exponent of about 1.6.

The first experiment shows that the nonlinearity occurs before or within a luminance gain control stage, which precedes cortical visual processing. The second experiment indicates that the nonlinearity is located before binocular summation stage. Both experiments refute uncertainty as the principal explanation for the contrast transducer nonlinearity and indicate that it has a pre-cortical origin.

Acknowledgment: This study was supported by NIH grant EY7890

Noise detection: bandwidth uncertainty and adjustable channels

Christopher P Taylor (taylorcp@mcmaster.ca), Patrick J Bennett, Allison B Sekuler; McMaster University, Canada—Previous work (Kersten, 1987) has shown that the detection of band-pass noise patterns is well described by an ideal observer, indicating that observers can integrate spatial frequency information efficiently over a six-octave wide band. One interpretation of this result is that observers use a channel with an adjustable bandwidth (Green, 1960) that matches the bandwidth of the signal when detecting band-pass noise. To investigate the notion that observers use adjustable bandwidth channels for spatial frequency, we had observers perform a noise detection task under two conditions: an uncertainty condition where the bandwidth of the noise could vary from trial to trial and a blocked condition where the bandwidth of the signal was held constant during a block. We used horizontal, one-dimensional, band-pass noise patterns that were Gaussian windowed. The center-frequency of the noise was 5 cycles/degree and bandwidth varied from one-half to four octaves. Seven bandwidths were used and a detection threshold measured at each bandwidth for both the blocked and uncertainty conditions. Stimuli were presented for 200ms. At each bandwidth, three 150 trial thresholds were collected. Noise detection i.m.s. contrast thresholds increase with the fourth-root of bandwidth for the ideal observer. For our blocked condition, we again found that human observers’ noise detection thresholds increase with the fourth-root of bandwidth (Kersten, 1987). Under conditions of bandwidth uncertainty, we found that detection thresholds continued to increase with the fourth-root of bandwidth. Our results support the notion that when detecting wide-band noise patterns, observers can adjust the band of spatial frequencies they use from trial to trial and select the frequency band efficiently. To explore adjustable channels further, we are investigating the effects of stimulus duration, center-frequency uncertainty and the combination of center-frequency and bandwidth uncertainty on noise detection.

Acknowledgment: Supported by NSERC grants OGP0042133 & OGP0105494

External noise yields a surprise: What template? Stanley A Klein (klein@spectacle.berkeley.edu), Dennis M Lent; School of Optometry, UC Berkeley, USA—Detection and discrimination of signals in external noise can provide a wealth of information about suprathreshold processing. Recently a number of researchers (including us) have used external noise to calculate the classification image that is presumably an estimate of the observer’s template. Here we call into question the fixed template framework.

We measured the detection and discrimination of a Gabor-like patch in the presence of external noise using a double-pass method. Our grating stimulus was: cos(ωx y)10cos(12ωx y) for y going from -0.5 to +0.5 deg. This is the sum of 11 harmonics from 1 to 11 c/deg. The superimposed noise was the sum of the same 11 harmonics with random amplitudes and random phase. The rms noise contrast was equal across components and varied over a wide range across runs. A rating scale method of constant stimuli was used. Linear regression of the observer’s responses on the eleven cosine noise components gives an accurate classification image (with far fewer trials than with the cross-correlation method). The experiment is repeated using identical random noise and identical stimuli. The consistency of the responses to the identical stimuli is used to estimate the ratio, R, specifying the consistent vs. the random component of multiplicative noise. An alternative method for calculating R is based on the ratio of the observer’s d’ divided by the d’ of an ideal observer using the observer’s classification template.

Our experimental results show that for both detection and discrimination, R, determined by the double pass method is about half of R determined by the d’ ratio. That is, the double pass method shows much more consistency
of responses than would be expected from the observers’ d’. The simplest explanation is that rather than there being a single template, the multichannel model is still operating at suprathreshold levels. Different channels are optimal on different trials producing a consistent, but inefficient response.

Acknowledgment: NIH R01 EY04776, R01 EY01728

cornea.berkeley.edu/presentations

TA12
STICKS: Image-representation via non-local comparisons
Benjamin J Balas (bjbalas@mit.edu), Pawan Sinha; Massachusetts Institute of Technology, USA – A fundamental question in visual neuroscience is how to represent image structure. The most commonly used representation schemes rely on spatially localized differential operators, approximated as Gabor filters with a set of excitatory and inhibitory lobes, which compare adjacent regions of an image. While well-suited to encoding local relationships, such operators have significant drawbacks. Specifically, they appear to be robust against significant image degradations such as poor spatial resolution and quantization of contrast levels. Based on these results, we believe that the sticks operator can serve as an effective scheme for representing image structure.

TA13
What is stored in the sensorimotor visual system: map or egocentric calibration? Bruce Bridgeman1 (bruceb@usc.edu), Paul Dassonville2, Jagdeep Bala2, Paul Thiem1, 1University of California, Santa Cruz, Ca, USA, 2University of Oregon, Eugene, Or USA – A tool used to differentiate the functions of cognitive “perceptual” and sensorimotor “action” visual systems has been the induced Roelofs effect, the misperception of a target’s location induced by a large frame, offset from a subject’s midline. The target is perceived to deviate in the direction opposite the frame’s offset (a cognitive task), though observers could accurately jab the target’s location (a sensorimotor task) (Bridgeman et al., VR 2000). A reinterpretation by Dassonville & Bala suggests that the Roelofs effect is caused by a frame-induced but unconscious deviation of the apparent midline. Using gaze rather than finger jab, Dassonville and Bala replicated four effects found by Bridgeman et al. (perceived Roelofs effect, delayed perceived Roelofs effect, no Roelofs effect in immediate pointing, Roelofs effect in delayed pointing) and explained them by apparent midline shifts, because gaze is calibrated to a midline shifted in the direction of the frame, compensating for the Roelofs illusion in the direction opposite the frame. After a few seconds in darkness, the apparent midline shifts back to the center, restoring the motor illusion. Thus both the two-visual-systems theory and the midline shift theory explain all four effects. Dassonville and Bridgeman developed a condition that yields different predictions in the two theories. An antijab in the direction symmetrically opposite the target’s deviation from straight ahead should yield a Roelofs effect of twice the perceived illusion amplitude in the midline shift theory, but no Roelofs effect in the two-visual-systems theory. In both Bridgeman’s and Dassonville’s lab, antijab or antagonist tasks unambiguously yielded twice the cognitive effect, supporting the midline shift theory. Amplitudes of the perceived Roelofs effect and the frame-induced straight-ahead shift were correlated in both labs. Thus the sensorimotor system stores an egocentric calibration but not a complete map of visual objects.
Lost in virtual space: estimating state uncertainty

Brian J Stankiewicz1 (bstankie@psg.utexas.edu), Matthew McCabe1, Tara Kelly2, Gordon E. Legge2,1 University of Texas, Austin, 2 University of Minnesota, Twin Cities—The current study investigates the cognitive limitations associated with navigating through familiar indoor environments. To better address this question we developed an ideal navigator to measure human action efficiencies. Previous studies have found that humans are inefficient at navigating through large-scale indoor environments. The current studies investigate whether the inefficiencies in navigation are due to accessing the cognitive map from memory, accurately estimating their position in the environment or their action decision strategy. To investigate this question we trained and tested subjects using first-person desktop virtual reality in randomly generated indoor environments. We first trained subjects in the environments until they reached criterion. Subjects were then tested by placing them at random locations within the environment with the instructions to go to a target location in the minimum number of actions (where an action was defined as a rotation or a translation). Human performance was measured by a wayfinding ratio (#actions ideal/#actions), a measure analogous to statistical efficiency. To determine whether navigation inefficiencies were due to accessing a cognitive map, estimating their position or their action strategy, we supplemented the display with a map image. There were three conditions: No Map; Map; Map+Belief Vector. In the Map condition a map of the environment was shown in the lower left corner of the computer display. In the Map+Belief Vector condition there was a map plus a series of symbols superimposed on the map indicating where the subject could be located in the environment given the subject’s previous actions and views. There was no difference in the navigation efficiencies between the No-Map and Map condition (efficiency = ~45%) but there was a significant increase between the Map and the Map+Belief Vector condition ( ~85%). This result suggests that subjects are inefficient at accurately estimating their position within a large-scale indoor environment.

Acknowledgment: Supported by NIH Grant EY102857 to GEL and University of Texas Summer Research Award to BJS

The role of effort and intention in distance perception

Jessica K Witt (jkw2ex@virginia.edu), Dennis R Proffitt, William Epstein; University of Virginia—Perception is a function of distal cues in the environment, what the perceiver is intending to do, and the effort associated with the intended action. Previous research demonstrates that effort for walking influences perception of slant and perception of distance (Proffitt et al, 1995; Proffitt et al, in press). First, we demonstrate that effort for other behaviors such as throwing influences perception. Second, we demonstrate that only effort for the intended action influences perception. We propose a model of perception in which perception and action are tightly connected. The environment is perceived in terms of the actions a perceiver is intending to perform and her ability to perform these actions. We argue that perception is tracking intended actions and the effort associated with these actions in order to plan actions that regulate energy expenditure.

The effects of restricted viewing conditions on egocentric distance judgments

Sarah H Creem-Regehr1 (sarah.creem@psych.utah.edu), Peter Willemsen2, Amy A Gooch2, William B Thompson2, 1Psychology Department, University of Utah, Salt Lake City, UT, 2School of Computing, University of Utah, Salt Lake City, UT—Egocentric distance perception under full-cue conditions has been shown to be accurate as revealed though visually directed action tasks. The present studies assessed the necessity of 1) binocular disparity, 2) full field of view and 3) seeing one's body standing on the ground plane, for accurate scaling of egocentric space at distances from 5 to 15 meters. An investigation of these viewing conditions is especially relevant to space perception in virtual environments in which restrictions are often present, and distance compression has been found. We provided complete pictorial depth cues (e.g., linear perspective, height in the plane, horizon ratio, familiar size) but restricted viewing conditions in a real-world egocentric distance judgment task. Participants walked to previously viewed targets on the ground plane at distances ranging from 5 to 15 meters using both direct and indirect walking tasks. The first study varied whether participants were able to view the supporting surface on which they were standing. Observers wore an occluding collar designed to block the view of their lower body and feet while viewing the target. A second study examined the influence of stereo over monocular viewing. A final study utilized three conditions varying field of view and restricting observers' ability to rotate their head. Vision was not restricted in the first condition. In the second condition, observers wore goggles to restrict field of view and could rotate their heads while viewing the target. In the third condition, observers wore the same goggles along with a cervical collar which constrained both head motion and the view of their feet on the ground. In all studies and all conditions, visually directed walking remained near veridical. These results emphasize the lack of influence of viewing restrictions on accurate egocentric distance judgments within 5 to 15 meters in the real-world and leave open the question of the factors influencing distance judgments in virtual environments.

Acknowledgment: Supported by NIH Grant 1R01EY12437.
Origins of size tuning in LGN neurons

TA19


1Department of Psychology, University of California - Santa Barbara, USA—
2Department of Neurobiology, Harvard Medical School, Boston, USA—
3Smith-Kettlewell Eye Research Institute, San Francisco, USA — Responses in lateral geniculate nucleus (LGN) exhibit size tuning (Jones and Sillito, 1991). This tuning is predicted by a simple model (Bonin et al. Soc Neurosci Aibs, 2002). Model LGN neurons have a linear receptive field (RF, a difference of Gaussians), and receive a divisive signal from a contrast integration field. This field is a region around the RF that estimates local contrast by filtering the retinal image and computing variance. What are the origins of the contrast integration field?

We recorded responses of LGN neurons in anesthetized, paralyzed cats to sums of drifting sinusoidal gratings varying in contrast, diameter, orientation and spatiotemporal frequency. The model provided good fits to the data. It explains: (1) size tuning; (2) contrast saturation; (3) masking caused by superimposed gratings (present in 19/25 cells). Moreover, it correctly predicts that size tuning increases with contrast, and is absent at low contrast. The contrast integration field is 2.4 ± 0.4 s.e.m. (N=28) times larger than the RF surround.

The contrast integration field is broadly selective for stimulus attributes:

(1) It depends weakly on orientation. In 13/19 cells masking was independent of orientation (p<0.05, ANOVA).

(2) It is selective for a broad range of spatial frequencies. Its selectivity was often lowpass, with high frequency cutoffs similar to those of the RF.

(3) It is selective for a broad range of temporal frequencies. High frequency cutoffs correlated with those of the RF (r=0.76, N=25).

The contrast integration field explains size tuning and other properties of LGN neurons. Its origins might include cortical feedback (Murphy and Sillito, 1987), but its broad selectivity for orientation and spatiotemporal frequency seems more consistent with a retinal or thalamic origin (Shapley and Victor, 1978).

Acknowledgment: Supported by Human Frontiers Science Program and Swiss National Science Foundation

Early Visual Processing

Saturday, May 10, 2003
10:45 am – 12:15 pm
South Hall
Moderator: Matteo Carandini

TA19

Origins of size tuning in LGN neurons Vincent Bonin1 (vincent@skt.org), Valerio Mante1, Matteo Carandini2, 1Swiss Federal Institute of Technology Zurich, Switzerland, 2Smith-Kettlewell Eye Research Institute, San Francisco, USA — Responses in lateral geniculate nucleus (LGN) exhibit size tuning (Jones and Sillito, 1991). This tuning is predicted by a simple model (Bonin et al. Soc Neurosci Abs, 2002). Model LGN neurons have a linear receptive field (RF, a difference of Gaussians), and receive a divisive signal from a contrast integration field. This field is a region around the RF that estimates local contrast by filtering the retinal image and computing variance. What are the origins of the contrast integration field?

We recorded responses of LGN neurons in anesthetized, paralyzed cats to sums of drifting sinusoidal gratings varying in contrast, diameter, orientation and spatiotemporal frequency. The model provided good fits to the data. It explains: (1) size tuning; (2) contrast saturation; (3) masking caused by superimposed gratings (present in 19/25 cells). Moreover, it correctly predicts that size tuning increases with contrast, and is absent at low contrast. The contrast integration field is 2.4 ± 0.4 s.e.m. (N=28) times larger than the RF surround.

The contrast integration field is broadly selective for stimulus attributes:

(1) It depends weakly on orientation. In 13/19 cells masking was independent of orientation (p<0.05, ANOVA).

(2) It is selective for a broad range of spatial frequencies. Its selectivity was often lowpass, with high frequency cutoffs similar to those of the RF.

(3) It is selective for a broad range of temporal frequencies. High frequency cutoffs correlated with those of the RF (r=0.76, N=25).

The contrast integration field explains size tuning and other properties of LGN neurons. Its origins might include cortical feedback (Murphy and Sillito, 1987), but its broad selectivity for orientation and spatiotemporal frequency seems more consistent with a retinal or thalamic origin (Shapley and Victor, 1978).

Acknowledgment: Supported by NSF grants 9623614 and 0080999

TA20

Linear and nonlinear orientation dynamics of receptive fields in cat area 17 Michael A Repucci (mar2022@med.cornell.edu), Ferenc Mechler, Jonathan D Victor; Weill Medical College of Cornell University — We present a new method to explore the linear and nonlinear interactions within the classical receptive field (cRF) and between the cRF and the non-classical receptive field (ncRF). We extend the method of Ringach et al. (1997), based on presentation of a rapid sequence (20 ms per frame) of full-field oriented gratings of optimal spatial frequency, by using a set of tokens that includes not only gratings but also "blanks" (mean luminance), and presenting patches of these tokens simultaneously in both the cRF and one or more contiguous regions of the ncRF. Moreover, the order of presentation of these tokens is dictated by a non-binary m-sequence, typically of length 7=1=16806 or 11=1=14640, which allows us to anticipate and minimize spurious stimulus-related correlations. We calculate the response kernels by correlating the neuronal response with the occurrence of specific tokens or combinations of tokens within the stimulus sequence. We recorded extracellular action potentials of single cells with tetrodes in area 17 of anesthetized, paralyzed cats. In 18 cells, the first-order kernels within the cRF provide well-resolved orientation tuning curves with expected profiles (peak responses typically 40-60 ms post-stimulus). In contrast, first-order kernels of the ncRF are not significantly different from zero, consistent with a modulatory rather than sub-threshold additive nature of ncRF signals. In 8/18 cells, second-order kernels within the cRF demonstrate an enhancement of spike rate when the gratings of preferred orientation is displayed 40 and 60 ms prior to response (two consecutive frames). In addition, there is a nonlinear facilitation when the preferred token is immediately preceded by a blank, and a nonlinear suppression when the preferred token is followed by a blank, consistent with a gain control mechanism. Analysis of second-order kernels between the cRF and the ncRF indicates that these interactions are much weaker than nonlinearities within the cRF.

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TA21

Orientation selectivity in V1 of alert monkeys Moshe Gur1 (mogi@biomed.technion.ac.il), Igor Kagan1,2, Max D Snodderly2; 1Dept. of Biomedical Engineering, Technion, Haifa, Israel, 2Schepens Eye Research Institute, Harvard Medical School, Boston, USA — Area V1 is known for its neural cell density and intricate histology. Physiological recordings, however, often are not integrated into this complex anatomy. We have previously shown, in alert monkeys, that physiological properties of single cells reflect an alternating arrangement of anatomical layers. Here we report how orientation selectivity is related to the cortical layers and to the cell properties of spontaneous activity, classical receptive field (CRF) size, and spatial
organization. Recordings were made from single cells in area V1 of alert monkeys performing a fixation task. The cells' spatial organization was studied with drifting increment and decrement bars while compensating for fixational drift. Orientation selectivity was measured by the orientation tuning curve bandwidth and by circular variance. Orientation selectivity by either measure was clearly correlated with CRF size and spontaneous activity not with overlap of increment and decrement zones (Simple/Complex) or with relative modulation in response to sinusoidal gratings. The former 3 measures were strongly predicted by the layer of origin such that small CRFs, low spontaneous activity, and a high degree of orientation selectivity were found in the output layers 2/3, 4B and 5 while the reverse was true for the input layers 4A, 4C and 6. We conclude that the conjunction of these physiological measures with their anatomical locations reflect interactions between excitatory and inhibitory mechanisms specific to each lamina. When excitation is stronger than inhibition, large CRFs, high spontaneous activity and a low degree of orientation tuning are found. When inhibition becomes dominant, CRFs shrink, spontaneous activity almost disappears and orientation selectivity is high.

Acknowledgment: Supported by NIH EY12243 and Fund 130372 for the Promotion of Research at the Technion

TA22
A new quantitative analysis of simple cell space-time receptive fields
M. Brandon Westover (westovem@medicine.wustl.edu), Charles H. Anderson, Gregory M. DeAngelis; Washington University in St. Louis, Dept. of Anatomy and Neurobiology—Many spatial aspects of simple cell receptive fields can be explained by models which assume that simple cells efficiently encode statistical structure in static natural images (Olshausen et al. 1996). We extend these results to the time domain by assuming primary visual cortex treats dynamic imagery locally as static natural image patches translating at constant velocity. We developed a unified model of linear spatiotemporal aspects of simple cell receptive fields based on these assumptions, and fit it to published data from 291 cat simple cells (DeAngelis et al. 1993, 1999). Highlights:

1. Spatial frequency bandwidth obeys the simple relation \( \sigma_k = a(k+k_0) \), which for preferred spatial frequency \( k >> k_0 \) yields a scale invariant representation. Our analysis of the cat data gives \( a = 0.39 \pm 0.03 \) and \( k_0 = 0.20 \pm 0.03 \) cycles per degree. Rough estimates derived from published monkey data (DeValois et al. 1982) give \( a = 0.39 \) and \( k_0 = 0.6 \). The identical scaling factor for cat and monkey implies identical asymptotic shape for simple cell filters across species, supporting the image statistics hypothesis.

2. Spatially filtering a uniformly translating image at a velocity \( v \) with a spatial frequency bandwidth \( \sigma_k \) produces a signal with temporal bandwidth \( \sigma_k v \). A cell with preferred spatial and temporal frequencies \( k \) and \( w \) is optimally tuned to a velocity \( v = w/k \). To avoid discarding signal energy, the cell's temporal bandwidth must be greater than \( \sigma_k^2 w/k \). This is found to be true for the vast majority of cells, supporting our model of image dynamics.

3. The space-time profiles of the cells are well fit by a weighted sum of two Gabors tuned to motion in opposite directions. The histogram of the directional weights is broad, but bimodal. One peak corresponds to equal tuning and the other is anisotropic, the second to a 2.5/1 ratio. In contrast, most current models utilize pure unidirectional tuning.

Acknowledgment: The Mathers Foundation

TA24
Chromatic tuning of binocular neurons in early visual cortex
Jonathan W Peirce (jwp@cns.nyu.edu), Samuel G Solomon, Jason Forte, John Krauskopf, Peter Lennie; Center for Neural Science, New York University, USA—Most simple and complex cells in V1 and V2 are binocularly driven. The spatial characteristics of the two eyes’ receptive fields are generally very similar. We wanted to know whether neurons strongly responsive to illuminant stimuli were also binocularly driven and, if so, how well matched were the chromatic properties of the receptive fields.

We recorded from single units in V1 and V2 of macaques prepared for acute physiological experiments. For each cell we characterized the spatial properties of the two receptive fields using drifting sinusoidal gratings. With gratings of optimal spatial configuration we then measured responsivity to chromatic modulation along a range of directions in color space. The preferred color direction was calculated for each cell, with confidence intervals determined by consistency of the responses across trials.

We found that many binocularly driven cells responded well to illuminant gratings. Furthermore, among cells that preferred illuminant modulation the optimal color directions in the two eyes never differed significantly. This similarity of chromatic tuning in the two receptive fields is unlikely to have arisen by chance, suggesting that it is important for the cells' function. Binocularly driven cells that respond well to illuminant modulation are a potential substrate for chromatic stereopsis. However, most of these cells exhibited low-pass spatial frequency tuning, and therefore lack the receptive field structure most commonly associated with disparity sensitivity. Their role in stereopsis remains in doubt.

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Visual STM

Saturday, May 10, 2003
1:30 – 3:00 pm
North Hall
Moderator: Patrick Cavanagh

1:30 Alvarez, Cavanagh, TA25
1:45 Wright, Alston, TA26
2:00 Xu, Nakayama, TA27
2:15 Droll, Hayhoe, Triesch, Sullivan, TA28
2:30 Gajewski, Henderson, TA29
2:45 Williams, Henderson, Zacks, TA30

TA25
Visual short-term memory capacity for orientations is lower for oriented Gabors than for oriented lines

George A Alvarez (geoalvarez@wjh.harvard.edu), Patrick Cavanagh; Harvard University, USA

Purpose: While previous research has shown that the orientation of a single grating can be stored in visual short-term memory with high fidelity (Magnussen, Idas, & Myhre, 1998), the following experiment demonstrates that the maximum number of orientations that can be remembered is lower for Gabors patches (sinusoidal gratings attenuated by a gaussian envelope) than for lines. Method: Memory capacity for orientation was estimated in separate blocks of trials for Gabor patches (high contrast gratings with a spatial frequency of 1 cpd and diameter 3 deg) and lines (a single black bar of a Gabor patch subtending 4 deg by 3 deg). On each trial 1-5 Gabors or lines of various orientations were briefly presented, followed by a blank interval, and then by a second presentation of objects. On half of the trials the two displays were identical, and on the other half one of the items changed orientation by 90 degrees. The task was to indicate whether or not any of the items changed orientation. Results: Averaged across 8 subjects, change detection accuracy was not significantly different for Gabors and lines at set size 1 (accuracy was greater than 95% for both). However, accuracy was significantly lower for Gabors compared to lines at larger set sizes, with an estimated capacity of approximately 2 for Gabor orientations but 3 for line orientations (t(7)=5.7, p<.001). Conclusion: Although a change in the orientation of a single Gabor can be detected as accurately as a change in the orientation of a single line, the maximum number of individual orientations that can be remembered is lower for Gabors than for lines. These findings suggest that orientation cannot be stored as an abstract code independently of the object that carries that orientation. Thus, visual short-term memory capacity for orientation is not fixed in terms of the number of orientations that can be stored, but depends on the type of objects to be remembered.

TA26
Limitations of visual memory in spatial frequency discrimination

Michael J Wright (michael.wright@brunel.ac.uk), Louise Alston; Department of Human Sciences, Brunel University, Uxbridge, UB8 3PH, U.K.

Spatial frequency (SF) discrimination of single stimuli showed little loss of precision when measured across an interstimulus interval (ISI). However the use of multiple target arrays gave large set size effects. Stimuli consisted of two 100 or 150 msec arrays of 1 to 8 Gabor patches, randomised in SF, with a 2 sec ISI. This was an 'all change' task, in which every Gabor patch changed its SF across the ISI, but only one patch (the target) was cued, and required a SF discrimination response. The task was designed to elicit visual short term memory (VSTM) of multiple individual SFs. Unlike many other two-frame discrimination tasks using the method of constant stimuli, it was not soluble on the basis of single-frame information, nor by averaging across stimuli. Analysis of psychometric functions showed that observers reacted to delayed cues by distributing attention across targets (sharing model) rather than ‘betting’ on a single target (mixture model). Cueing before the onset of the first frame was optimal, in the sense that pre-cueing a single target gave the same thresholds as presenting that target alone. There was a modest (0.1-0.2 log unit) rise in thresholds for cues placed immediately after the first frame, requiring the spatial distribution of attention across multiple targets. Within the 2sec ISI itself, there was little further increase in thresholds with cue delay, suggesting a relatively durable representation of multiple stimuli, once registered. Noise masks >50msec after the first frame were ineffective, confirming the memory during the ISI is not iconic, but Gabor masks placed in the ISI disrupted performance, in agreement with reported “memory masking” effects. The greatest rise in thresholds (0.4-0.8 log unit) occurred for cues placed after the second frame. The results are interpreted in terms of distributed attention and interference effects within VSTM.

Acknowledgments: The Wellcome Trust

TA27
Placing objects at different depths increases visual short-term memory capacity

Yaoda Xu (yaoda@wjh.harvard.edu), Ken Nakayama; Vision Sciences Laboratory, Psychology Department, Harvard University, USA

Visual short-term memory (VSTM) has been shown to have a limited capacity. Studies documenting this limitation have all presented objects in the same depth plane. Objects in our surroundings, however, are typically laid out at different depths. It is thus possible that the reported VSTM capacity limitation is restricted to a particular depth, and that our visual system is capable of holding more objects if they are placed at different depths. In a series of experiments using the change detection paradigm, we found that VSTM capacity increases when objects are laid out in two depth planes as compared to one depth plane. This increase in capacity was not a result of grouping, because when only one depth plane was present, no benefit was observed when objects were grouped into circles and squares, grouped into a stationary group and a moving group, or grouped into a left group and a right group at the same depth. These results indicate that depth plays an important role in determining VSTM capacity.

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TA28
Task relevance of object features modulates the content of visual working memory

Jason A Droll1 (jdroll@rochester.edu), Mary M Hayhoe1, Jochen Triesch2, Brian T Sullivan1; 1University of Rochester, USA, 2UC San Diego, USA

The visual information retained following a change in gaze is limited and depends on the distribution of attention in the pre-saccadic fixation. It is commonly accepted that objects that have been attended are retained in visual memory in the form of “object files”, representing bound features. The current study suggests that this is too general a description, and the precise nature of the information required for the immediate task determines the information acquired and maintained. In order to approximate the attentional demands of ordinary behavior, Subjects performed a sorting task in a virtual environment with haptic feedback. Each trial required participants to select one of five bricks based on a particular feature (color, width, height or texture) and then sort the brick onto one of two conveyor belts on the basis of that feature. A change was made to one of the features on about 10% of trials, and Subjects were told to discard the brick into a “waste bin” if they detected a change. The relevant feature was fixed for any one subject, but varied across groups. When color was relevant, color change was detected often (83%) and no changes in any other feature were detected. When width was relevant, color change detection dropped (38%) and width changes were noticed (25%). Similarly, only when height was relevant were height...
changes detected (42%). Performance was predicted by the relevance of each of the four features in the task in addition to intrinsic salience of the different features. Trials in which subjects did not identify a change nonetheless frequently showed response changes in hand movement. We conclude that working memory representations are not necessarily composed of integrated objects. Rather, visual memory representations depend on the precise information required by the task, and directing attention to an object does not necessarily ensure a coherent representation.

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**TA29**

Eye movements are cheaper than memory: evidence from a scene comparison task  
Daniel A Gajewski (dan@eyelab.msu.edu), John M Henderson; Department of Psychology & Cognitive Science Program, Michigan State University, USA – Does the amount of information stored in visual short-term memory (VSTM) reflect the specific demands of the ongoing task or does the system routinely make full use of its capacity? Eye movement behavior in multi-modal (i.e., visual-manual) tasks suggests a preference for a ‘just in time’ processing strategy that minimizes the use of memory. In the present study, a scene comparison paradigm was introduced to determine whether the preference holds when the task is primarily visual and when more complex naturalistic scenes are used as stimuli. Participants made same or different judgments in response to simultaneously presented pairs of scenes that were identical or differed by one object. In Experiment 1, differences were created by deleting an object, replacing it with an item from the same basic-level category (token-substitution) or replacing it with an item from a different basic-level category (type-substitution). The number of objects fixated during each glance to a scene and the number of fixations intervening between glances to corresponding objects suggest that frequently one object at a time is maintained in VSTM. In Experiment 2, type- and token-substitution conditions were administered in blocks in order to test the hypothesis that the preferred strategy would depend on whether detection could be based solely on conceptual information versus when visual information was needed. There were no differences between substitution conditions, suggesting either that participants relied on visual information even when identity information would have been sufficient, or that the minimal memory preference extends to the use of identity codes. A third experiment using arrays of objects and the objects’ names was conducted to explore this latter possibility. Overall, the results suggest a strong general bias toward minimal use of VSTM in complex visual tasks.

**Acknowledgment:** NSF BCS-0094433, DGE-0114378, & ARO DAAD19-00-1-0519

**TA30**

Incidental memory in visual search: both targets and rejected distractors leave a lingering trace  
Carrick C Williams3 (carrickc@eyelab.msu.edu), John M Henderson1,2, Rose T Zacks1,2; 1Department of Psychology, Michigan State University, 2Cognitive Science Program, Michigan State University – The current study examined long-term incidental memory for both targets and distractors in a visual search task. Participants counted the number (0-3) of targets (identified by a color and category, e.g. yellow car) present in an array containing 12 real-world objects. Search targets were changed on each search trial. In addition to the targets, the array contained color distractors, category distractors, and unrelated distractors (objects that were neither the same category nor color as the search target). Every object presented was a unique token (384 objects/participant) and appeared in only one search array. Participants were shown each of the 32 arrays twice, but the arrangement of the objects and the number of targets in the arrays was different in the two presentations. Following presentation of all of the search arrays and a filled interval of approximately 10 minutes, participants’ memory was tested using a surprise token discrimination task. A target, and one color distractor, category distractor, and unrelated distractor were tested from each search array. Memory for targets was reliably better than distractors. Of most interest for this study, however, was memory for the distractor items. Color and category distractors were discriminated from foils at similar levels and both were discriminated reliably better than the unrelated distractors. We also examined the eye movements that were made during the search task and will relate these to the memory results. We conclude that visual search for real-world objects leaves a lingering memory trace of both targets and attended distractors. This trace is incidentally generated, is relatively long-lasting, and contains enough visual detail to support discrimination of a presented object from a visually similar memory foil.

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input by itself. When the difference between the two inputs is large, the model exhibits statistical robustness. The model can be expanded to incorporate inputs from several sensory cues.

**Acknowledgment:** NIH Grant

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**TA32**

**Learning to fuse unrelated cues**

Marc O Ernst¹ (marc.ernst@tuebingen.mpg.de), Frank Jäkel²; ¹Max-Planck-Institut für biologische Kybernetik, Tübingen, Germany, ²Graduate School of Neural & Behavioural Sciences, Tübingen, Germany – Humans integrate visual and haptic size information in a statistically optimal fashion (Ernst & Banks, 2002). That is, the perceived size is a weighted average of the individual estimates with weights proportional to their inverse variances. More importantly, the fused percept has lower variance than each individual estimate. Fusion of visual and haptic size estimates is reasonable because in the natural environment these cues to an object’s size are highly correlated. The purpose of this study is to investigate whether cue fusion is learned based on the correlation between cues. Therefore, we took naturally uncorrelated cues – the luminance of an object (visual cue) and its stiffness (haptic cue) – and trained 6 subjects for approximately one hour in an environment where these cues were correlated. To test whether training had an effect we compared subject’s discrimination performance before and after training for two intermixed conditions: One condition in which the two cues were consistent with the correlation during training (congruent) and the other condition in which the two cues were anti-correlated relative to the training phase (incongruent). If training had an effect we would predict that the stimuli with congruent cues elicit an improvement in discrimination performance relative to the incongruent condition, because if the cues are fused after training the variance of the combined estimate should get lower. In agreement with our prediction we found a significant interaction between pre- and post-test for the two congruent and incongruent conditions (F[1,5]=20.3; p<0.01). This indicates that subjects indeed picked up the correlation in the training phase and fused the two cues. We conclude that fusion of cues can be learned on a relatively short timeframe based on the statistics of their co-occurrence.

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http://www.vkb.tuebingen.mpg.de/~marc

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**TA33**

**Visual cortex as a site of cross-modal integration**

Ladan Shams¹ (ladan@caltech.edu), Shigeki Tanaka², Geraint Rees³, Sunao Iwaki⁴, Shinusuke Shimojo⁵, Toshihito Itakura⁶; ¹California Institute of Technology, U.S.A., ²Jinnai Institute, Japan, ³University College London, U.K., ⁴AIST, Japan, ⁵Kyoto University, Japan – It has been shown that visual perception can be strongly affected by auditory stimuli. It is unclear, however, what brain circuitry subserves these interactions. We used the sound-induced illusory flash effect (a single flash accompanied by two auditory beeps is perceived as two flashes (Nature 2000)) as a tool to investigate this question. This illusion is much stronger in the periphery than fovea. In a previous ERP study (NeuroReport 2001), the temporal onsets and patterns of modulation suggested that the modulation of activity by sound occurs within the visual cortex. In the present study we tried to localize the brain regions involved in the perception of the illusory flash more directly and accurately using event-related fMRI. We collected functional images of 3 participants in the following conditions. Unimodal conditions Vp and Vf consisted of visual stimulation: a small disk flashed once in the periphery or fovea, respectively. Bimodal conditions AVp and AVf consisted of auditory-visual stimulation: combination of 2 beeps with visual stimuli Vp and Vf, respectively. In another unimodal condition, Vp2, a physical auditory-visual stimulation: combination of 2 beeps with visual stimuli Vp or fovea, respectively. Bimodal conditions AVp and AVf consisted of visual stimulation: a small disk flashed once in the periphery or a physical second flash. These results altogether suggest that the activity in the early visual cortical areas is modulated by sound.

Thus, the auditory stimulation, per se, or attentional effects, could not account for the visual cortex activity associated with the illusory flash percept. Considering that the visual stimulus was identical in AVp and Vp, the enhanced activity of early visual areas in AVp can only be attributed to the perception of the illusory flash caused by sound. Similar brain areas were indicated when contrasting Vp2 against Vp, corresponding to a physical second flash. These results altogether suggest that the activity in the early visual cortical areas is modulated by sound.

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**TA34**

**Recalibration of audiovisual simultaneity by adaptation to a constant time lag**

Waka Fujisaki¹ (fujisaki@arcg.brl.tnt.ntt.co.jp), Shinusuke Shimojo², Makio Kashino³, Shin’ya Nishida⁴; ¹NTT Communication Science Laboratories, NTT Corporation, Japan, ²California Institute of Technology, USA – To find simultaneity between visual and audio events is a challenging problem for our sensory system since there are differences in both physical transmission time and neural processing time. One strategy the brain might take to overcome this difficulty is to adaptively recalibrate the point of simultaneity from daily experience of audiovisual events, rather than using a fixed neural circuit, as has been generally believed. If this is true, and the time constant of the recalibration is short enough, one may be able to see that after adaptation to a fixed temporal lag between visual and auditory events, subjective simultaneity is shifted in the direction to the adapted lag.

Audiovisual stimuli consisted of a white ring (5 deg in diameter) flashed for one refresh on an 85-Hz CRT monitor, and a 10-ms tone pip (1800-Hz) binaurally presented through headphones. During adaptation, an audiovisual pair was repeatedly presented with the average interval of 1.5 s. Each pair was given a constant time lag, ranging from –350 ms to +350 ms, with the negative sign indicating a tone ahead of a flash. In a test trial, the same audiovisual pair was presented with a lag randomly chosen from 13 values between –410 and +410 ms (method of constant stimuli), and subjects were asked to make a yes-no simultaneity judgment. Initial adaptation lasted 3 min, and a top-up adaptation (inserted between test trials) was 10 s.

The results indicate that the adaptation to an audiovisual lag shifted the point of subjective simultaneity in the direction to the adapted lag. The shift size, taken as a distance between the largest shifts in the opposite directions, amounted to 29, 61 and 137 ms for the three subjects we used.

This finding, which we believe is the first demonstration of a cross-modal aftereffect in the temporal domain, is consistent with a hypothesis that the brain adaptively calibrates the subjective audiovisual simultaneity to current environment.

**Acknowledgment:** This work was supported by the Max Planck Society and was conducted within the EU-Projekt TOUCH-HapSys (IST-2001-38040)

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**TA35**

**Kinesthetic visual capture induced by apparent motion**

David C Somers (somers@bu.edu), Rebecca McNally; Dept. of Psychology, Boston University, USA – “Visual Capture” describes a class of phenomena in which visual perception strongly influences a somatosensory percept. In prior studies, it has been reported that viewing one’s own arm through a displacing prism can shift the sense of hand position and cause large reaching errors. Here, we report a kinesthetic form of visual capture. Subjects held their hand 6-12 inches in front of their eyes. At this distance, the two eyes receive disparate views of the hand with different occlusions. By winking or with the aid of stereo goggles, subjects alternated (1-2 Hz) between left and right eye views of their stationary hand. At this speed and distance, visual apparent motion was induced within a few cycles. In addition, subjects reported a kinesthetic sensation that their own hand was being moved. The kinesthetic sensation typically required several cycles in order to approach full strength. The sensation typically grew with repeated cycling and with additional trials. Subjects reported the sensation as a non-painful “tingling” which was largely localized to the joint or joints required to produce the motion observed visually. Four different canonical hand positions were employed which produced kinesthetic
sensations referred to the wrist, elbow, or one of two knuckle joints. When the hand was positioned so that “anatomically impossible” motion was perceived visually, the kinesthetic percept persisted. Subjects reported feeling mildly disturbed but amused by impossible motion. Consistent with Shimojo’s work on visual capture, we observed that shifting the focus of attention influenced both the visual and capture perceptions. We also observed that the kinesthetic percept depended strongly on identifying the viewed hand as your own, suggesting that visual capture is driven by the visual recognition (or “What”) pathway as well as by the visual spatial location (or “Where/How”) pathway.

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TA36 Multisensory integration in self-motion Hong-Jin Sun (sunhong@mcmaster.ca), Jennifer L Campos, George SW Chan, Da-Hui Zhang, Amanda J Lee; McMaster University, Canada – We assessed the relative contributions of visual and proprioceptive/motor information during self-motion using a distance discrimination task in virtual reality. Subjects (8s) wore a head-mounted display and rode a stationary bicycle along a straight path in an empty, seemingly infinite hallway with random surface texture. During each trial, Ss traversed two distances: a standard distance and a comparison distance, and subsequently reported whether the second distance was longer than the first distance. The standard distance remained fixed while the comparison distance was varied according to the method of constant stimuli. Visual and proprioceptive incongruency was created through software by varying the optic flow gain (OFG) between the two distances within a trial. If Ss relied exclusively on vision or exclusively on proprioception, OFG variations would lead to different estimates. When OFG was varied between three different magnitudes, three separate psychometric functions were observed, indicating that Ss used the weighted average of visual and proprioceptive cues. The magnitude of the separation between the three psychometric functions depended upon the size of the perceptual conflict. Distance discriminations were also affected by whether OFG was varied during the comparison and/or standard distance. When OFG was only varied in the comparison distance, responses seemed to indicate that visual and proprioceptive cues contributed about equally to the final estimate. However, when OFG was varied in both the standard and comparison distances, Ss appeared to predominantly use vision. These results are reminiscent of the concepts underlying the statistical optimization model, which predicts that sensory information from multiple sources is weighted according to the estimated reliability of each cue. Our results suggest that across trials, the stability or variability of a particular cue contributes to how it is weighted during sensory integration.

TA37 Competitive selection of superimposed stimuli moving through space Mazzar Fallah (mazz@salk.edu), Gene R Stoner, John H Reynolds; The Salk Institute, USA – Single unit studies in monkey extrastriate cortex have identified competitive circuits that could conceivably mediate either spatial or object-based attention. These studies have used stimuli at separate locations, confounding these two possibilities. We recorded responses of V4 neurons to stimuli that were spatially superimposed and could not, therefore, be selected by a purely spatial mechanism. We presented in the neuronal receptive field (RF) patterns of dots that rotated rigidly in opposite directions around a common center, yielding the percept of superimposed transparent surfaces. One set of dots was of the neuron’s preferred color and the other was of an equiluminant non-preferred color. Psychophysical studies using these stimuli have found that when one surface is cued by delaying its onset relative to the other surface, human observers can more accurately judge brief changes in the motion of the new than of the old surface. This effect of cueing lasts for approximately 600 milliseconds following the onset of the new surface. This result would be expected if competition were biased in favor of neurons selective for the new surface. V4 neurons were driven preferentially by the new surface for approximately the same period of time as the perceptual conflict. We found that the cueing effect survived when cueing occurred outside the RF and the two superimposed surfaces then moved into the RF. These results show that competitive circuits in V4 are not limited to mediating competition between spatial locations, and that selection occurring outside the RF persists when the selected stimulus then moves into the RF.

TA38 Macaque area V4 neurons translate the attended features of a visual stimulus into behaviorally relevant categories Giovanni Mirabella1 (giovanni.mirabella@uniroma1.it), Ines Sanegno2, Giuseppe Bertini3, Bjorg E Kilavik4, Deborah Frilli4, Alessandra Fanzini4, Leonardo Chelazzi4, 1Dep. of Neurological and Vison Science, Sect. Phsiology, University of Verona, 2Sect. Neuroscience, International School for Advanced Studies, 3Dept. of Morphological and Biomedical Sciences, Sect. of Anatomy and Histology, University of Verona, 4Dep. of Neurological and Vison Science, Sect. Physiology, University of Verona – It is well known that visual attention can enhance processing of restricted regions of space or of individual objects. Recent work has shown that visual attention can also lead to selective processing of individual object features, but clear demonstrations of these feature-specific modulatory effects are still lacking at the level of single neurons. In the present study we cued two macaque monkeys to discriminate either the color or the orientation of a stimulus, while ignoring the other feature of the same stimulus. Sixteen different stimuli varying in color and orientation were presented inside the receptive field (RF) of isolated, dorsal area V4 neurons, while the animal was centrally fixating. We recorded the responses of around 150 cells in the two animals. Attending to a given feature might be expected to sharpen neural selectivity for that feature at the expense of selectivity for the other feature. We assessed this possibility by comparing selectivity for the color and the orientation of the stimuli when either feature was behaviorally relevant. Although ~40% of the recorded cells were significantly modulated by feature-selective attention, no consistent changes in tuning were found across the cell population, in agreement with previous studies of V4. However, for about one third of the cells, while activity in an early phase post-stimulus onset mainly encoded the features of the RF stimulus, regardless of the specific feature to be attended, activity in a later phase developed to encode which of two alternative behavioral responses was required by the relevant feature of the stimulus. Thus, it appears that feature-selective attention can modulate neural activity in area V4 by translating the attended feature of a visual object into a task-relevant category, i.e., by explicitly representing only the information that is relevant to guide behavior.

Attention Mechanisms

Saturday, May 10, 2003 3:15 – 4:45 pm
North Hall
Moderator: Jeremy Wolfe

3:15 Fallah, Stoner, Reynolds, TA37
3:30 Mirabella, Saneng, Bertini, Kilavik, Frilli, Fanzini, Chelazzi, TA38
3:45 Gottlieb, TA39
4:00 Luck, Vogel, Woodman, Hyun, TA40
4:15 Burr, Veges, Morrone, Baldassi, TA41
4:30 Vallines, Bodis-Wollner, Oezyurt, Rutschmann, Greenlee, TA42
neurons had been recently activated by the cue. This suggests that... it than if the cue was in the RF... evolving 200-300 ms later if the cue was in the RF than if it... neurons responded... both to the cue and to the saccade target but not to stable non-target objects. If only the cue (but not the target) was in the RF, neurons had strong responses that peaked within 50-100 ms of cue onset and declined gradually during the delay period, persisting at a low level until the saccade. If only the target (but not the cue) was in the RF, neural activity gradually increased during the delay period, remaining elevated from ~150-200 ms after cue onset until the saccade. Thus, responses to the cue and to the target were sustained in parallel, throughout the delay period, in populations of LIP neurons with non-overlapping receptive fields. However, if both cue and target were in the RF, neurons responded serially, first to the cue and only later to the target. Directional selectivity for the target evolved 200-300 ms later if the cue was in the RF than if it was not, indicating that the target response was temporarily suppressed if neurons had been recently activated by the cue. This suggests that competitive interactions within a RF curtail the capacity for parallel representation at spatial separations on the order of RF size.

**TA40**

**Toward an embedded process metatheory of selective attention**

Steven J Luck¹ (steven-luck@uiowa.edu), Edward K Vogel², Geoffrey W Woodman³, Joo-seok Hyun⁴, University of Iowa, USA, ²University of Oregon, USA, ³Vanderbilt University, USA—What should a theory of selective attention look like? Almost all current theories treat selective attention as a unitary process that operates according to one set of principles to achieve a single computational goal. In contrast, we will argue that selective attention should be treated as a general type of process that is embedded within many different cognitive subsystems and is used within different subsystems under different conditions. Specifically, attention will operate within a given subsystem when that subsystem faces an overload of inputs and different tasks will therefore elicit the use of attention within different subsystems. In addition, because representational formats, processing algorithms, and computational goals vary across cognitive subsystems, the details of how selective attention operates will vary across subsystems. Moreover, because different cognitive subsystems may sometimes need to focus on separate sources of information at a given moment in time, attention may sometimes operate independently within different subsystems. Thus, theories of attention must recognize that attention is a set of partially independent processes that are embedded within specific cognitive subsystems and operate in a manner that reflects the properties of those subsystems. To provide empirical support for this embedded process metatheory of attention, we will review recent evidence that: (a) attention operates within different cognitive subsystems depending on the stimuli and task; (b) attention has different properties depending on the subsystem in which it is operating; and (c) attention can be simultaneously focused on different sources of information within different cognitive subsystems.

**Acknowledgment:** This research was made possible by grants R01 MH63001 and R01 MH65034 from the National Institute of Mental Health.

**TA41**

**Search for motion direction: pop-out and set-size dependencies explained by stimulus and intrinsic uncertainty**

David C Burr¹ (dave@in.pi.cnr.it), Preeti Verghese², Concetta Morrone³, Stefano Baldassi²; ¹Istituto di Neuroscienze del CNR, Pisa, Italy, ²Smith Kettlewell Eye Research Institute, San Francisco, CA, USA, ³Department of Psychology, Universita Vita-Salute San Raffaele, Milan, Italy—We measured motion coherence and contrast thresholds for determining the direction of motion of a random dot pattern. Dots within a “target” region falling in one of 8 positions equally spaced around a circle moved either leftwards or rightwards (limited life 2-4 frames) for 150 ms. Subjects were required to identify the direction of motion, not the position of the patch. The target was cued by a partial cueing technique, where 1, 2, 4 or 8 spokes pointed to the target, as well as to a variable number of “distractors”. The 8 potential-target regions could either be contiguous with the background random dots or be windowed as distinct stimuli behind a grey background. Coherence thresholds were lowest when the target was cued by a single spoke, and increased with the square-root of the number of spokes. We also measured contrast sensitivity for motion direction and found no set-size effect; but if we added a field of high-contrast noise dots only on the target and distractor regions, there was a square-root set-size effect for contrast thresholds. Interestingly, in conditions where a set-size effect was observed, the slope of the psychometric function also increased with set-size; when set-size had no effect on threshold, the slope of the psychometric function was always steep. A model based on the largest response of the pool of monitored detectors predicts that the slope of the psychometric function increases with set-size (uncertainty), and that the presence or absence of a set size effect depends on stimulus and intrinsic uncertainty. The high intrinsic uncertainty for contrast thresholds may reflect an underlying large neuronal population (such as V1), while the low uncertainty associated with coherence thresholds may reflect a smaller population with large receptive fields (such as MT).

**Acknowledgment:** Supported by Italian MUIR and NASA grant NAG9-1163

**TA42**

**Perisaccadic V1 activity is not due to shifting visuo-spatial attention**

Ignacio Valleynes¹ (Jose.i.vallynes.garcia@mail.uni-oldenburg.de), Ivan Bodis-Wollner²,³, Jale Oezurt¹, Roland M. Rutschmann², Mark W. Greenlee¹; ¹Carl von Ossietzky University, Oldenburg, Germany, ²State University of New York, USA, ³Hanse Institute for Advance Studies, Delmenhorst, Germany—It has been previously shown in human imaging studies that striate cortex is active when saccadic eye movements are executed even in the absence of visual input. It is commonly accepted that a shift in visuo-spatial attention immediately precedes saccades. Therefore, it is plausible that perisaccadic V1 responses could be the product of this shift in visuospatial attention rather than being directly related to saccadic activity. We have studied functional MRI in 13 subjects who either executed saccades reflexively to visual targets or performed voluntary saccades in the absence of visual stimuli. Eye movements were recorded with an MR compatible eye tracker. Perisaccadic cortical responses were compared to responses obtained when attention was covertly directed to the same peripheral locations while maintaining central fixation. Results show, besides frontal and parietal activation foci, strong perisaccadic V1 activity whether a visual target is present or not. Shifts of attention are associated with activation in parietal and frontal cortices but not in V1. These findings suggest a dynamic interplay between visual and oculomotor cortex while subjects perform saccades.

**Acknowledgment:** Hanse Institute for Advance Studies, Delmenhorst, Germany. European Graduate School of Neurosensory Science, Oldenburg, Germany
Natural Images
Saturday, May 10, 2003
3:15 – 4:45 pm
South Hall
Moderator: Jan Theeuwes

3:15 Fowlkes, Martin, Malik, TA43
3:30 Dastjerdi, Dong, TA44
3:45 Dong, Simpson, Weyand, TA45
4:00 Zetzsche, Nuding, TA46
4:15 Olman, Ugurbil, Kersten, TA47
4:30 Adelson, TA48

TA43
Ecological statistics of grouping by similarity
Charless C. Fowlkes (fowlkes@eecs.berkeley.edu), David R. Martin, Jitendra Malik; Department of Electrical Engineering and Computer Science, University of California, Berkeley, USA – Goal: Wertheimer (1923) proposed visual similarity as a key grouping factor but a precise definition has proved elusive. We formalize similarity by designing a function $W(i,j)$ whose value is the probability that a pair of points $i$ and $j$ belong to the same visual group. Our goal is to learn an optimal functional form for $W(i,j)$ based on brightness, texture and color measurements, and to quantify the relative power of these cues. Methods: A large dataset (~1000) of natural images, each segmented by multiple human observers (~10), provides the ground truth $S(i,j)$ for pairs of pixels. $S(i,j) = 1$ if the pair lies in the same segment, 0 otherwise and will serve as the target function for $W(i,j)$. We consider both region and boundary cues for computing $W(i,j)$. Region cues are based on brightness, color, and texture differences between image patches at $i$ and $j$, each characterized by histograms of the outputs of $V_1$ like mechanisms. Oriented filter responses are used for texture and $a^*$, $b^*$ features in CIE L*a*b* space for color. Boundary cues are incorporated by looking for the presence of an “intervening contour”, a large gradient (in brightness, texture or color) along a straight line connecting two pixels. The parameters of the patch and gradient features are calibrated using the human segmented images. Performance was evaluated on a separate test set using precision-recall curves as well as mutual information between $W(i,j)$ and $S(i,j)$ based on various cues. Results: For brightness, gradients yield better results than patch differences. However, for color, patches outperform gradients. Texture is the single most powerful cue, with both patches and gradients carrying significant independent information. The mutual information between $S(i,j)$ and $W(i,j)$ using all similarity cues is 0.19 nats, just 0.06 short of that between different human subjects. The mutual information between $S(i,j)$ and $W(i,j)$ using all similarity cues is 0.19 nats, just 0.06 short of that between different human subjects. The mutual information between $S(i,j)$ and $W(i,j)$ using all similarity cues is 0.19 nats, just 0.06 short of that between different human subjects.

Acknowledgment: supported in part by FAU RIA-25
http://dove.cs.fau.edu/abstracts/03VSS-3.html

TA44
Independent component analysis of natural time-varying images under the constraint of the minimum time delay
Mohammad Dastjerdi (mohammad@dove.cs.fau.edu), Danwei W. Dong; Center for Complex Systems and Brain Sciences, Florida Atlantic University, Boca Raton, FL, USA – The objective of this study is to understand the relationship between the response properties of visual neurons and the statistical structure of natural time varying images. It has been proposed that sensory systems such as the human visual system reduce the redundancy in the sensory input to produce independent output (Attneave F 1954, Barlow HB 1961, Atick JJ 1992). Such a coding strategy gives the brain evolutionary advantages. Removing second order spatial and temporal correlations with the constraint of the minimum time delay leads to the filters which agree quantitatively with the receptive fields of retinal ganglion cell and LGN (Dong DW, Atick JJ 1995). Removing higher order spatial correlations leads to the emergence of oriented spatial filters (Olshausen BA, Field DJ 1996; Bell AJ, Sejnowski TJ 1997), which are similar to the simple cell’s spatial receptive fields. But to quantitatively understand the receptive fields of simple cells, we need to take into account space and time simultaneously. In the previous studies the emergence of spatiotemporal filters through independent component analysis of TV videos was demonstrated (van Hateren JH, Ruderman DL 1998). But those spatiotemporal filters have markedly different characteristics from the spatiotemporal receptive fields of simple cells. Specifically the real biological neurons respond to visual inputs with much shorter time delays. It has been proposed that it is also vital, from the evolutionary point of view, for the sensory systems to respond to sensory inputs as soon as possible (Dong DW and Atick J J 1995). We believe that this is another important principle for the organization of sensory systems. Adding the cost function of time delay to the independent component algorithm forces the emergence of oriented spatiotemporal filters with minimum time delay, which are closer to the simple cell’s receptive fields.

http://dove.cs.fau.edu/abstracts/03VSS-2.html

TA45
No suppression, only dynamic decorrelation: saccadic effects on the visual responses to natural time-varying images
Dawei W. Dong1,2 (dawei@dove.cs.fau.edu), Geoffrey B. Simpson1,2, Theodore G. Weyand3; 1Center for Complex Systems and Brain Sciences, Florida Atlantic University, Boca Raton, 2Florida Center for Complex Systems and Brain Sciences, Florida Atlantic University, Boca Raton, Florida, USA, 3Department of Cell Biology and Anatomy Louisiana State University Medical Center, New Orleans, Louisiana, USA – Natural time-varying images possess significant temporal correlations. It has been shown that the LGN improves efficiency of visual representation through temporal decorrelation of the retinal signal (Dong, Atick 1995). But under natural viewing conditions, the temporal correlations are changed significantly by the saccadic eye movements and hence the signal sent to the LGN has quite different correlation characteristics across and between saccades. Based on the measured statistical properties of visual input during free viewing of natural time-varying images, we predicted that the LGN changes its temporal filter dynamically according to saccade timing to maintain decorrelation (Truccolo, Dong 2000, 2001; Dong 2001). To verify the prediction quantitatively, we recently developed new experimental paradigms, in which alert subjects watch natural time-varying images and their eye movements are tracked. We have done two sets of experiments: extra- and quasi intra-cellular (S-potential) recordings of the LGN during free-viewing by awake cats which are allowed to move their eyes (both input and output spikes are recorded); fMRI recordings of the visual cortex during free-viewing and during fixed gaze viewing (of the same image sequences as free-viewing) by awake human subjects (the overall visual cortex activation by the LGN is recorded). The experimental results confirmed our theoretical predictions. Both right before/after and between saccades, the information transfer through LGN is optimized during natural viewing. Such optimization is achieved by dynamic temporal decorrelation through LGN: right before/after a saccade, temporal low-pass filtering; whereas between two saccades, temporal difference (band-pass) filtering. The predicted filter also agrees quantitatively with human psychophysical experiments (Diamond et al 2000). In conclusion, the theory of efficient coding gives a quantitative account for visual response differences across and between saccades.

http://dove.cs.fau.edu/abstracts/03VSS-2.html
TA46

Extra-classical receptive field properties: relation to natural scene statistics and development of nonlinear model structures

Christoph Zetzsche (Christoph.Zetzsche@imp.med.uni-muenchen.de), Ulrich Nuding; Inst. f. Mediz. Psychologie, Universität München, Germany – Stimulation of the extra-classical surrounds of receptive fields leads to highly nonlinear effects not explainable within the classical linear filter paradigm. We investigate these effects from two perspectives. On the one hand, we study a nonlinear multi-layer architecture which consists of linear filter mechanisms and simple ON/OF nonlinearities. The filter mechanisms in each layer are learned (PCA, ICA) to yield an optimal adaption to the statistical properties of natural scenes. The resulting nonlinear processing properties are then compared with recent neurophysiological data on extra-classical properties. The same is done in an alternative approach by a class of nonlinear models that is based on Volterra-Wiener theory and generalized measures from differential geometry. Here the basic nonlinear interactions are AND-like (multiplicative) and the selected nonlinear combinations are intended to yield a higher-order whitening of the polyspectra of natural images. We show that both types of nonlinear architectures can capture basic extra-classical properties, like surround suppression effects, and we reveal the existence of equivalence classes in which one and the same input-output behavior can be obtained by models which differ apparently substantial in their structure. From a theoretical perspective, the concept of AND-like combinations of spatial frequency components is an attractive nonlinear extension of the classical linear spatial filter paradigm, since it is quite general and comprises, for example, also all linear-nonlinear-linear schemes with squaring rectifiers. Regarding the actual implementation of models, explicit AND operations seem to yield a somewhat more general class, since they enable a higher sensitivity and can describe subtle effects, like the components of intracellular recordings, or the complete cancellation of inhibitory influences, which are difficult to understand in terms of nonlinear inhibition schemes.

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TA47

Effects of image structure on perceived contrast and cortical activity in early visual areas

Cheryl A Olman1 (cheryl@cmr.cnm.umn.edu), Kamil Ugurbil2, Daniel Kersten2; 1Department of Neuroscience, University of Minnesota, Minneapolis, MN, USA, 2Department of Radiology, University of Minnesota, Minneapolis, MN, USA – We are studying the effect of spatial frequency content on the perceived contrast of broadband images and the corresponding activity in early visual areas, as indicated by BOLD fMRI. Natural images (in this study, gray level photographs) have a characteristic "1/f" spatial frequency spectrum in which low spatial frequencies are more strongly represented than high spatial frequencies. Flattening the spatial frequency spectrum while maintaining the area under the power spectrum produces "whitened" images of the same RMS contrast. We used a psychophysical contrast-matching task to quantify the changes in perceived contrast that result from image whitening, and BOLD fMRI measurements of activity in early visual areas during presentation of natural and whitened images to study the relationship between perceived contrast and activity in early visual areas. We also measured contrast discrimination thresholds for the two image sets to compare against the BOLD data. Finally, we are taking advantage of the increased spatial resolution and signal specificity offered by high field functional imaging to investigate the relationship between these results and theories of efficient encoding in early visual areas.

We have measured significant decreases in both perceived contrast and BOLD fMRI activity for the whitened images, relative to the natural images. A simple linear model of spatial frequency processing in multiple channels can predict this result. The higher contrast response predicts lower contrast discrimination thresholds for natural images than for whitened, but this is not observed in psychophysical measurements of threshold versus contrast for the two image sets. Preliminary results indicate increased spatial heterogeneity in BOLD signal during viewing of natural images.

Acknowledgment: Acknowledgements. BTRR P41-RR008079, NSF/IGERT DGE 9870633, the Keck Foundation, and the MIND Institute.

TA48

Textural statistics and surface perception

Edward H. Adelson; MIT, Cambridge, MA, USA – It has previously been shown that image statistics, similar to those used for texture analysis, can be useful in recognizing optical qualities such as gloss. The results are strongest for smooth objects of known geometry. We now consider the case of complex surfaces of unknown geometry such as crumpled paper. We find that textural statistics are quite informative here as well. We analyzed images of natural materials (paper, cloth, powder, vegetables) and found that the statistics were highly dependent on the lightness and color of the material. This is apparently due to the influence of interreflections and transmission within the surface itself (related to the effects in Gilchrist’s black and white rooms, and Langer’s colored rooms). As a result, it should be possible to do a certain amount of lightness and color constancy by looking at a single isolated surface, without comparing it to a surrounding context. I will describe a number of perceptual phenomena that are consistent with this expectation, and which indicate that humans use textural statistics for much more than just texture analysis.

Acknowledgment: Supported by NIH EY1105-4, and a grant from NTT.

Binocular Vision

Sunday, May 11, 2003
9:00 – 10:30 am
North Hall
Moderator: Satoru Suzuki

9:00 Aslin, Jacobs, Battaglia, TA49
9:15 Blake, Sobel, TA50
9:30 Lee, Blake, Heeger, TA51
9:45 Wilson, TA52
10:00 White, Gao, Zhou, TA53
10:15 Kim, Grabowecky, Suzuki, TA54

TA49

Depth-dependent contrast gain-control

Richard N Aslin (aslin@cns.rochester.edu), Robert A Jacobs, Peter W Battaglia; University of Rochester, USA – The brain has evolved mechanisms of adaptive contrast gain-control to compensate for variations in retinal contrast (or receptor sensitivity) that are present despite a uniform stimulus contrast. Retinally localized increments or decrements in contrast undergo rapid adaptation, resulting in contrast constancy across the visual field. We extend this contrast adaptation to the third dimension by introducing a retinally localized decrement in contrast that is present only in a near or far depth plane. Subjects fixated a small cross that moved smoothly across a sine wave grating (2 c/d, 60% contrast). The grating was viewed stereoscopically and depicted a near and a far surface, side-by-side, containing disparity, texture, and perspective cues, with a sharp depth gradient in between. A patch of the grating (2-D Gaussian, 3 deg diameter), located 7 deg below the fixation cross, contained a region of contrast decrement (from 60% to 0%). This region of contrast decrement was present only when the fixation cross was on the near or the far surface.
Thus, if that region of the retina underwent depth-dependent contrast adaptation, contrast gain should increase after extended viewing, but only for the depth surface that was adapted. Subjects were adapted for 3 min as the fixation cross oscillated across both the near and far surfaces. A contrast matching task assessed contrast adaptation at the near surface and at the far surface, with the standard Gabor patch located 7 deg above the fixation cross and the comparison Gabor patch located 7 deg below the fixation cross, coincident with the location of the Gaussian contrast decrement. Results indicated that contrast gain increased for the adapted retinal location, but only for test trials presented at the near (or far) surface that contained the contrast decrement. These results suggest that contrast gain-control has an adaptive mechanism that is sensitive to and conditioned upon the depth of the adapted surface.

Acknowledgment: Supported by NSF SPR-9873477 and NEI EY13149

TA50

Motion prolongs perceptual dominance during binocular rivalry

Randolph Blake (randolph.blake@vanderbilt.edu), Kenith Sobel; Vanderbilt University, USA — Purpose: The reason for perceptual alternations during binocular rivalry remains debatable. Some believe that neural adaptation plays a key role in the alternation process while others construe alternations as an adaptive sampling of possible perceptual interpretations driven by an intrinsic oscillator. Using a novel display procedure, we have found that rivalry alternations can be substantially slowed when the rival targets themselves continuously move around the visual field, constantly shifting their neural representations onto fresh, unadapted neural tissue. Methods: During 2-min observation periods, observers maintained strict central fixation and used keypresses to report binocular rivalry alternations. On some trials the rival targets moved smoothly in tandem around an imaginary circle centered on the fixation point, and on the remaining trials the targets remained stationary at a given location on the circle’s circumference. Results: Among a large sample of observers, dominance durations during the “moving” condition were typically quite long compared to their “stationary” durations, resulting in significantly slower alternation rates when the rival targets moved. Alternation rates were not slowed, however, when observers used pursuit eye movements to track the moving targets, thereby keeping the images of the targets on approximately the same retinal location. Alternations were reliably triggered when rival targets passed through a local region of the visual field that had been preadapted to one of the rival targets. There was no tendency for alternations, when they did occur, to coincide with transitions from one hemisphere to the other. Conclusions: Continuous movement of the rival targets may preclude local neural adaption, leading to a relatively stable balance between excitatory and inhibitory interactions between the two competing neural representations.

Acknowledgment: NIH EY13358 and EY13924

http://www.psych.vanderbilt.edu/faculty/blake/rivalry/movingRivalry.html

TA51

Traveling waves of activity in V1 correlate with perceptual dominance during binocular rivalry

Sang-Hun Lee1, (lehshh@stanford.edu), Randolph Blake2, David J Heeger1, 1Stanford University, USA, 2Vanderbilt University, USA, 3New York University, USA — Background: When the two eyes view large dissimilar patterns, alternating waves of visibility are experienced, as one pattern sweeps the other out of awareness. As shown by Wilson et al (2001), the dynamics of these waves coincide with the functional architecture of early visual cortex: retinotopic organization, cortical magnification and collinear facilitation. This coincidence suggests that V1 is a possible site of the neural events promoting perceptual waves. Methods: Observers dichoptically viewed a low-contrast radial annulus and a high-contrast spiral annulus, each 4 in radius and .72 in width, while fMRI signals were measured in a 3T scanner. Each 9-sec trial started with the low-contrast annulus presented to one eye, which was followed immediately by the high-contrast annulus to the other eye. This mode of presentation promoted complete suppression of the low-contrast annulus at the beginning of every trial. Shortly thereafter, a brief contrast increment appeared in a narrow region at the top of the suppressed annulus. This contrast increment usually triggered dominance of that region of the annulus, with this dominance then spreading such that the low-contrast annulus progressively erased the high-contrast annulus from awareness, over a period of 1.5 – 3 s. When the wave reached the bottom of the annulus, observers pressed a key, which caused the entire display to disappear, then classified dominance waves based on their direction and quality: ‘left hemifield’, ‘right hemifield’ or ‘no’ wave. Results: In V1, temporal phases of fMRI signals varied orderly across the retinotopic map: signal fluctuations were more delayed in more dorsal portions of this map. Furthermore, the differences in phase were correlated with the latency, direction and quality of waves reported by observers. Conclusion: The fine-scale analysis of fMRI signals reveals a tight link between spatiotemporal dynamics of dominance waves during rivalry and concomitant neural events in V1.

Acknowledgment: R01-EY11794

TA52

A dynamical hierarchy of rivalry stages in vision

Hugh R. Wilson (hwilson@yorku.ca); Centre for Vision Research, York University, Toronto, Ontario, Canada — Cortical form vision comprises multiple, hierarchically arranged areas with feedforward and feedback interconnections. This complex architecture poses difficulties when scientists attempt to link perceptual phenomena to a particular level of the system. This difficulty has been especially salient in recent research into binocular rivalry alternations, where there is seemingly conflicting evidence for a locus in primary visual cortex or alternatively in higher cortical areas devoted to object perception. In particular, it has been shown that if orthogonal monocular gratings are flickered at 18.0 Hz and switched between eyes at 1.5 Hz, dominance of one grating survives 6-7 eye switches, thus implicating a higher binocular level for rivalry in this case. A nonlinear neural model for rivalry demonstrates that the data require two hierarchic rivalry stages for their explanation. This model demonstrates that competitive inhibition in the monocular rivalry stage is defeated by the 18.0 Hz flicker, 1.5 Hz eye switching stimulus dynamics, thereby revealing properties of a subsequent binocular rivalry stage. This result produces a synthesis of alternative rivalry theories and suggests that neural competition may be a characteristic of multiple cortical areas in the form vision pathway.

Acknowledgment: Supported in part by NSERC (Canada) Grant #OP22724

TA53

Fractal statistics of perceptual switching time series

Keith D White1, (kwhite@ufl.edu), Jianbo Gao2, Yihui Zhou2, 1Dept. of Psychology, Univ. of Florida, Gainesville, FL USA, 2Dept. of Computer & Electrical Engineering, Univ. of Florida, Gainesville FL — We examined perceptual switching during ambiguous depth perception, with a Necker cube (10 subjects); during ambiguous motion perception, with the Boneh et al rotating ball (56 subjects); and during binocular rivalry, with small moving gratings (56 subjects). Autocorrelation analysis of perceptual dominance time series showed that successive response durations are essentially independent, as has long been known, on a time scale of 20 sec to 1 min (10+ responses). However, variance-sample size analysis (VSS), data shuffling, and log-normal distributional properties all show that these time series behave like 1/f noise with long range correlations. VSS detects lack of response independence for a range from roughly 30 to 100 responses (time scale on the order of 2 to 10 min) as evidenced in three ways. First, the Hurst parameter (an index of fractal self-similarity derived from second-order statistics) was as large as 0.84. A stochastic process theoretically has this Hurst parameter value = 0.5 while a predictable process, such as a sine wave, has H(2) = 1.0. Secondly, shuffling the perceptual dominance periods of each time series into randomized order
and then repeating the VSS analysis showed that variances in the naturally ordered time series were significantly larger than corresponding variances in the shuffled time series. This was expected given their Hurst correlations, and it was was shown empirically by F and binomial tests. Thirdly, the histograms of H(2) for shuffled time series, randomly reordered from 1000 to 9000 times each for a subset of the data, are sharply peaked near 0.50 with a standard deviation less than 0.10. This empirically estimated sampling distribution for H(2) shows that many of the natural time series have Hurst correlations unlikely to have happened by chance in random time series. Power spectral densities of these time series and the good fits of theoretically expected log-normal probability density functions to data histograms further support the method of multifractal analysis.

http://www.psych.ufl.edu/~white

TA54
Stochastic resonance in bistable binocular rivalry Yee Joon Kim\textsuperscript{1} (paticca-vajra@northwestern.edu), Marcia Grabowecky\textsuperscript{2}, Satoru Suzuki\textsuperscript{2};\textsuperscript{1}Northwestern University Institute for Neuroscience, Evanston, IL, USA;\textsuperscript{2}Department of Psychology, Northwestern University, Evanston, IL, USA –

When a different stimulus is presented to each eye, the perceived image spontaneously and stochastically alternates between the two stimuli (binocular rivalry). The dynamics of perceptual bistability can be modeled by a system consisting of two potential energy minima, corresponding to the two predominantly perceived images, with internal stochastic noise (e.g., spontaneous neural discharge) generating the spontaneous perceptual shifts. We investigated the properties of this model by examining how the binocular rivalry responded to an external periodic signal. The relative strengths (contrast) of the left-eye and right-eye stimuli were oscillated at various frequencies and amplitudes, while observers continuously reported dynamic alternations between the two perceived images. Distributions of dominance phase durations were obtained for various driving frequencies and for the non-driven control. Synchronization of binocular rivalry was indexed by an increase (relative to the non-driven control) in the “resonant” component of the dominance phase durations matching the half-period of the driving oscillation (i.e. matching the driving frequency). We found evidence of stochastic resonance in that the proportion of the resonant component within each dominance-phase distribution was maximal when the driving frequency was near the mean alternation frequency in the non-driven control (Kramer’s rate). By analyzing the dependence of the dominance-phase distribution on the driving frequency and amplitude, we inferred the relationship between the depth of the two potential minima and the intensity of the internal noise for the double-well potential model.

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TA55
Lightness constancy in 4-month-old infants: The effect of a local luminance ratio cue Sarina Hui-Lin Chien (yp@physiol.ox.ac.uk), Kevin W Bronson-Castain; Department of Psychology, University of Washington, Seattle, WA –

The luminance ratios of adjacent regions often stay constant across changes in illumination (Wallach, 1948). Chien (ARVO 2002) found that 4-month-old infants showed lightness constancy when a consistent local luminance ratio cue was present across changes in illumination. By manipulating the reflectance of the surround, we tested whether infant lightness constancy breaks down when the local luminance ratio cue was inconsistent across changes in illumination. Methods. The forced-choice novelty preference method (Chien, Palmer & Teller, in press) was used. Two incandescent illuminations differing by about a factor of 3 were used. The stimuli were light-grey (refl. 60%) and dark-grey (20%) papers, patterned as smiley faces, and were surrounded by either a white (90%) or a mid-grey (30%) surround. Three conditions were tested. In the “control” condition, both the surround and the illumination were unchanged between the study and the test phase. In the “change of surround” condition, the surround was changed from white to mid-grey but the illumination remained unchanged. In the “change of surround and illumination” condition, a change of illumination from low to high was further added. In the study phase of each trial, an infant was presented two identical faces with one surround and one illumination. In the test phase, the infant was presented one face that had the same reflectance and another face with a novel reflectance with a possibly different surround and illumination. The key was that, with a different test surround, the reflectance-matched face yielded an inconsistent (novel) luminance ratio, and this could cause a failure of lightness constancy. Results. In the control condition, infants showed preferences to the face with a novel reflectance. Neither the change of surround nor the change of illumination and surround conditions showed the same results. This suggests that constancy in infants depends at least in part on a local luminance ratio cue.

TA56
The highest luminance anchoring rule in lightness perception: A counterexample and an alternative model Michael E Rudd (mrudd@uwashington.edu), Iris K Zemach; University of Washington –

It is commonly believed that lightness computation occurs in a series of stages that involve: 1) extraction of local border contrast or luminance ratios; 2) edge integration to combine contrast or luminance ratios across space; and 3) lightness anchoring to relate the relative lightness scale computed in Stage 2 to the scale of reflectances in the image. The results of a number of psychophysical experiments have been interpreted as supporting the highest luminance anchoring rule, which states that the highest luminance in the scene appears white. There is a fundamental problem with this scheme for computing lightness that has not been previously addressed: The last stage of lightness computation: anchoring, has no direct access to luminance information, which is lost after Stage 1; instead it only knows about the output of the edge integration stage. So how can it anchor to the highest luminance? We have previously proposed a quantitative model of edge integration based on the idea that underlying lightness and darkness induction signals fill in from borders and combine to create an achromatic color signal (Rudd, 2001; Rudd & Arrington, 2001; Rudd & Zemach, 2002).

Our model predicts that two or more regions within a scene can have the same highest luminance yet appear different depending on their spatial context, whereas the highest luminance rule predicts that these regions should appear equally white. We tested these competing hypotheses by having subjects match the lightnesses of two disks, each surrounded by one or more dimmer rings of varying luminance, presented side-by-side on a flat-panel monitor. Our results demonstrate that two regions can have the same highest luminance yet be seen as having different lightnesses depending on their surrounds, consistent with the model. And conversely, we devise displays such that, in order for two regions to appear equally white their actual luminances must differ. Thus the highest luminance is not always seen as white.
TA57
**IMRI of brightness perception**  Frans W Cornelissen1 (f.w.cornelissen@med.rug.nl), Alex R Wade2, Robert F Dougherty3, Brian A Wandell2;
1Laboratory of Experimental Ophthalmology, University of Groningen, The Netherlands, 2Smith Kettlewell Eye Research Institute; San Francisco, CA USA, 3Psychology Department, Stanford University, CA, USA – Introduction: The perceived brightness of a region depends on the luminance in that the region and the spatial distribution of nearby luminance values. The brightness of a region can change dramatically even though its own luminance remains constant. To begin tracing the neural basis of this perceptual phenomenon, we made fMRI measurements in human V1 while subjects viewed disks that underwent perceptually similar brightness changes caused either by changes in disk luminance or by changes in the surround luminary.

Methods: Subjects viewed disk (14 deg diameter) and annulus (7-17 deg) stimuli while their brains were scanned. Varying the luminance of either the disk itself or the surrounding annulus (1 Hz), we modulated the brightness of the central disk. Periods of 12 s of stimulus modulation alternated with 12 s of a fixation point on a medium gray background. We measured the fMRI BOLD signal in primary visual cortex (V1; identified by retinotopic mapping) and compared activation caused by modulations of either the disk or annulus.

Results: Powerful responses were found at the V1 locations representing the boundary between the disk and annulus in both conditions. The activity fell with distance from the edge representation, eventually reaching zero response. Within the region representing the disk, modulating the luminance of the annulus resulted in lower activation than modulating the luminance of the disk itself.

Conclusion: fMRI signals in human V1 are greatest at the contrast edges between the disk and annulus with relatively little modulation over spatially uniform portions of the image even when the spatially uniform region modulates in time. Brightness changes in the central visual field are not accompanied by commensurate modulations of the BOLD signal in retinotopically corresponding cortex in V1. This suggests that the computation that associates brightness with a retinotopic location occurs at a later stage in human visual cortex.

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TA58
**Layered image representations and the perception of lightness**  Barton L Anderson (bart@mit.edu), Jonathan A Winawer; Dept. of Brain and Cognitive Sciences, MIT, USA – One of the fundamental issues in lightness perception concerns the structure of lightness representations. A central debate involves the role of layered image representations in the computation of surface lightness. Barrow & Tenenbaum (1978) suggested that the visual system performs an analysis in which the image is decomposed into a series of layered maps that represent the illumination, shape and lightness of surfaces in the image. More recently, a number of authors have questioned the role of layered image representations in the computation of surface lightness (Gilchrist et al., 1999; Adelson, 2000). We present a new class of lightness illusions that definitively demonstrate the role of layered image representations in the computation of surface lightness. We generated random patches of texture with a power spectrum that varies as 1/f^n (n>2). The spatial frequency components were then summed with random phases and orientations. Three versions of each image were constructed with this seed image: a higher contrast (HC) image; an image in which the maximal luminance in the texture fell below the mean of the HC display (a dark texture); and an image in which the minimal luminance was above the mean luminance of the HC image (a light texture). A small circular central patch of the HC image was placed on the corresponding position on both the dark and light textures. Both HC targets appeared as homogeneous circular discs overlaid with a transparent layer. Observers matched the perceived lightness of the central HC patch on each background. Our results revealed the largest lightness illusion reported to date: the HC target on the light background appeared black, and the HC target on the dark background appeared white. We show that the contrast relationships between the target patch and the surround are critical in causing these effects, particularly the polarity relationships. These results demonstrate that layered image representations can play a critical role in determining perceived surface lightness.

TA59
**How does the perception of shape interact with the perception of shiny material?**  Bruce Hartung (hartung@cs.wmu.edu), Daniel Kersten; University of Minnesota – Intensity variations within the image boundaries of an object are a function of variations in illumination, surface reflectance, and shape. Even if the shape is known, there is an inherent ambiguity in distinguishing whether variations are due to pigment change or reflections. This ambiguity is particularly acute for highly specular shiny surfaces. The traditional view is that specular highlights are crucial to the perception of shiny material; however, other more subtle information may be important to perceiving material. Hartung & Kersten (2002) showed that reflections that are ‘stuck’ to a rotating object are perceived to be paint, presumably because they move like paint. Dror, Leung, Adelson & Wandell (2001) showed that natural illumination maps exhibit statistical regularity similar to that of natural images. Fleming, Dror & Adelson (2001) showed that subjects more accurately estimate material under natural rather than unnatural illumination. This suggests that the visual system has knowledge of how natural illumination is warped by the shape of the reflecting object. But how does the perception of shape interact with the perception of material? We investigated the roles of local surface curvature and global contour on the perception of material. Because areas of high curvature ‘see’ more of the illuminating environment, reflections are compressed in the direction of high curvature and stretched in the direction of low curvature. We show luminance features consistent with this stretching are perceived as reflections. When rotated across the object’s surface so as to be inconsistent with this stretching, these features are perceived to be paint. We also show that when global contour affects perceived local shape, the perceived shininess of the material is also affected. These studies show that the visual system uses prior knowledge of the interaction of shape and illumination to distinguish reflections from pigment changes.

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http://www.kersten.org

TA60
**Blackshot: an unexpected dimension of human sensitivity to contrast**  Michael S Landy1 (landy@nyu.edu), Charles Chubb2, John Econopouly1; 1Dept. of Psychology and Ctr. for Neural Sci., New York Univ., USA, 2Cognitive Sciences, Univ. of CA, Irvine, CA, USA – PURPOSE. We studied the perceptual segregation of texture pairs consisting of a grid of uniform, square texture elements, differing only in the distribution of intensities across those elements. If two textures differ in mean intensity ("lightness") or in the variance of intensity ("contrast"), then they are easily segregated. Chubb, Econopouly & Landy (JOSA A, 11, 2350, 1994) demonstrated the existence of a 3rd mechanism B (in addition to mechanisms L and C, coding lightness and contrast respectively) that was solely responsible for the segregation of textures equated for mean and contrast. Here, we determine the sensitivity of B to textures differing in mean or variance, thus fully specifying its (highly nonlinear) contrast response function. METHOD. Two textures have gray-level histograms H1 and H2 chosen so as to equate both mean and variance so that B alone discriminates them. The magnitude of the difference D=H1-H2 was varied to find a segregation threshold t*D. Then, D was perturbed (e.g., D'=t*D+P) so that the two textures differed in mean or variance, and segregation performance was assessed. RESULTS. Differences in texture...
mean and in texture variance traded off linearly with changes in D. This implies that even when the textures differ slightly in mean or variance, it is still B alone that discriminates between them. The slopes of the lines relating changes in mean and variance to changes in the amplitude of D reflect the sensitivity of B to texture mean and variance. Combining these findings with our previous results reveals that B is (i) highly sensitive to texture elements of the lowest contrast (near -1), and (ii) has a response that saturates by a contrast of -3/4 (dark gray). That is, this "blackshot mechanism" discriminates textures by comparing the number of the blackest pixels in each.

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TA62

Reduced binocular disparity selectivity of V4 neurons to anti-correlated random-dot stereograms

Seiji Tanabe1,2 (tanabe@bpe.es.osaka), Ichiro Fujita1,2; 1Laboratory for Cognitive Neuroscience, Graduate School of Frontier Biosciences, 2Graduate School of Engineering Science, Osaka University, Osaka, Japan — A plane lying in depth is vividly perceived when a random-dot stereogram (RDS) is fused with slight binocular disparity. By reversing the contrast of dots seen by one of the eyes to generate an anti-correlated RDS, the perception of depth is lost or diminished, and the stimulus is perceived as merely rivalrous. This perceptual phenomenon became a useful tool for testing whether neural responses in the striate cortex (Cumming & Parker 1997) and extrastriate cortical areas MT and MST (Krug et al. 2000; Takemura et al. 2001) correlate with stereoscopic depth perception. When anti-correlated RDSs are used as stimuli, only a small number of neurons in these areas lose their disparity selectivity while the majority still modulate their responses dependent on binocular disparities. Neuronal activities in these areas thus do not correlate with depth perception. We examined neural responses to anti-correlated RDSs in area V4, where disparity selectivity of neurons to bar stimuli has been recently demonstrated (Hinkle & Connor 2001; Watanabe et al. 2002). We recorded extracellular action potentials from 32 and 27 V4 neurons in two awake, fixating monkeys (Macaca fascicularis). Twenty-four cells (12 each from the 2 monkeys) significantly modulated their responses according to disparities in correlated RDSs covering their receptive fields (ANOVA p<0.05). The majority of these cells (N=18/24) lost their selectivity for disparity when the RDS was anti-correlated (ANOVA p>0.05). For a subset of the cells that were also sensitive to disparities in anti-correlated RDS (3 out of the 6 cells), the disparity tuning curves followed a Gabor function. The tuning curves were shifted by ~#90°; between correlated and anti-correlated RDSs, which is reminiscent of the characteristic of striate neurons. Our results suggest that responses to false-matches between contrast-reversed dots in the left and right eye images elicited in the striate cortex are substantially reduced in or before V4.

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TA63

The cost of resolving stereo ambiguity

Suzanne P McKee1 (suzanne@ski.org), Bart Farell2, Preeti Verghees3; 1Smith-Kettlewell Eye Research Institute, San Francisco, CA, USA, 2Institute for Sensory Research, Syracuse University, NY, USA — The disparity range of an infinitely long sinusoidal grating would be limited to phase shifts of less than half a period, because shifts > 180 degrees are physically ambiguous. However, grating segments, 3 – 6 deg wide and presented in a rectangular envelope, are seen at or near the disparity specified by their ‘edges’. The disparity range for these segments is not constrained to phase shifts < 180 degrees; instead the range is limited to roughly 60 arcmin. Thus, the ‘edges’ disambiguate the depth of a grating (carrier) and extend its disparity range.

To study the interaction between edges and carrier, we measured how the edge disparity affects stereocuity for small phase disparities. The disparity of the edges was varied parametrically over the 0 – 60 arcmin range, but, for any block of trials, the edge disparity was fixed. The interocular phase difference(phase disparity) was varied from trial-to-trial in small increments. Subjects judged whether the grating appeared in front or behind a small fixed probe, presented below the grating segment. To control convergence shifts, the subject aligned nonius lines before initiating a trial; grating duration was 200 msec.

The benefits of edge disambiguation come at a substantial cost in sensitivity. For a 3cpd carrier, a 20 arcmin edge disparity shifts the carrier 1 full period (360 deg). From the perspective of the carrier, sensitivity should be the same for a disparity of 0 or 360 deg. To the contrary, we found that phase disparity thresholds were 2-3 times higher at an edge disparity of 20 arcmin than at 0 edge disparity (fixation plane). Shifting the grating off the fixation plane produces the same loss in sensitivity as reducing the contrast of a grating presented in the fixation plane. Generally, phase
sensitivity declines with increasing pedestal (edge) disparity much like stereoeacuity for bars, lines or random dots. Apparently, the stereo system treats a sinusoidal grating as a texture on a surface.

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TA64
The effect of absolute and relative disparity on stereoeacuity
Alexander J. M. Foulkes (ajmf@physiol.ox.ac.uk), Andrew J. Parker; University Laboratory of Physiology, Oxford, UK – Westheimer (1979) showed that stereoeacuity thresholds were an order of magnitude poorer when only absolute disparity information was available compared with relative disparity information. He proposed that this reflected an early mechanism that measured disparity differences, and was hence insensitive to fluctuations in absolute disparity. To examine this possibility explicitly, 3 subjects performed a stereoacuity task with a centrally fixated, circular, dynamic RDS stimulus (2.8 deg diam.) consisting of centre and surround regions of equal area between which a relative disparity was introduced, all against an uncorrelated background. This avoided monocular cues to the depth in the stimulus and allowed for simultaneous variation of both absolute and relative disparities. Normally distributed noise (s.d. 0 to 4 arcmin) was added to the centre and surround on each refresh frame in such a way as to disrupt either absolute disparities only (absolute noise) or relative disparities also (relative noise). The average relative disparity of the noise added to the stimulus over each 1-sec trial was arranged to be zero, so the noise would not disrupt the performance of an ideal observer. Absolute and relative disparity noise could also be combined to look at interactions. Absolute disparity noise was much better tolerated than relative disparity noise, consistent with Westheimer. For noise of 4 arcmin s.d., thresholds were an order of magnitude higher for relative noise than for absolute noise. 2D regression analysis showed that there was no interaction between the effects of absolute and relative disparity noise: they summed linearly. This result is consistent with the presence of a specialized mechanism for processing relative disparity that is insensitive to absolute disparity over the range tested, and the disruptiveness of relative disparity noise shows that subjects were unable simply to integrate disparity information over the 1-sec trial to estimate relative disparity.

Acknowledgment: Supported by The Wellcome Trust

TA65
Disparity gradient between the target and its surroundings defines depth discrimination threshold
Yury Petrov (yp@physiol.ox.ac.uk), Andrew Glennerster; Oxford University, UK – Stereoeacuity thresholds have been shown to depend on the disparity of a point with respect to a slanted reference plane through neighbouring points (A. Glennerster et al., Current Biology, vol. 12, 825-828 (2002)). Here we explored a wider range of conditions, including slanting the reference points about a horizontal axis and varying the spacing of the reference dots, allowing alternative hypotheses for the effect to be distinguished. The stimulus consisted of 3 dots; the outer two defined a line that was slanted in depth. Observers judged in which of two intervals the third, central dot was displaced from the location midway between the outer reference dots. The displacement consisted of both a disparity and a shift in the fronto-parallel plane. We compared performance for pairs of conditions in which the disparity was the same but the fronto-parallel shifts were in opposite directions. Models based purely on relative disparity do not predict a difference in performance for these conditions. We found consistent differences. Performance was always better when the target had a greater disparity with respect to the line joining the reference dots. The other stimulus parameters varied were: target disparity (concave/convex), stimulus size (large/small), slant sign (sky/ground) and axis (vertical/horizontal). Performance was only affected significantly by changing the stimulus orientation from vertical to horizontal. The results suggest that disparity gradient change, rather than disparity or disparity curvature, determines the depth discrimination threshold for these stimuli.

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Eye Movements – Cognitive

TA66
Focus cues to display distance affect perceived depth from disparity
Simon J. Watt1 (sp@physiol.ox.ac.uk), Kurt Akeley2, Martin S. Banks3; 1School of Optometry, University of California, Berkeley, USA, 2Electrical Engineering Department, Stanford University, USA – To recover absolute depth from binocular disparity, horizontal disparities must be scaled by an estimate of fixation distance. Conventional 3D digital displays present stimuli at one focal distance and this could result in distortions of perceived depth at simulated distances other than the actual distance to the display. To investigate this we independently varied distance specified by the eyes’ vergence and by focal distance using a novel display that allowed us to interleave stimulus presentations at different focal planes within a block of trials. Observers viewed sparse random-dot stereograms depicting two planes forming a hinge (“open book”) and adjusted the dihedral angle until it appeared to be 90 deg. The vertical size of the stimulus was always small (2 deg) to minimize the contribution of distance information from vertical disparity. Depth constancy (with changes in vergence-specified distance) was assessed by calculating, for each stimulus configuration, the distance at which the patterns of disparities set by the observers would have corresponded to a dihedral angle of 90 deg. When focal distance was fixed, depth constancy was poor (around 40%). However, when the focal distance varied appropriately with vergence-specified distance, depth constancy increased (in some subjects to as much as 65%). Depth constancy was highest in a baseline condition in which the stimulus was a real hinge with all depth cues available, but even then constancy rarely exceeded 80%. These results show that focus cues to distance can have a significant effect on the percept of depth in 3D displays and point to the need in vision research to develop means of circumventing or minimizing cue conflicts created by conventional displays.

Acknowledgment: This research was supported by The Wellcome Trust and AFOSR

Sunday, May 11, 2003
10:45 am – 12:15 pm
South Hall
Moderator: Eileen Kowler

10:45 Castelhano, Henderson, TA67
11:00 Geisler, Perry, Najemnik, TA68
11:15 Caspi, Beutter, Eckstein, TA69
11:30 Körner, Gilchrist, TA70
11:45 Gersch, Kowler, Dosher, TA71
12:00 Beintema, Van Loon, Hooge, Van den Berg, TA72

TA67
Flashing scenes and moving windows: an effect of initial scene gist on eye movements
Monica S. Castelhano (castella@msu.edu), John M. Henderson; Department of Psychology & Cognitive Science Program, Michigan State University, USA – The current study used a new flash preview/moving window paradigm to investigate the nature of the information initially acquired from a real-world scene. On each trial, participants were first shown a preview photograph for 250 ms. A word identifying a target object was then presented for 2 s. Finally, participants
searched for a target while viewing the scene through a two-degree window that was centered at fixation and moved with the eyes. The scene was not visible outside the moving window. In the first experiment, the preview scene was either identical to the search scene, a different scene, or a meaningless mask. A flash preview benefit, indexed by more efficient eye movements to the target, was found for the identical preview condition over the different scene or mask conditions. The second experiment explored the contribution of scene category to the flash preview benefit. In this experiment, the preview scene was either identical to the search scene, a different scene from the same basic-level category as the search scene (i.e., same gist), or a scene from a different category. The same gist scene did not contain the target object or share the same spatial layout as the search scene. Results indicated that basic-level scene category alone was not the source of the benefit. In the third experiment, the contribution of target recognition to the flash preview benefit was explored by including or excluding the target object from the identical scene preview. Results from this and further experiments exploring other possible sources for this facilitation (e.g., extraction of spatial layout) will be reported. We conclude that the scene information acquired during an initial glimpse can be preserved in sufficient detail and over sufficient time to facilitate subsequent eye movements through the scene, and that the flash preview/moving window paradigm provides a useful tool for exploring the nature of this initially acquired scene information.

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TA68
Visual search: Gaze contingent displays and optimal search strategies
Wilson S. Geisler (geisler@psy.utexas.edu), Jeffrey S. Perry, Jiří Najemník; Center for Perceptual Systems, University of Texas at Austin, USA

Although generic visual search in the real world involves integrating information over multiple fixations, most research has focused on single-fixation tasks where stimuli are presented briefly. At least two factors have held back progress in understanding visual processing in more natural search tasks: (1) the difficulty of precisely controlling and manipulating the stimulus on the retina and (2) the lack of a Bayesian ideal-observer theory for multiple-fixation (extended) visual search. To enable precise stimulus control in extended search tasks, we developed “gaze-contingent” software (see http://svi.cps.utexas.edu/) that allows real-time control of the content of video displays relative to the observer’s current gaze direction (measured with an eye tracker). In our first experiment, we measured search time and eye movements while subjects searched for Gabor targets in 1/f noise. We varied parametrically: target spatial frequency, noise contrast, and rate of fall-off in display resolution from the point of fixation. This experiment provides quantitative data on how much information can be removed from the periphery (how much foveation can be tolerated) without affecting search time or the pattern of eye movements. We find that the shape of the function describing search time versus degree of foveation is dependent upon target spatial frequency, but is (interestingly) independent of noise contrast. To provide an appropriate benchmark against which to evaluate search performance, and to provide a starting point for developing models of search performance, we derived the ideal observer for visual search in broadband noise, where the ideal searcher is constrained by an arbitrary function describing sensitivity across the retina and by some level of internal noise. We compare the eye movements and performance of ideal and real observers. More details of the ideal visual searcher are given in another presentation (Najemník et al. VSS 2003).

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TA69
The accumulation of visual information driving the 1st saccade during visual search probed with spatiotemporal noise
Avi Caspi1 (avi.caspi@psych.ucsb.edu), Brent R. Beutter2, Miguel P. Eckstein1;

1Department of Psychology UC Santa Barbara, US, 2NASA Ames Research Center, US—Visual information presented during saccadic preparatory time does not influence the saccade destination. Less is known about how visual information is integrated prior to the saccade preparatory time. Here, we use a search task for a target added to a time sequence of independent samples of spatially uncorrelated noise (i.e., spatiotemporal noise) to examine how the information used to choose where to make saccades accumulates over time.

We recorded eye movements of two observers in a 5 alternatives force choice (AFC) search task. On each trial a sequence of frames was presented at 40 Hz for 500 ms. The observer’s task was to saccade to a bright Gaussian target among 4 dim Gaussian distractors (SNR of a single frame was 2.8). The target and the distractors were placed within boxes equidistant along an imaginary circle with diameter of 6.4 deg. We considered the saccadic decision to be correct if its endpoint was closest to the target location. Performance (d’) of the 1st search saccade was measured as a function of the number of frames presented before the onset of the saccade (number of frames = saccadic latency / duration of a frame). For short latencies (< 200 ms.) observers made few saccades and accuracy was low (d’ < 1.0). For medium latencies (200-325 ms) observers made many saccades and d’ increased linearly as a function of the square root of the number of noise samples. For long latencies (> 325 ms), observers made few saccades and d’ was approximately constant (d’ = 2.3). An ideal observer integrates information from all available frames predicting that performance (d’) should increase as the square root of the number of frames presented prior to the saccade. In contrast, human observers appear to only accumulate information from frames within a brief temporal window prior to the saccadic preparatory time.

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TA70
Target tagging in visual search
Christof Körner (christof.korner@bristol.ac.uk), Iain D. Gildersleeve; Department of Experimental Psychology, University of Bristol, UK—Gibson et al. (2000) reported reaction time results from a visual search task in which participants searched for one versus two targets. These results suggested that targets were tagged, i.e., that there is memory in visual search.

We report two experiments in which we replicate the Gibson et al. (2000) task and employ a traditional target present-absent search task. We also recorded participants' eye movements. There were four key conditions in two blocks: one-target vs. two-target and target-present vs. target-absent. In Experiment 1 we replicated the manual response times for the multiple target search. If search proceeded in a serial exhaustive manner we would expect identical performance in the one-target and the target-absent conditions. However, response times were longer and the number of fixations was greater in the one-target condition. This suggests that there was a cost associated with tagging the target.

The eye movement data from Experiment 2 showed that this difference was due to an increase in the number of distractor refixations in the one-target condition. Specifically, in the one-target condition the proportion of refixations was substantially greater than would be expected from analysis of any of the other conditions. These results suggest that searching for multiple targets and tagging targets carried a cost as measured by search performance. In turn, these differences suggest that this target-tagging process is not the same one that is deployed to tag distractors in traditional target-present-absent search.

Acknowledgment: Supported by EU MCF grant and the Wellcome Trust (UK).

TA71
Dynamic allocation of visual attention during the execution of sequences of saccades
Timothy M. Gersch1, Eileen Koehler1, Barbara Dosher2; 1Rutgers University New Jersey, USA,
2University of California at Irvine, CA – Most laboratory tasks used to study vision and attention require steady fixation. By contrast, natural visual processing occurs during the pauses between successive saccades. We assessed vision during intersaccadic pauses as subjects made repetitive sequences of saccades. Displays contained 6 outline squares located along the perimeter of an imaginary circle (diam 4 deg). Saccades were made to every other square. The visual task was to identify the orientation (2AFC) of a Gabor test stimulus that appeared briefly (90 ms) along with superimposed noise in one of the squares during a randomly selected intersaccadic pause. Gabor location was cued before each trial and noise frames were presented in all squares to avoid drawing attention to the location of the visual test.

Contrast thresholds during intersaccadic pauses were as much as two times higher in control trials with steady fixation. Surprisingly, slowing down scanning rate in an effort to pay more attention to the cued location did not help. Thresholds improved over time during the intersaccadic pause. Lowest thresholds relative to steady fixation were found for the pair of locations that were the targets of the next 2 saccades in the sequence. Highest thresholds relative to steady fixation were found for the location intermediate between the current fixation position and the target of the next saccade.

These results show that vision during intersaccadic pauses is modulated by the distribution of attention, as well as by visual suppression that may be related to the execution of saccades. Attention is allocated to targets for the entire saccadic sequence, not exclusively to the target of the next saccade. Changes in visual thresholds accompanying sequences of saccades are larger than those reported prior to the execution of single saccades, and larger than those induced by attentional cuing during steady fixation.

Acknowledgment: Supported by AFOSR F49620-02-1-0112

TA72

Saccadic decision-rate distributions reveal competition process Jaap A. Beintema1 (jaap.beintema@bio.uu.nl), Editha L. Van Loon2, Ignace Th. C. Hooge2, Albert V. Van den Berg1; 1Functional Neurobiology, Utrecht University, the Netherlands, 2School of Psychology, University of Nottingham, United Kingdom. 3Psychonomy, Utrecht University, the Netherlands – Reddi & Carpenter (2000) proposed that the saccadic latency reflects the reciprocal rate of visual processing for reaching a decision threshold. They observed that the rates (=reciprocal latencies) of 1st saccades were distributed normally. This observation does not apply to saccade sequences, because for visual search tasks van Loon et al. (2002) found that the rate distributions for 2nd and later saccades are skewed, much like Gamma distributions. Gamma distributions arise when many independent stochastic processes contribute to the decision, suggesting the skewing results from a reduced number of processes in later saccades. However, skewed distributions can also be explained by a competition process that pits two rate signals against each other (van den Berg, NS 2001). Such extended decision model, with for instance ‘make saccade’ vs ‘keep fixating’ decision signals, would enable the saccade sequence to stop. Interestingly, the model predicts beta distributions, which typically have more tail at high rates than gamma distributions. Furthermore, the beta function’s two parameters represent the thresholds of the two competing signals. Here, we investigated the evidence for a beta rate distribution and for systematic variations in its parameters. Subjects were to saccade as quickly as possible towards a target that deviated in line orientation from distractors consisting of lines arranged in a radial pattern. The number of distractors (Exp. I) or the chance of the target appearing at the fixation point (Exp. II) was varied. In both experiments, the rate distributions for second and later saccades were significantly better fit by beta than by gamma functions. Moreover, significant changes in the beta fit parameters were found in Exp. I for the later saccades, with threshold changes as predicted by the competition model. Our results are consistent with a competition between two decision signals underlying the timing of saccades.

Acknowledgment: NWO 809.37.003

TA73

How image statistics drive shape-from-texture and shape-from-specularity Roland W. Fleming (roland@psyche.mit.edu), Antonio Torralba, Ron O. Dror, Edward H. Adelson; Massachusetts Institute of Technology, USA – We present a new visual cue that allows the visual system to solve two key perceptual problems under a large range of circumstances. The first problem is our ability to distinguish specular reflections from texture markings. The second problem is the estimation of 3D object shape from monocular images.

Textures and specular reflections both lead to stochastic patterns in images. How can we tell them apart? Recently we have argued that textures and reflections have different statistical properties (e.g. specular reflections of the real world have heavily skewed pixel histograms). However, there is an additional cue, which results from the way that patterns are distorted by 3D shape.

As a textured plane is oriented away from frontoparallel, the image of the texture becomes compressed. This provides a cue for 3D shape: if the visual system can measure the compression of the texture at each image location, it can recover local orientation and thus shape. We argue that specular reflections can be treated a bit like textures, because they also lead to stochastic image patterns with well-conserved statistics. When the world is reflected in a specular surface, the reflection is distorted by the shape of the object. The pattern of distortion is a function of the 3D shape, just as it is with textures. Crucially, however, for specularities the compression is a function of surface curvature as well as orientation. Hence, the mapping from image compression to 3D shape follows different rules for specular vs. textured surfaces.

We call the pattern of compressions across an image the ‘texture trajectory’. Texture trajectories can allow the visual system to distinguish specular reflections from textures, and to estimate 3D shape for both textured and specular objects. The texture trajectory cue is weakest for spheres and planes, and strongest for objects with very different surface curvatures in orthogonal directions (e.g. cylinders). We exploit this to generate some powerful demos.

Acknowledgment: Research supported by NIH grant EY12690-02 to E.H.A., and by a Hugh Hampton Young Fellowship to R.W.F.

TA74

Can we see the shape of a mirror? Silvio Savarese (savarese@vision.caltech.edu), Fei Fei Li, Pietro Perona; California Institute of Technology, USA – The three-dimensional shape of a surface may be perceived from a monocular static image. Contours, shading, texture gradients, perspective and occlusion are well-studied cues to this percept. When looking at the surface of a smooth reflecting object, such as a well washed car, one additional cue is potentially available: the surrounding scene is reflected,
and the deformation of this reflection is a function of the shape of the object's surface. Is this cue used by the human visual system? May it be used in isolation, i.e. when other visual cues are not available?

In order to investigate this question we asked a number of human observers to discriminate between images of mirror surfaces of qualitatively different shapes: a sphere, a cylinder and the neck of a vase. Such shapes have positive, zero and negative Gaussian curvature and reflect the same scene with distinctly different distortions. The experimental stimuli were 144 photographs of large patches of each mirror surface reflecting one of six regular patterns which had been shown to the subjects in advance. Each patch was obtained by vignetting one of the photographs using irregularly shaped boundaries, in order to eliminate occluding boundary information. It was viewed monocularly and centrally on a standard computer monitor for 1 second. Each patch subtended in average a visual angle of 20 degrees. The subjects were instructed to respond to three forced alternative choices (sphere, cylinder, vase).

Our subjects are only slightly better than chance in discriminating such shape differences. Our ideal observer analysis indicates that mirror reflections allow recovery of depth, tangent plane and surface curvature when the surrounding world has a known shape.

However, when the surrounding world is (partially) unknown, the problem is underconstrained and many solutions are possible. Our experiments confirm this analysis indicating that mirror reflections are a weak cue for most human observers when additional information is not available.

TA75
The influence of object orientation and shading on pictorial relief of Lambertian surfaces Harold T. Nefs (h.t.nefs@phys.uu.nl), Jan J. Koenderink, Astrid M.L. Kappers; Universiteit Utrecht / Helmholtz Instituut, The Netherlands – We studied the influence of object orientation and lighting direction on pictorial relief of 2D images of generic 3D objects. We used two objects, namely a globally convex object with a furrow in it and a globally convex object with a dimple in it. Participants adjusted a local surface reflecting one of six regular patterns which had been shown to the subjects in advance. Each patch was obtained by vignetting one of the photographs using irregularly shaped boundaries, in order to eliminate occluding boundary information. It was viewed monocularly and centrally on a standard computer monitor for 1 second. Each patch subtended in average a visual angle of 20 degrees. The subjects were instructed to respond to three forced alternative choices (sphere, cylinder, vase).

Our subjects are only slightly better than chance in discriminating such shape differences. Our ideal observer analysis indicates that mirror reflections allow recovery of depth, tangent plane and surface curvature when the surrounding world has a known shape.

However, when the surrounding world is (partially) unknown, the problem is underconstrained and many solutions are possible. Our experiments confirm this analysis indicating that mirror reflections are a weak cue for most human observers when additional information is not available.

TA76
3D shape-colour interactions in a real object similarity task Yazhu Ling (yazhu.ling@ncl.ac.uk), Anya C Hurlbert; Henry Wellcome Building for Neuroecology, University of Newcastle upon Tyne, UK – In the natural world, objects are characterised by a variety of attributes, including colour and 3D shape. The contributions of these two attributes to object recognition are typically studied independently of each other, yet they are likely to interact in natural tasks. In this experiment, observers viewed a display of 16 real 3D objects, hemispheres sculpted from plaster of Paris and painted matte white. Distinct apparent surface colours were applied to the object surfaces and independently varied between trials. On each trial, any given shape might appear with any one of a fixed set of colours evenly distributed around the neutral chromaticity of the background. The observer’s task was to select which of two indicated test objects was most similar to the designated reference object; both test and reference objects varied between trials. Each test object had either the same colour and different shape or the same shape and different colour relative to the reference object, and both shape and colour differences varied from sub- to supra-threshold values, as determined from independent single-variable shape- and colour-discrimination measurements with the same objects. The results demonstrate that 3D shape and colour interact significantly in determining object similarity: both shape-difference and colour-difference thresholds in the object similarity task were larger than in the single-variable discrimination measurements. Furthermore, threshold colour differences for object similarity increase as 3D shape differences decrease, and vice versa.

Acknowledgment: YL is sponsored by a Unilever PLC Research Studentship.

TA77
Depth and size scaling created by the differential perspective of ground plane surfaces Brian J Rogers (bjo@psy.ox.ac.uk); University of Oxford, UK – The horizontal gradient of differential vertical size in the two eyes (differential perspective) provides information about the absolute distance to a frontal surface which has been shown to be effective in both size and depth scaling (Rogers and Bradshaw, 1993, Nature, 361). In the real world, however, extensive frontal surfaces are rare and the more typical ground plane surface instead creates a complex, higher-order gradient of differential perspective. It is straightforward to show that these higher-order gradients provide sufficient information to scale the retinal sizes and horizontal disparities of all objects lying on the ground plane surface as well as providing a potential source of information to calibrate binocular vergence. The present experiments were designed to measure the effectiveness of ground plane differential perspective gradients for size and disparity scaling and for vergence calibration. Large visual field stimuli were created by projecting binocular images onto separate ground plane screens in a modified Wheatstone stereo-cone configuration. The test objects were triangular wave corrugations in which observers had to judge the corrugation angle (shape task) and the separation between the peaks (size task). The ground plane gradient of differential perspective was manipulated independently of the vergence demands of the simulated surface. The results show that both size and depth constancy were high (70-80%) when the differential perspective gradient and vergence cues were consistent and appropriate. A substantial independent effect of the differential perspective gradient on size and depth constancy was also revealed when it was set in conflict with the vergence demands of the simulated surface.

TA78
A new kind of global stereopsis: The ability to determine slant or occlusion from patterns of horizontal disparity Barbara Gillam (bjo@psy.ox.ac.uk), Philip Grove; University of New South Wales, Australia – Disparity for a single horizontal line is ambiguous. It can originate either from slant, which magnifies one image, or from occlusion by a nearer surface, which truncates the image more for the eye on the side of the surface. Even without an explicit surface present, disambiguating information can exist in the pattern of disparities among a set of parallel horizontal lines if they vary in length. Slant produces magnification proportional to width so that lines of different initial length would also have different additional lengths in the magnified image. Occlusion will simply truncate each line by a constant amount in one eye regardless of its length. Gillam et al (ECVP, 2001) found a strong subjective occluding contour along the aligned side of a set of horizontal lines of different lengths when a constant length was added for the eye on the side of the edge alignment (valid occlusion stimulus). Here we compare perceived
slant for uniocular truncation and magnification for sets of horizontal lines, measuring slant for a long and a short line within each set. Both disparity directions were used, consistent with valid or invalid occlusion or with positive or negative slant. Method. A stereo probe measured perceived depth at each end of the designated line from which its slant was calculated. Results. For valid occlusion conditions the lines were perceived as approximately flat and at the depth predicted from occlusion considerations. For the invalid occlusion conditions lines were seen at different slants. For the magnification conditions uniform slant was seen, closely in accordance with prediction from the magnification present. Conclusions. Despite the complete ambiguity of each line with respect to slant / occlusion, subjects were able to perceive a line as slanted or not with considerable accuracy and precision based on a comparison of disparities across the set of lines. This reveals a novel global stereoscopic ability overriding local disparity information.

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TA79 Flexible patches for recovering surfaces from binocular disparity Quoc C Vuong1 (Quoc_Vuong@brown.edu), Fulvio Dominii, Corrado Candek2; 2Brown University, USA, 3University of Trieste, Italy – Observers are faced with the difficult task of inferring surfaces from retinal information. The problem is that the same retinal images are projected by infinitely many 3D structures. However, Lappin and Craft (2000) showed that second-order spatial derivatives taken locally along two spatial dimensions of smooth surface regions (i.e., 2D spatial manifolds) are isomorphic to second-order derivatives of image properties (e.g, disparities). That is, there is a one-to-one mapping between surface structures and image properties. In line with this analysis, they found that observers measured these properties very consistently. In this work, we argue that disparity fields specified by a few texture elements sampled from random spatial positions on surfaces are inherently ambiguous. Given this ambiguity, two alternative hypotheses can be formulated: (1) 2D second-order spatial manifolds can interpolate the sparse data (Lappin & Craft, 2000), or (2) simple planar or low-curvature “flexible” patches can fit local image regions. According to the first hypothesis, we expect that human performance on tasks involving the placement of probe dots on smooth surfaces (Exp. 1) or discriminating smooth from randomly depth-jittered surfaces (Exp. 2) should not depend on the magnitude of local curvature of quadratic (second-order) surfaces that are simulated in random-dot stereo displays. On the contrary, we found that human performance systematically decreased with curvature. Moreover, we found that observers more accurately discriminated planar surfaces from curved surfaces (using at-threshold curvature values for individual observers) than from depth-jittered surfaces with the same range of disparities as the curved surfaces (Exp. 3). Thus, given ambiguous retinal information, the results across the three experiments suggest that observers infer surfaces by fitting simple yet “flexible” patches to sparse data.

Acknowledgment: Supported by an NSERC scholarship to Q.V. and National Science Foundation grant 78441 to F.D.

TA80 Slant anisotropy and tilt-dependent variations in stereo precision Tandra Ghose1 (tandra@ucdlink.berkeley.edu), James M Hillis2, Simon J. Watt3, Michael S Landy4, Martin S Banks4; 1Vision Science Program, University of California, Berkeley, CA, USA, 2Dept. of Psychology, University of Pennsylvania, PA, USA, 3Dept. of Psychology & Ctr. for Neural Sci., New York Univ., New York, NY, USA – It has frequently been reported that stereoscopically-defined, slanted surfaces have greater perceived slant when the rotation axis is horizontal (tilt = 90 deg) than when it is vertical (tilt = 0 deg). It has also been observed in cue-contrast experiments that more weight is given to the slant specified by monocular cues when tilt = 90 deg than when tilt = 0 deg. We asked whether these two effects—which have been called slant anisotropy—are caused by a reduction in the precision of stereoscopic slant estimates for tilt=90 deg compared to tilt=0 deg. We measured slant discrimination thresholds for disparity alone and for texture alone for a variety of base slants, and for tilts of 0 and 90 deg. Discrimination thresholds for disparity alone were slightly lower when tilt = 90 deg and thresholds for texture alone did not vary consistently with tilt. From those thresholds, we can determine the variances of the disparity and texture estimators at different slants and tilts. We next examined how disparity and texture are weighted when both cues are relevant to the task. From the single-cue variances (measured in the single-cue discrimination experiment), we can predict the relative weights that should be given to disparity and texture in a cue-combination experiment. The agreement between predicted and observed weights was quite reasonable. More weight was given to texture as base slant increased due to a concomitant increase in the reliability of slant-from-texture. Slightly more weight was given to disparity for tilt = 90 deg than for tilt = 0 deg. However, the small tilt variation we observed in stereoscopic precision was insufficient to explain the large variations in perceived slant that has been previously reported.

Acknowledgment: Supported by an NSERC scholarship to Q.V. and National Science Foundation grant 78441 to F.D.

TA81 Brain activity reflects perceptual learning of point-light biological motion Emily D Grossman1 (edg@wjh.harvard.edu), Chai-You Kim2, Randolph Blake2; 1Harvard Vision Sciences Lab, Harvard University, USA, 2Vanderbilt Vision Research Center, Vanderbilt University, USA – Background. Individuals get better with practice on a variety of perceptual and cognitive tasks, and this learning is thought to reflect plasticity in underlying neural mechanisms. Is perceptual learning of biological motion reflected in the neural activity of the brain areas underlying perception of these displays, namely STSp and FFA? We trained naïve observers to discriminate biological from scrambled motion in displays masked with noise dots and measured neural activity associated with the learning using fMRI. Methods. Naïve observers viewed point-light biological and scrambled motion animations superimposed in noise dots. The number of noise dots was adjusted such that prior to training the observers performed at near chance levels for discriminating the two kinds of animations. Brain activity was measured while observers performed a 1-back task on these masked displays. Next observers received daily training sessions in which the difficulty of the task was continuously adjusted as observers improved Following this training, brain activity was again measured while observers viewed the masked animations. Results. D-
prime measures prior and subsequent to training indicate that observers became more proficient at discriminating the biological from scrambled animations in the masked displays, with the degree of improvement varying among observers. Prior to learning, neural activity in STSp and FFA were suppressed in the masked condition relative to the unmasked animations, but after learning, BOLD signal levels were equivalent during the masked and unmasked conditions. These results were replicated when the same observers viewed a novel set of biological motion animations not seen during the training sessions. The degree of learning was positively correlated with the changes in BOLD signals. Thus observers become more sensitive to biological motion with learning, and this change in sensitivity is reflected in the amplitude of the neural signals in STSp and FFA.

**Acknowledgment:** Supported by NSF BCS0079579 and NSF BCS0121962

**TA82**

**Biological motion perception is impaired in unilateral parietal patients**

Lorella Battelli1; Battelli@wjh.harvard.edu, Patrick Cavanagh1, Ian M Thornton2; 1Harvard University, USA, 2Max Planck Institute for Biological Cybernetics, Tübingen, Germany—Purpose: Although the perception of biological motion mimicking human walking is compelling and seems spontaneous and effortless, it actually demands attention (Cavanagh, Labianca, & Thornton, 2001). Since unilateral parietal patients show deficits in perceiving attention-based apparent motion (Battelli et al, 2002), we explored whether these patients would also be impaired in the perception of biological motion. Method: Three unilateral parietal patients were tested in three experiments. One low-level form-from-motion and two visual search tasks were used. In the first visual search experiment subjects searched for a walker facing opposite to the distractors walker, while in the second they searched for a normal walker among jumbled ones. In both search tasks set size varied between one and four items randomly across trials. Accuracy and reaction times were measured. Results: All patients could easily perform the classical low-level motion task at normal levels. However, they were severely impaired in the visual search tasks using biological motion sequences showing elevated error rates and reaction time compared to normals. Furthermore the left parietal patient performed much worse than the right parietals. Conclusions: Since our patients' low-level motion mechanisms are preserved, we suggest that the perception of biological motion requires high-level analysis of dynamic patterns, an attention-based process that is impaired in parietal lobe patients.


**TA83**

**Metric category spaces of biological motion**

Martin A. Giese1 (martin.giese@tuebingen.mpg.de), Ian M Thornton2; 1Dept. of Cognitive Neurology, University Clinic, Tuebingen, Germany, 2MPI for Biological Cybernetics, Tuebingen, Germany—Converging experimental evidence suggests that shape categories are mentally represented as continuous spaces that preserve the parametric similarities among individual object shapes. Here we show that perception of biological motion likewise preserves the metric of spatio-temporal similarities among motion patterns. We presented subjects with animated images of point light dots corresponding to trajectories generated by spatio-temporal morphing among three prototypical human locomotion patterns. Using a novel morphing algorithm that composes linear combinations of complex movement trajectories in space-time, we generated motion stimuli that corresponded to two-dimensional geometrical configurations in a metrical pattern space defined by the weights of the linear combination. Two configurations were used, one consisting of 7 patterns arranged in the form of a (T)riangle, and the other in the form of the letter L. For each configuration, observers were asked to judge the similarity between all pairs of stimuli using a comparison-of-pairs paradigm. A measure of perceived dissimilarity computed from these judgments was submitted to multidimensional scaling. The recovered 2D configurations in the reconstructed perceptual space were quantitatively compared with the configurations in the original linear morphing space. The recovered metric structure closely matched the original metric structure in the morphing space. (Coefficients of congruence 0.98 and 0.88 for T (n=14) and L (n=19); Procrustes distances 0.41 and 0.96; corresponding to bootstrap-estimated d2 equivalents between 2.99 and 8.15). We recovered a very similar metric structure from the neural responses of a physiologically plausible model of biological motion recognition. We conclude: (a) The visual system represents related categories of locomotion in a common metric space that reflects spatio-temporal similarities of motion trajectories. (b) These representations can be realized with known cortical mechanisms.

**Acknowledgment:** Supported by the Deutsche Volkswagenstiftung and Max-Planck-Gesellschaft.

**TA84**

**Role of learning in biological motion recognition**

Jan Jastorff1 (jan.jastorff@tuebingen.mpg.de), Zoe Kourtzi2, Martin A Giese1; 1ARL, Department of Cognitive Neurology, University Clinic, Tuebingen, Germany, 2Max Planck Institute for Biological Cybernetics, Tuebingen, Germany—It has been shown, that humans can learn to discriminate between different styles of natural movements (e.g. gait or sports movements). However, it remains unknown whether this learning is based on ‘innate’ templates for biological movement patterns, or if humans can learn new representations of arbitrary complex movements. We address this question by investigating, whether subjects can learn novel artificial biological movement stimuli. These stimuli were generated by linearly combining prototypical trajectories of very dissimilar natural movements in space-time using spatio-temporal morphable models (Giese & Poggio, 2000). Most of the tested stimuli do not correspond to naturally occurring movements, and some of them likely even violate the physical laws of human body movement. Subjects had to discriminate between pairs of these stimuli, containing slightly different weights of the prototypes. The stimuli were presented as standard point light walker (PLW), and as point light walker with position jitter (generated by adding random displacements of the dots along the skeleton of the walker for every frame). Subjects trained with standard PLW learned relatively quickly (after about 8 trials) to discriminate between these stimuli. Testing different subjects with stimuli that were rotated by 90 deg in the image plane showed that the learned representation transferred to rotated stimuli. Subjects that were trained with PLW with position jitter learned the discrimination task equally fast (8 trials). However, another set of subjects trained with the same stimuli and tested with rotated stimuli did not show transfer of the learned discrimination to rotated stimuli. We draw the following conclusions from this experiment: (1) New templates for biological movement recognition can be acquired very quickly. (2) Learning affects at least two different levels of representation (local and holistic). (3) The learned holistic representations seem to be viewpoint-dependent.

**Acknowledgment:** ZK is supported by the Max Planck Society; MG is supported by the Deutsche Volkswagenstiftung

**TA85**

**Critical features for biological motion**

Antonino Casta1 (casse@tuebingen.mpg.de), Martin Giese; Department of Cognitive Neurology, University Clinic, Tuebingen, Germany—Since the seminal work by Johansson, it has been widely accepted that mostly motion information is relevant for the perception of point light walkers. Beintema & Lappe (2002) have proposed a novel point light stimulus (sequential position walker, SPW) that strongly degrades local motion information by randomly displacing the dots along the limbs. Despite this degradation, their subjects were still able to judge the direction of walking, suggesting that the perception of these stimuli was based purely on form information, presumably by fitting an internal kinematic model. To test this hypothesis
we designed another point light stimulus that is composed of regions containing either purely randomly moving dots, or dots with deterministic opponent motion along the horizontal axes, but random vertical motion. Despite the fact that this stimulus is highly incompatible with the kinematics of a walker subjects perceived it as a walking person. By slight variation of the stimulus outline the percept could be reliably shifted between rightward and leftward walking. Psychophysical experiments show no difference in recognition between the two stimuli (N=5, p>0.7). This result points against a relevance of kinematic models in the recognition of point light stimuli. Additional evidence against the necessity of form information was obtained in a quantitative modeling study using a neurophysiologically plausible model with a motion and a form pathway. The motion pathway of the model that analyzes local motion information achieves reliable recognition of SPW stimuli, whereas the form pathway contributes only weakly. We conclude that, though form information undoubtedly can be exploited for the recognition of biological stimuli, it might not be sufficient for the recognition of point light walkers. Instead, our experimental results suggest that their recognition might implicate the use of opponent motion features that can be extracted by relatively simple neural detectors.

Acknowledgment: Supported by the Deutsche Volkswagenstiftung.

TA86
Gender and attractiveness from biological motion Nikolaus F Troje (troje@rub.de); Ruhr-University-Bochum, Germany – Biological motion contains plenty of visual information about several attributes of biological and psychological significance. In particular, we can accurately determine the sex of a walker from the way he or she moves. Furthermore, motion patterns vary to a large extent in perceived sexual attractiveness. In this study, we investigate the relation between perceived attractiveness and gender using dynamic point-light displays from 40 male and 40 female walkers. Using a linear, morphable stimulus space, we determined discriminant functions based on attractiveness ratings of 12 male and 12 female participants. In a first block observers were shown with displays of the other sex and asked to rate the walkers in terms of their sexual attractiveness. In the second block they were presented with walkers of their own sex and asked to rate the assumed attractiveness on the other sex. The resulting discriminant functions are visualized in terms of caricatured walking displays and compared with the linear discriminant function that best classifies the sex of a walker. The results show that female attractiveness as rated by male observers highly correlates with gender – i.e. with the projection of a walker onto the linear sex classifier. In contrast, female attractiveness as rated by female observers is virtually independent of gender and rather appears to display a vivacious, energetic character. Male attractiveness as rated by male and female observers shows a similar tendency. Whereas male observers assume themselves to be rated attractive by females when displaying masculinity, the discriminant function based on the ratings of female observers is in fact almost perpendicular to the gender discriminant function.

Acknowledgment: The work was funded by the Volkswagen Foundation http://www.biomotionlab.de/Demos/attractivity.html

TA87
Inversion effects on the structural encoding and recognition of biological motion Daniel Jokisch (Daniel.Jokisch@ruhr-uni-bochum.de), Nikolaus F Troje, Thomas Kress, Irene Daum; Institute of Cognitive Neuroscience, University of Bochum, Germany – The human visual system is very sensitive to animate motion patterns. Humans can detect efficiently another living being in a visual scene and retrieve many features of psychological, biological and social relevance. By representing the main joints of a person’s body by bright dots against a dark background, observers can easily recognize a human walker and determine his/her gender, recognize various action patterns and identify individual persons. The importance of the perception of biologically relevant motion patterns is reflected by the identification of a specific neural circuitry as shown by brain imaging studies. Whereas basic principles of the neural basis of perception of biological motion are understood, many issues concerning the temporal characteristics of the processing of such kind of information are as yet unclear.

In the present study we investigated how inversion of biological motion stimuli affects components of event related potentials (ERP). ERPs were recorded in response to point-light displays of an upright walking person, point-light displays of an inverted walking person and displays of scrambled motion, in which the moving dots had the same motion vectors as in biological motion displays with their initial starting positions being randomized.

Analysis yielded a N170 component at parieto-occipital electrodes, which was more pronounced for upright walkers than for inverted walkers and scrambled motion. A later component in the time window between 300 and 400 ms after stimulus onset had a larger amplitude for upright walkers and inverted walkers as compared to scrambled walkers. We hypothesize that the N 170 component reflects the holistic recognition of prototypical configurations of a human body, whereas the later component is associated with the integration of the dots’ interrelations to a coherent percept.

Acknowledgment: NEI grant R01 EY12300

TA88
Walk with me: Self-relative gait speed judgments are influenced by observer action Alissa Jacobs (ajacobs@psychology.rutgers.edu), Maggie Shiffrar; Rutgers University-Newark, NJ – Human observers exhibit a remarkable degree of visual sensitivity to the movements of other people. From the motions of a few point-lights, observers can readily identify human actions and even psychological attributes, such as gender, mood, and effort. What accounts for this exquisite level of visual sensitivity to human movement? One possibility is suggested by the fact that human movement represents the only motion category which humans both produce and perceive. To that extent, the visual and motor systems interact, this raises the question of whether observers’ own bodily actions can influence their visual analysis of the human movement. To that end, we examined how well observers can compare their own movements to the movements of other people. To do this, point-light walker displays were presented next to subjects walking on a treadmill. The point-light walker always produced a physically possible gait. The gait speeds of the point-light walker and the walking subjects systematically varied between 2.0 and 6.5 km/hr across trials. In a 2AFC procedure, on each trial, subjects reported whether their speed was faster or slower than the point-light walker’s speed. Across conditions, subjects wore a vest with or without weights while performing this self-relative speed discrimination task. To the extent that the visual and motor systems interact during the visual analysis of human movement, visual sensitivity to gait speed should vary as a function of observers’ own motor activity. Consistent with this prediction, the results revealed accuracy increments with increases in the difference between gait speeds of the subject and point-light walker. Importantly, a systematic performance shift was evident when observers wore the weighted vest. The more weighted or fatigued the subjects, the faster the point-light walkers appeared to move. Thus, motor activity influences the visual analysis of human movement.

Acknowledgment: Supported by the Volkswagenstiftung.
Over the past three decades Rüdiger Wehner's research has revolved around the general question how a 0.1-mg brain of a 10-mg insect solves complex computational tasks. In trying to answer this question he focused on the extraordinary navigational skills of visually guided desert ants, *Cataglyphis*, and did so by interactively combining behavioural experiments with optical, neurophysiological and neuroanatomical studies, computer simulations and, most recently, robotics implementations. This interdisciplinary enterprise has led to the analysis of a number of dedicated neural systems that deal with particular aspects of the ant's overall navigational task. How these neural modules interact provides insights into the computational strategies of neural systems and the insect's "distributed intelligence".

### Face Perception I

**Monday, May 12, 2003**

*9:00 – 10:30 am*

**North Hall**

**Moderator:** Pawan Sinha

**9:00** Boutet, Collin, Fauvert, TA89

**9:15** Ostrovsky, Sinha, TA90

**9:30** Nakayama, TA91

**9:45** Gauthier, Tanaka, Brown, TA92

**10:00** Nederhouser, Mangini, Biederman, Okada, TA93

**10:15** Goffaux, Jacques, Mouraux, Gosselin, Schyns, Rossion, TA94

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**TA89**

Is there a relationship between the band of spatial frequencies critical for face recognition and configural encoding? Isabelle Boutet1 (i.boutet@umontreal.ca), Charles Collin2, Jocelyn Fauvert1; 1École d’optométrie, Université de Montréal, Canada; 2National Research Council, Canada – Configural relations and a critical band of spatial frequencies (SF) in the middle range are particularly important for face recognition. We report the results of four experiments that examine the relationship between these two types of information. In Experiments 1, 2A and 2B, the face inversion effect (FIE) was used to probe configural face encoding. Recognition of upright and inverted faces and non-face objects was measured in four conditions: a no-filter condition, and three SF filtering conditions, low-, medium-, and high-frequency. We found significant FIE of comparable magnitude for all filtering conditions. An advantage for recognition of medium-frequency faces was observed in all three experiments. However, this effect was weaker when learn faces were filtered. There was a tendency for medium-frequency objects to be best recognized in Exps. 1 and 2A, and a clear advantage for that filter condition in Exp. 2B. Finally, a RT advantage for inverted faces and upright and inverted objects in the medium-frequency condition was observed in all three experiments. In Experiment 3, simultaneous discrimination of faces on the basis of either configural or featural modifications was measured under the same four conditions. Although the ability to discriminate configural modifications was superior in the medium-frequency condition, so was the ability to discriminate featural modifications. We conclude that the band of SF that is critical for face recognition does not contribute preferentially to configural encoding. Rather, a sufficient amount of overlapping information and contrast may be partially responsible for the medium frequency advantage for faces.

**Acknowledgment:** This research was supported by a fellowship from the Canadian Institutes of Health Research (CIHR) to IB and a CIHR grant R0010026 to JF.

**TA90**

Integration of low and high frequency information in facial recognition Yuri Ostrovsky (yosr@mit.edu), Pawan Sinha; MIT Brain and Cognitive Sciences, USA – The goal of our work is to understand the role of low-, mid-, and high- spatial frequency bands in face recognition. Using stimuli containing only partial spatial frequency information (e.g., low resolution images), our experiments seek to titrate out the contribution of the different bands by examining under what circumstances the loss of information causes a failure in recognition. It is believed that featural information is carried by the high spatial frequencies (sf) while configural information resides in the lower sf bands. This predicts that featural changes would be harder to detect than configural ones as the sf content in an image shifts towards the low frequencies. However, contrary to expectations, we find that the detectability of both configural and featural changes degrades at the same rate across this transformation. We additionally find that reaction times for recognition are higher for low-resolution images, and that observers’ tolerance to image degradations is enhanced by familiarity with the individuals depicted in the images. The pattern of results so far suggests that the human visual system might use an iterative process and prior experience with faces to compensate for missing information. This led us to implement a computational technique for information “fill-in” using a database of calibrated faces as “prior knowledge.” Relying on statistical dependencies between different parts of the image, the information missing in a given image due to, say, occlusion or blurring, can be reconstructed from the database patch-by-patch. This technique may serve as a model of cognitive processes underlying top-down influences on image analysis.

**Acknowledgment:** DARPA HumanID Program

**TA91**

Face specific processing: role of local features in an affine metric Ken Nakayama (ken@wjh.harvard.edu); Harvard University, USA – To understand the nature of face specific holistic/configural processing, we compared the effect of narrow band masking noise on the discrimination of upright and inverted faces. Signal to noise thresholds in a four-alternative forced-choice task with faces of varying lighting and constant pose showed that face processing is most degraded by noise of approximately 12 cycles/face, with a much broader masking function for inverted as opposed to upright faces. As such, face-specific processing (the ratio of upright to inverted masking) preferentially samples in this spatial frequency band. Using notch-filtered noise, having all spatial frequencies except those most important for face specific encoding, we created a stimulus which selectively isolates face processing and shows a consistent two-fold difference in threshold for upright vs inverted faces. In the presence of notch filtered noise, face recognition thresholds are largely unaffected by affine image distortions but are significantly elevated by a non-linear spatial distortion. Conclusion: The peak spatial frequency of the face specific processing at 12 cycles/face indicates the importance of local
When misaligned faces are processed holistically Isabel Gauthier1, James W Tanaka2, Danielle D Brown1, 1Vanderbilt University, 2Oberlin College, US – Holistic processing for faces (and objects of expertise) can be measured in tasks where subjects are instructed to selectively attend to a part (e.g., the mouth) of two objects to compare them and told to ignore the other parts. Holistic processing is evidenced by a congruency effect between the correct response on the target and irrelevant part. In addition, configural processing can be operationally defined as a reduction of this congruency effect when the two parts are misaligned. Most accounts of holistic and configural effects postulate a representational locus as the basis for these phenomena (e.g., Farah et al., 1998) but recent work using formal modeling argues for a decisional locus (Wenger & Ingvalson, 2002). In several experiments using a sequential matching paradigm, we investigate the importance of the configuration at encoding. On each trial, a first stimulus (S1) is encoded, followed by a cue indicating which part is the target (top/bottom half), followed by a second stimulus (S2) on which a same/different judgment is made. Different groups were tested with aligned or misaligned S1 stimuli, with either faces or objects (asymmetrical Greebles). For objects, we find a congruency effect for both aligned and misaligned S2s when the S1 is misaligned, but not when the S1 is aligned. This suggests that for novel objects, requiring subjects to attend to misaligned S1 parts can reduce the subjects’ ability to ignore any irrelevant part on S2 stimuli. For faces, we find strong congruency and configural effects at S2 for both aligned and misaligned S1 faces, indicating that encoding configuration had little effect on holistic processing. These results are consistent with the idea that the locus of holistic and configural effects is not representationally and could result from attentional biases. Alternatively, to account for these results the notion of holistic encoding could include the capacity to construct a holistic template from disjunct parts. 

Acknowledgment: Supported by a grant from NSF (BCS-0091752) to IG and (BCS-0078745) to J.W.T. and by the James S. McDonnell Foundation to I.G. and J.W.T.

Invariance to contrast inversion when matching objects with face-like surface structure and pigmentation Marissa Nederhauser1 (mneder@usc.edu), Michael C. Mangini2, Irving Biederman1, Kazunori Okada1, 1University of Southern California, USA, 2Massachusetts Institute of Technology – There is a marked cost in face matching performance when members of a sequentially presented pair of faces differ in contrast polarity, i.e., reversal of luminance, but no such costs are apparent when matching objects (Subramaniam & Biederman, 1997). This result holds true even when the faces and chairs, on different trials, are of equal similarity, as assessed by a Gabor-jet similarity measure. Unlike face matching, object matching can generally be accomplished by using differences in parts and nonaccidental shape properties defined by edges that would be unaffected by changes in contrast polarity. Would object recognition remain invariant when such differences were not available?

Subjects performed a match-to-sample forced-choice task on smooth, blobby volumes generated by varying the amplitudes of the 2nd & 3rd harmonics of a sphere. These stimuli did not resemble faces although their discrimination was presumed to require the same type of information as that for faces. In Exp.1, their discrimination required matching the objects based on fine differences in surface curvature. In Exp.2, the subjects could also use pigmentation information in the form of a constrained set of high contrast patches. Stimulus pairs in trials spanned a large range of similarity, comparable to both faces and objects.

Both expert and novice performance on these tasks was examined, as well as that of a prosopagnosic. Differences in contrast between stimuli resulted in no costs in stimulus matching, for experts and novices, throughout the range of similarity. The experts had markedly lower RTs and error rates than the novices, even on a new configuration of stimuli, indicating a transfer of expertise. The extremely poor performance of the prosopagnosic suggests that the discrimination of these stimuli might engage the same processing as that involved in faces. These results suggest, as did our prior studies, that faces are special with respect to the costs of contrast reversal.

http://www-sf.usc.edu/~mneder/prof/prof.html

Superstitious perceptions of a face revealed by non-phase-locked gamma oscillations in the human brain Valerie Goffaux1,2 (valerie.goffaux@psp.ucl.ac.be), Corentin Jacques1,2, Andre Mouraux2, Frederic Gosselin3, Philippe G Schyns4, Bruno Rossion1,5, 1Unité de Neurosciences cognitives (NESC), UCL, Belgium, 2Laboratoire de Neurophysiologie (NEFY), UCL, Belgium, 3Département de Psychologie, Université de Montréal, 4Department of Psychology, 5Department of cognitive and linguistic science, Brown University University of Glasgow – In humans, non phase-locked (NPL) brain oscillations in the gamma band (30 - 80 Hz) have been related to the integration of widely distributed cortical representations and are thought to participate in the top-down modulations of visual processes, and more generally in the constructive aspects of perception (Engel et al., 2001). In the present study, we employed the technique of Superstitious Perceptions (Gosselin & Schyns, 2003) to better understand the neurophysiological determinants of the superstitious perception of a face. Using high-density EEG recording, sixteen observers were asked to detect a face while stimulated with only white noise (400 different templates of 32 x 43 pixels, to mirror the aspect ratio of a face). Superstitious perceptions occur whenever the observer believes that a face is present in the white noise. This paradigm is better suited to isolate top-down components of visual processing because white noise is only very weakly correlated with a face signal. The observers detected a face on 36% of the noise templates, on average. When observers reported seeing a face, EEG recordings at posterior-visual scalp regions revealed a NPL increase of gamma (~40 Hz) oscillation amplitudes centred around 200 ms post-stimulus onset. A classification image rendered the face information that best predicts the superstitious perceptions, and the gamma activity. This image reveals two eyes, bilaterally organized around the X axis, at about 2/3 height on the Y axis. This study shows that NPL gamma oscillations in the human visual system subvent the type of top-down activity required for superstitious visual perceptions.

Motion and Depth

Monday, May 12, 2003
9:00 – 10:30 am
South Hall

Moderator: Constance Royden
**TA95**

Perception of binocular 3-D motion: visual direction is more important than binocular disparity  
*Julie M Harris* (j.harris@ucl.ac.uk), *Phillip J Dean*; University of Newcastle upon Tyne, United Kingdom — When an object moves in three dimensions (3-D), a combination of binocular disparity and lateral motion (change in visual direction) can, in principle, be used to determine its direction. We know from previous research that observers can be very poor at judging 3-D direction (e.g. Harris, ECVP, 2000). However, we do not know whether the misperception is due to errors in the processing of visual direction or of binocular disparity. Here we tested how well observers can detect different trajectory angles when disparity, or visual direction, are varied separately.

We compared two conditions. In the first, the distance moved in depth by a target (with respect to a stationary reference) was held constant at 27.3 min arc (15.2 cm in depth). Trajectory angle was varied by changing the extent of lateral target motion (hence changing the final visual direction of the target), to produce trajectories ranging from straight ahead to 20 deg to the left or right of the nose. In the second condition, the lateral distance moved was held constant at 1.2 cm to the left or right of straight ahead, and the change in depth of the target was varied to create the same range of trajectory angles. Stimuli were presented stereoscopically using stereo shutter goggles running at 120 Hz.

When depth was held constant, observers were highly inaccurate at perceiving the trajectory angle, but there was a monotonic relationship between physical and perceived angle: wider physical angles were perceived as wider. However, when visual direction was held constant, many observers perceived the whole range of angles as being very similar. The results suggest that observers may be basing their responses primarily on the visual direction of the target, rather than on the relative extent laterally and in depth. Although in principle disparity and lateral position specify 3-D trajectory angle, in practise the human brain may use very much simpler strategies.

**Acknowledgment:** EPSRC (UK)

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**TA96**

Task-specific contribution of area MT to stereoscopic depth discrimination  
*Takanori Uka* (uka@cabernet.wustl.edu), *Gregory C. DeAngelis*; Dept. of Anatomy and Neurobiology, Washington University School of Medicine, St. Louis, MO, USA — We have previously reported the involvement of area MT in a coarse depth discrimination task: single MT neurons exhibit sensitivity comparable to that of monkeys, and trial-to-trial fluctuations in MT responses are correlated with monkeys’ perceptual choices (VSS 2001). Here we asked whether MT is engaged in a stereo task with different information processing demands: we recorded from 98 MT neurons in two monkeys while they performed a fine depth discrimination (stereocuity) task.

Visual stimuli were bi-partite (center/surround) random-dot stereograms tailored to match the receptive field properties of each neuron. Monkeys discriminated the relative depth between the two patches. The disparity of the surround patch was chosen to lie at the steepest slope of each neuron’s disparity-tuning curve. Task difficulty was titrated around psychophysical threshold by finely varying the disparity of the center patch.

Neuronal and psychophysical thresholds were calculated using ROC analysis (e.g. Britten et al. 1992). Fifty seven neurons had thresholds significantly larger than the corresponding psychophysical thresholds, and we only found 13 neurons with thresholds lower than the monkeys’.

The average neuronal to psychophysical threshold ratio was 1.76. We also tested whether MT responses were correlated with perceptual reports by computing “choice probabilities” (Britten et al. 1996). The average choice probability (0.52) was not significantly above chance (p>0.91), and equal numbers of neurons had significant choice probabilities above and below 0.5. Thus, we found no consistent relationship between neuronal responses and behavioral choice in this task.

Results are consistent with the idea that MT does not contribute to fine judgments of relative depth, which may be due to MT neurons not encoding relative disparity (VSS 2002). This contrasts with our previous findings in the coarse depth discrimination task, and argues for a task-specific role of MT in stereopsis.

**Acknowledgment:** Supported by NEI EY013644, JSPS, and HFSP.

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**TA97**

Is depth perception of stereo plaids predicted by intersection of constraints, vector average or second-order features?  
*Louise S Delcato* (lbd040@columbia.edu), *Ning Qian*; Center for Neurobiology and Behavior, Columbia University, New York, USA — Stereo plaids were created to investigate whether depth perception is determined by an Intersection of Constraints (IOC) or Vector Average (VA) operation on the Fourier components, or by the second-order features in a pattern. Since depth discrimination of stimuli with vertical disparity is much poorer than stimuli with horizontal disparity (Westheimer, 1984), disparity may be better suited than motion for isolating the contribution of IOC, VA or second-order features. After confirming this difference between vertical and horizontal disparity using plaids, we created type II plaid stimuli where IOC predicted vertical disparity, VA predicted positive diagonal disparity and second-order features predicted negative diagonal disparity.

The stimuli were comprised of a sinusoidal component with zero disparity (oriented at 0 degrees, from vertical) and a sinusoidal component with variable disparity (oriented at ±45 degrees). In a depth discrimination task, observers indicated whether they perceived the pattern as ‘near’ or ‘far’ relative to a zero disparity aperture. Observers’ perception was consistent with the disparity predicted by the second-order features, indicating their dominance over IOC and VA. Additional stimuli in which these second-order features predicted vertical disparity were created to investigate whether they would dominate perception when they were no longer reliable. In this case, observers’ performance was consistent with disparity predicted by an IOC or VA of the Fourier components, not the second-order features. These experiments suggest that the visual system implements more than one approach when faced with the problem of recovering depth from disparity. Although many methods may be available to the visual system, it makes use of the most reliable cue for a given condition.

**Acknowledgment:** Supported by an NIH grant # MH54125 and the McDonnell Foundation

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**TA98**

Widespread cortical specializations for disparate lateral motion  
*Christopher W Tyler* (cw@ski.org), *Lora T Likova*, *Alex R Wade*; *Smith-Kettlewell Eye Research Institute, San Francisco, USA* — Purpose: Disparity selectivity for motion stimuli is well established in the MT area of monkey cortex (deAngelis & Newsome, 1999, J Neurosci). Activation by disparate moving stimuli has also been reported in the human brain by fMRI techniques (Rutschmann et al., 2000, Exp Brain Res) in the dorsolateral occipital cortex, but not the motion area V5. We investigated this discrepancy in an fMRI study of long-range disparate apparent motion.

Methods. BOLD responses were collected on a GE Sigma 3T scanner in 22 near-coronal slices spanning the posterior half of the brain. The test-null stimuli were alternated for 9s each in 8 blocks, totaling 144 s plus a fixation period. The stimuli were presented as regular-dot autostereograms, with lateral motion at 1 Hz and disparity present above and below a static row of nondisparate fixation dots. The test stimuli thus had disparity, depth and 3D form, but were equated with the nulls in both motion and kinetic borders.

Results. Regions on both the anterior and posterior banks of the occipito-temporal sulcus responded strongly to apparent motion versus static dots, and were identified as the human homologs of monkey MT and MST motion areas. Neither early retinotopic areas nor these motion areas were...
selective for disparate versus flat motion, but such disparity/depth selectivity was observed in four other localized areas: a lateral occipital area corresponding to LO, a ventromedial area in the anterior calcarine sulcus (non-retinotopic for our stimuli), a temporal lobe area anterior to the MST homolog, and parietal area near the temporoparieto-partial junction.

Conclusion. Motion-based disparity information activates a distributed network of focal areas in human cortex involved in the perception of depth structure and spatial form. The ventromedial depth area lies between retinotopic V1 and the parahippocampal place area (Epstein & Kanwisher, 1998, Nature), suggesting a role in space integration.

Acknowledgment: Supported by EY 7890
http://www.ski.org/cwt

TA99
Analysing optic flow generated by locomotion through a natural environment Johannes M Zanker1 (j.zanker@rhul.ac.uk), Jochen Zeil2;
1Department of Psychology, Royal Holloway University of London, England,
2Centre for Visual Sciences, The Australian National University, Australia—
Purpose. When an observer moves through the three-dimensional world, a characteristic field of velocity vectors is generated on the retina. Although many theoretical, psychophysical, and physiological studies have demonstrated the use of such optic flowfields for a number of navigational tasks under laboratory conditions, surprisingly little is known about the actual motion signal distribution under natural operating conditions. We intended to study what motion information is available to the visual system in the real world.

Methods. A panoramic imaging device was mounted on a stepping-motor driven gantry and on moved on accurately defined three-dimensional paths in outdoors environments. The captured image sequences were processed by a biologically inspired motion detector network which allows us to analyse the distribution of motion signals generated by various types of locomotion.

Results. We found that motion signals are sparsely distributed in space and that local directions can be ambiguous and noisy. Spatial pooling or temporal integration can help to retrieve reliable information about local motion vectors from such motion signal maps which local direction and strength can vary considerably. On the other hand, the overall structure of the flowfield, with distinct centres of expansion and contraction, is obvious even in sparse and noisy motion signal maps, and a simple algorithm can be used to retrieve rather accurately the direction of heading, demonstrating the richness of information contained in the panoramic field of view.

Conclusions. Our approach is a first step to assess the role of behavioural, environmental and computational constraints in natural optic flow processing. Although the local motion information in natural flowfields tends to be sparse and noisy, the extended pattern of motion signals is a rich source of information about observer locomotion.

TA100
Simultaneous computation of heading and depth in the presence of rotations: A physiologically based model. Constance S. Royden (croyden@mathcs.holycross.edu), Laura J. Picone; College of the Holy Cross, USA—A moving observer can determine her direction of motion and the relative distance to surfaces from the pattern of motion on her retina. Rotations due to the observer's eye or head movements can interfere with the direct computation of heading and depth from velocity magnitudes alone. Subtraction of neighboring image velocities removes the confounding rotation information, allowing a simpler computation of both heading and depth. A physiologically based model for computing heading (Royden, 1997) performs a motion subtraction using motion-opponent operators based on physiological properties of cells in the Middle Temporal visual area (MT). This model computes heading well in the presence of rotations. Here, we test the model's ability to signal the change in relative depth between surfaces at different distances from the observer. We simulated motion toward a frontoparallel plane, 1000 cm from the observer, with a smaller wall in front at a distance of 400 cm. Simulated observer motion consisted of translation toward the scene combined with rotation of 0 or 5 deg/sec about the vertical axis. In all cases, the motion-opponent operators gave a maximum response in the locations that coincided with the positions of the edges between surfaces, irrespective of the amount of rotation. In contrast, in the rotation condition, the response magnitude of pure direction selective cells varied across the frontoparallel plane, eliminating the direct correlation between response magnitude and relative distance. When the simulated distance of the front wall was varied between 100 and 600 cm, the response of the motion-opponent operators at the depth edges was proportional to the difference between the inverse depths of the two surfaces. In simulations of two walls, the motion-opponent operators signaled the positions of all depth edges in the scene. These results suggest that motion-opponency can be used for simultaneous computation of heading and relative depth.

Acknowledgment: Supported by NSF Grant #IBN-0196068.
differ depending on intrinsic or contextual definition of faces. The results have implications for the nature of processes that underlie face-perception in complex scenes.

**Acknowledgment:** Alfred P. Sloan Foundation

**TA102**

Isolating Face-Dependent and Face-Independent Processing of Expression and Direction of Gaze

Tzvi Ganel1 (tganel@uwo.ca), Yonatan Goshen-Gottstein2, Metl ogni A Goodale2; 1University of Western Ontario, Canada, 2Tel-Aviv University, Israel—Several models of face recognition have used data from neuroimaging and neurological studies to argue that the perception of facial expression and gaze direction are mediated by the same neural system – and therefore cannot be independently processed. In three experiments, we tested this notion using Garner’s selective-attention task, which provides a measure of the degree of interdependence between a given pair of stimulus dimensions. In our experiments, participants made speeded classifications of either facial expression or gaze direction while the other dimension either remained constant (Baseline) or varied randomly across trials (Filtering). Slower performance in Filtering as compared to Baseline indicates that the two dimensions cannot be perceived independently and suggests a common locus of processing. In Exp. 1, upright photos depicting two different emotions (happy or angry) and two different gaze directions (looking towards or away from the observer) were presented. Performance in Filtering was found to be slower than performance in Baseline for both expression and gaze, suggesting that these dimensions cannot be independently processed. In Exp. 2, the same pattern of results was obtained even when the gaze was always directed away from the observer (to the left or right). In Exp. 3, we inverted the faces to isolate face-dependent from face-independent effects. Inversion had a striking effect on selective attention to expression, which was now unaffected by the irrelevant variations in gaze. In contrast, inversion had no effect on the pattern of selective attention to gaze. These results suggest that the failure of selective attention to expression, but not to gaze, in upright faces is due to face-related processing. Although these results support the idea that the perception of expression and gaze direction are mediated by the same underlying neural system, they also reveal important differences in the way these two dimensions are processed.

**TA103**

Normal object discrimination in a developmental prosopagnosic

Bradley C Duchaine1 (brad@wjh.harvard.edu), Edward J Buttersworth1, Ken Nakayama1; 1Department of Psychology, Harvard University, USA, 2Department of Medical Physics, Memorial Sloan-Kettering Cancer Center, NY, NY, USA—The subordinate level hypothesis states that prosopagnosics have impairments to mechanisms required for recognition of specific exemplars, and so it predicts that individuals with face recognition impairments should also be impaired with non-face recognition. Edward, a 51-year-old developmental prosopagnosic, is severely impaired with recognition of identity, emotions, and gender from the face. He was able to name only 3 of 25 famous faces despite reporting significant exposure to 19 of these celebrities and performed far out of the normal range on a test of unfamiliar face recognition. In order to test the subordinate level hypothesis, we tested his face and non-face discrimination using the same method. On two versions of the task that used faces, Edward’s accuracy was severely impaired, and his response times were also far longer than the controls. His accuracy was normal with horses, cars, houses, and tools, borderline with guns, and impaired with landscapes. These results demonstrate that face discrimination can be impaired while discrimination with non-face categories is normal, and so it suggests that the subordinate level hypothesis cannot account for some cases of prosopagnosia. Finally, because Edward’s difficulties with faces appear to be the result of developmental problems, the results suggest that different developmental processes are responsible for building the separate mechanisms involved with face and non-face recognition.

**TA104**

Face classification following long-term visual deprivation

Pawan Sinha (sinha@ai.mit.edu); MIT Brain and Cognitive Sciences, USA—The influence of early visual experience on the development of human face processing skills is a topic of much scientific and applied significance, but experimental data on this issue is scarce. A few studies have reported profound impairments in face recognition following early visual deprivation. However, it is unknown how extended visual deprivation influences performance on the more basic task of face versus non-face classification. Here we report studies with two children, both of whom suffered from congenital blindness lasting at least the first 7 years of life. We assessed their face classification skills following surgical restoration of sight. For one child, the experiments were performed 1.5 months after surgery and for the other, four years post-surgery. Our results indicate that these children are able to detect faces and distinguish them from distracters with high reliability comparable to control subjects. Furthermore, this ability appears to be based on the use of overall facial configuration rather than individual features — a finding that presents an interesting contrast to the hypothesis of piecemeal processing used to explain impairments in face identification. These findings have implications for the nature of face-concept learning schemes in human and computational vision systems.

**Acknowledgment:** Alfred P. Sloan Fellowship in Neuroscience

**TA105**

Faces versus expertise: Early maturity of face recognition in children

Elinor McKone (Elinor.McKone@bnu.edu.au), Anna Gilchrist; Australian National University, Australia—In adults, faces are “special” in that configural (holistic) processing occurs for upright faces, but not inverted faces or most objects. A major debate is whether this reflects an innate face recognition module, or the many years of expertise that adults have with faces. Important empirical evidence is the rate of childhood development of face recognition. Widely cited early studies claimed that configural processing for faces did not begin until 10 yrs. This view has continued to drive a focus on 6 - 14 yrs as the age range to test, and an almost reflexive claim that expertise in face processing takes many years to mature. Here, we argue that this view is wrong. Using appropriate methodological criteria (e.g., discounting studies with floor effects in the younger age groups), a literature review indicates that many key phenomena of adult face processing – inversion effect, composite effect, cross-race deficit, etc – are present in 6 yr olds (the youngest age group tested). In new work, we show distinctiveness effects in 6-7 yr olds. A set of Original faces was made to look more distinctive (“would stand out more in a crowd”) either by a Configural manipulation (eyes closer together) or by a Local feature manipulation (eyebrows bushier; Leder & Bruce, 1998). In adults, recognition memory was more accurate for the Configural version than for the Original, and also for the Local version than for the Original; also, the Local effect was equally strong upright and inverted, while the Configural effect occurred only for upright faces. The same qualitative pattern of distinctiveness and inversion effects occurred in 6-7 yr olds. Moreover, when memory for Original faces was equated across age groups, there was no age-related increase even in the quantitative size of the effects. We conclude that the focus of future studies must shift to much younger children. Indeed, recent infant studies suggest that face recognition may mature on a similar timescale to language.

**Acknowledgment:** Supported by the Australian Research Council Small Grant scheme (2000 Grant #F00093; 2001 Grant #F01027)

**TA106**

Selective tuning of face perception

Minna Ng (mng@psy.ucsd.edu), Daniel Kaplng2, Michael A. Webster1, Stuart Anstis1, Ione Fine1; 1Department of Psychology, UCSD, USA, 2University of Nevada, Reno, USA—PURPOSE: Face-selective neurons in monkeys are highly selective for emotion and gender (Toovey, Neuron 1998). Also, the perception of human faces shows...
Cortical Organization

Monday, May 12, 2003
10:45 am – 12:15 pm

South Hall

Moderator: Zoe Kourtzi

Monday, May 12, 2003
10:45 am – 12:15 pm

South Hall

Moderator: Zoe Kourtzi

10:45
Xu, Boyd, Gallucci, Thomas, Emeric, Barahimi, Stefansic, Shima, Melzer, Allison, Bonds, Casagrande, TA107

11:00
Adams, Horton, TA108

11:15
Tjian, Lestou, Bülthoff, Kourtzi, TA109

11:30
Motter, TA110

11:45
Whitney, Goltz, Thomas, Goodale, TA111

12:00
Conner, Schwartz, Odom, Mendola, TA112

TA107
Spatial frequency preference maps of primate visual cortex revealed by optical imaging of intrinsic signals

Xiangmin Xu1 (xangmin.xu@wanderbilt.edu), Jamie Boyd2, Michael Gallucci3, Alicia Thomas3, Erik Emeric4, Behin Barahimi5, James Stefansic6, Daniel Shima6, Peter Melzer7, John Allison8, AB Bonds8, Vivien Casagrande4,5,6, 1Dept. of Psychology, Vanderbilt University, USA, 2Dept. of Biological Sciences, Simon Fraser University, Canada, 3Dept. of Biomedical Engineering, Vanderbilt University, USA, 4Cognitive and Integrative Neuroscience Program, Vanderbilt University, USA, 5Dept. of Cell & Developmental Biology, Vanderbilt University, USA, 6Vanderbilt Vision Research Center, Vanderbilt University, USA, 7Kennedy Center, Vanderbilt University, 8Dept. of Electrical Engineering & Computer Science, Vanderbilt University: — Electrophysiological studies designed to determine the geometry of spatial frequency (SF) preference in primate primary visual cortex (V1) have reported either columnar or laminar differences. In this study we used optical imaging to examine the cortical organization of SF preference in bush babies and owl monkeys using sine wave gratings of a range of SFs at 4 orientations. Both species are nocturnal but owl monkeys have a cutoff behavioral acuity of 10 c/deg whereas bush babies have a cutoff acuity of 5 c/deg. In spite of these behavioral differences both species showed the same basic tangential organization of SF preference within V1. As expected, the range of SFs close to the area centralis was shifted to higher SFs in comparison to the range of SFs seen at more eccentric locations. Examination of the activation patterns produced by the extremes of the SF range showed that these were different and revealed clusters of activation within neighboring territories. In some regions, however, high and low SFs overlapped. Iso-SF domains were generally smaller and had a different appearance than iso-orientation domains, although color-coded maps of SF preference did reveal pinwheel-like structures in some regions in both species. Comparison of maps of SF and orientation preference in the same animal suggested that these maps are largely independent. Our data supports a V1 model in which spatial frequency is mapped continuously across cortex in the form of multiple SF processing domains. (Supported by EY01779, S10RR13947, EY08126, HD15082)

TA108
Cortical columns without a function

Daniel L Adams (dadams@itsa.ucsf.edu), Jonathan C Horton; Beckman Vision Center, UCSF, USA — In many higher mammals, geniculate inputs to striate cortex serving the left and right eye are segregated into stripes within layer 4 known as ocular dominance columns. These columns can be labeled by processing the cortex for cytochrome oxidase (CO) activity after enucleation of one eye. Because CO levels reflect physiological activity, loss of staining occurs in the columns formerly driven by the missing eye. For many years, the squirrel monkey was regarded as an anomaly among primates because it was shown repeatedly to lack ocular dominance columns. We visualized the column patterns of 12 normal squirrel monkeys and found a huge range of ocular dominance column periodicity and segregation. At one extreme, columns were large and sharply segregated, resembling those found in macaques and humans. At the other extreme, they were rudimentary and almost entirely absent. In some cases, columns were well defined in some portions of striate cortex, yet absent elsewhere. It it natural to suppose that ocular dominance columns are required for some aspect of vision, such as stereopsis. Squirrel monkeys, however, have excellent stereopsis. One might propose that a subset of squirrel monkeys, namely, those with weak columns, has poor stereopsis. This possibility should be examined, but it is worth pointing out that columns were virtually absent in 4/12 animals. It seems unlikely that a third of the members of a primate species harbors an innate deficiency in stereopsis, or any other visual function vital for survival. Monkeys with regional expression of columns provided the most compelling evidence against a functional role for ocular dominance columns. It is difficult to conceive of a visual faculty that has a similar distribution across the visual field. These findings lead us inexorably to the conclusion that ocular dominance columns have no functional significance, at least in the squirrel monkey.

TA109
An fmri method for identifying the sequential stages of processing in the ventral visual pathway

Bosco S Tjian1 (btjian@wusci.edu), Vaia Lestou2, Heinrich H Bülthoff3, Zoe Kourtzi;1 Max-Planck Institute, Tübingen, Germany, 2University of Glasgow, UK, 3Max-Planck Institute, Tübingen, Germany — Visual processing in the human ventral cortex entails extraction of features from retinal images that mediate perception. In the human ventral cortex, early and late visual areas have been implicated in the analysis of simple and complex features respectively. If we view this processing pathway as a sequence of decision stages, each extracting progressively more abstract and invariant features from the output of preceding stages, then by considering the relationship
between signal uncertainty and the slope of a psychometric function, we can show that the extent to which the output of a decision stage is perturbed by noise added to the visual stimulus will be more threshold-like (steeper log-log slope) for a decision stage further down the decision cascade. To test this theory, we used images of scenes and added visual noise that matched the signal’s spatial-frequency power spectrum. The resulting images were rescaled to maintain a constant mean luminance and rms contrast across all noise levels. We localized individually in observers the retinotopic regions and the LOC, and measured event-related BOLD response in these regions during a scene discrimination task performed at 4 noise levels. Behavioral performance increased with increasing signal-to-noise ratio. We found that log %BOLD signal change from fixation baseline vs. log SNR is well-described by a straight line for all visual areas. The regression slope increased monotonically from early to late areas along the ventral stream. A factor of 8 change in SNR produced little change to the BOLD response in V1/V2, but resulted in progressively larger changes in V4v, posterior (LO), and anterior (pFs) subregions of the LOC. In accordance with our theory on noise perturbation, the results suggest approximately ordered decision stages in the ventral pathway.

Acknowledgment: Supported by: Max-Planck Society & USC Zambarge

TA10
The cortical magnification factor for area V4
Brad C Motter
(motterb@cnyrc.org); Veterans Affairs Medical Center, Syracuse, NY, USA—Extrastriate area V4 neurons have receptive field (RF) profiles that are radially elongated. Response sensitivity gradients are steep on the side of the RF near the fovea and are stretched toward the periphery. Do the observed elongated response contours of V4 RFs represent a convergent sampling of the visual field that is different than the cortical magnification factor associated with area V1? To address this question V4 RFs were determined in 4 macaque monkeys. V4 RFs centered from 1.5 to 10 degrees in eccentricity were mapped with flashed stimuli using a 16 x 16 position grid adjusted for RF size. Two principle issues were addressed. 1) Do the V4 RFs represent a convergent weighted sampling of a circular patch of V1 relayed presumably through V2, and 2) are eccentricity dependent V4 RF size differences related to differences in the size of the sampled V1 patch? To visualize these issues the elongated V4 RF contours were projected onto a 3D model of the V1 surface. When projected onto the V1 surface the V4 RF contours appear as concentric circles. These observations were quantified by fitting the V4 receptive fields to an elliptical sampling model on the curved V1 surface. Receptive fields of area V4 neurons appear to represent a sampling of the V1 representation of the visual field corresponding to a circularly symmetric gaussian sampling with a SD of about 5 mm of cortical extent that is independent of eccentricity. Consequently except for a simple gain function, the cortical magnification factor for V4 neurons is the same as it is for V1 neurons, that is, there is no eccentricity dependent gain between V1 and V4.

Acknowledgment: Supported by the VA Medical Research Program.

TA111
Flexible retinotopy: Motion dependent position coding in visual cortex
David Whitney (dwh@uw.ca), Herbert C Golz, Christopher G Thomas, Melvyn A Goodale; University of Western Ontario, Canada—A fundamental characteristic of the visual cortex is that it is organized retinotopically—relative positions on the retina are maintained in the cortex. Although this largely determines our perception of a stable world, there are a number of additional sources of information that contribute to the perceived positions of objects. For example, motion signals that are present in a scene can shift the apparent location of an object. Yet, it is not clear how or where in the brain motion and position signals are integrated. Here we show that the retinotopic representation of an object in visual cortex, as revealed by fMRI, is systematically shifted when there are motion signals present in the scene; strict retinotopy breaks down in the presence of motion. We presented stationary patches filled with moving texture and measured localized activation in visual cortex. Perceptually, the patches appear shifted in the direction of the moving texture. Surprisingly, the representation of the patches in visual cortex is also shifted by a comparable magnitude—but in a direction opposite that of perception (eye movements cannot explain the pattern of results). Peak activation for the patches occurs not where the patches appear, but in positions that correspond to where the patches are not perceived. That is, when a patch filled with moving texture appears shifted in position, there is a region of the visual field (the trailing edge of the moving texture) in which the stimulus is physically present but does not appear to be present. It is this region that produces peak activation. The results show that motion signals are incorporated into the retinotopic representation of an object’s position even at early cortical visual areas. Moreover, the activation we observed correlated with what subjects did not perceive.

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TA112
Monocular retinotopic mapping in amblyopic adults
Ian P Conner (iconner@mix.wvu.edu), Terry L Schwartz, James V Odom, Janine D Mendola; West Virginia University—The visual abilities in humans with amblyopia have been well studied using psychophysical measures, but neurological characterization is incomplete. Prior fMRI investigation of visual cortex in amblyopia provided retinotopic boundaries from stimulation of the nonamblyopic eye only. This study seeks to determine whether the apparent retinotopic organization of visual cortex in amblyopic subjects is dependent upon the eye stimulated for the mapping. We used the fMRI BOLD technique at 1.5T and high contrast, chromatic eccentricity and polar angle stimuli to map retinotopic organization in 8 control, 7 anisometropic, and 9 strabismic amblyopic adults. Each eye was stimulated separately while the other eye viewed an isoluminant gray screen, and fixation stability was monitored with the Avotec-SMI system. Despite slightly worse fixation stability in the amblyopic population, this factor does not explain our results. The major abnormality seen for anisometropic subjects is decreased and disorganized signal from the amblyopic eye, including loss of foveal representation in eccentricity maps. For strabismic eyes, eccentricity representation appears normal, with some expansion of peripheral field representation. Polar angle maps indicate a bias favoring the ipsilateral hemisphere for strabismic eyes and even fellow eyes, i.e., temporal better than nasal retina. In a separate analysis making a specific comparison of nasal and temporal retina stimulation, we further revealed a surprising representation of temporal retina in the hemisphere contralateral to the amblyopic eye in a subset of the strabismic amblyopes. This abnormal representation may originate from transcallosal connections. We conclude that large scale changes in visual field representation occur in amblyopia, and distinguish the major subtypes.

Acknowledgment: Supported by NIH/NCRR IP20RR15574
develop a model that accounts for the main findings on neural border ownership is the phenomenon that contrast edges, lines, or illusory color and texture

**Purpose:** Border

Hartmut Schuetze (h.schuetze@biologie.hu), Ernst Niebur, Rüdiger von der Heydt, Johns Hopkins University, Baltimore, MD, USA — Purpose: Neurons in area V2 code for border ownership in displays of a single figure or two overlapping figures (Zhou et al., J Neurosci 20:6594, 2000). To further test the hypothesis of border ownership coding we studied displays of crossed transparent bars (or a shadow across a white bar). If transparency is properly represented, the borders of the intersection should be assigned to the intersecting bars. Because it is unlikely that border ownership assignment is reversed later on in the visual process we conjectured that V2 should resolve configurations of transparent overlay to assign border ownership correctly.

Methods: Single unit responses were recorded in alert monkeys during behaviorally induced fixation. Test stimulus T1 consisted of five squares portraying the crossing of a white bar with a dark bar of 50% transparency (see http://vlab.mb.jhu.edu/vss03fq). The gray of the central square A (the intersection) was the same as the background gray. The border between square A and one of the outer squares, B, was centered in the receptive field. Test stimulus T2 consisted of square B alone (square A was the same as in T1, but now blended with the background). Thus, stimuli T1 and T2 were identical over the region A+B in which the receptive field was centered. To measure side preference, T1 and T2 were flipped about the edge in the receptive field.

Result: Of 76 orientation selective V2 cells, 29 (38%) showed border ownership selectivity for the single square (T2), and 25 of these (86%) changed their responses significantly when T2 was replaced by T1. In 22 cells (76%) the side preference was reversed (the border was assigned to the intersecting bar), in 3 cells it was only reduced.

Conclusion: Neural signals in V2 represent border ownership for displays of simple figures as well as configurations of superimposed transparent objects, or cast shadows on objects. These results suggest that area V2 plays a fundamental role in figure-ground organization.

**Acknowledgment:** Supported by: NIH 1R01EY02966

http://vlab.mb.jhu.edu/vss03fq/

**TA115**

**Interaction of border ownership and transparency in monkey visual cortex**

Fangti T Qiu (qiut@jhu.edu), Rüdiger von der Heydt; Johns Hopkins University, Baltimore, MD, USA — Purpose: Neurons in area V2 code for border ownership correctly for squares and rectangles over a range of sizes, as well as for C-shaped figures and for different configurations of overlapping figures. Furthermore, the G cells provide handles for object-based selection. By activating a G cell one can enhance the edge signals of one of the figures in the display. Conclusion: A simple model explains how the visual cortex assigns border ownership and how visual cortical mechanisms might provide a structure for object-based attention.

**Acknowledgment:** Supported by: NIH 1R01EY02966

http://vlab.mb.jhu.edu/vss03fq/

**TA114**

**Modelling cortical mechanisms of border ownership coding**

Hartmut Schuetze (h.schuetze@biologie.hu), Ernst Niebur, Rüdiger von der Heydt; Johns Hopkins University, Baltimore MD, USA — Purpose: Border ownership is the phenomenon that contrast edges, lines, or illusory contours are perceived as belonging to one of the adjacent image regions as if they were contours of a 3D object. The aim of this study was to develop a model that accounts for the main findings on neural border ownership coding (Zhou et al., 2000) and can be expanded to explain object-based attention. Methods: Numerical solution of systems of linear equations. Results: The model uses an array of edge detector cells E in which each position and orientation is represented by a pair of cells corresponding to the two sides of ownership. Edges excite both members equally, T junctions excite only one member of a pair. Grouping cells G sum the signals of E cells according to roughly circular templates and enhance the gain of the same E cells. Each E cell communicates only with G cells on one side of its receptive field (the ownership side), and the two members of an E pair inhibit each other. Thus, two groups of G cells effectively compete at each edge location. Common activation of the two E cells represents contour strength, differential activation represents border ownership. With two sizes of templates the model assigns border ownership correctly for squares and rectangles over a range of sizes, as well as for C-shaped figures and for different configurations of overlapping figures. Furthermore, the G cells provide handles for object-based selection. By activating a G cell one can enhance the edge signals of one of the figures in the display. Conclusion: A simple model explains how the visual cortex assigns border ownership and how visual cortical mechanisms might provide a structure for object-based attention.

**Acknowledgment:** Supported by: NIH 1R01EY02966

http://vlab.mb.jhu.edu/vss03fq/

**TA113**

**Learning to optimally detect image boundaries using brightness, color and texture**

David R Martin (dmartin@cs.berkeley.edu), Charless C Fowlkes, Malik; Computer Science Division, UC Berkeley, USA — Goal: Psychophysics, e.g. Rivest and Cavanagh (1996), has shown that humans make combined use of multiple cues to detect and localize boundaries in images. We use a dataset of natural images to learn optimum cue combination of local brightness, texture and color, as well as quantify the relative power of these cues. Methods: Cue combination is formulated as supervised learning. A large dataset (~1000) of natural images, each segmented by multiple human observers (~10), provides the ground truth label for each pixel as having an oriented boundary element or not. The task is to model the posterior probability of a pixel being at a boundary, at a particular orientation, conditioned on local features derived from brightness, texture and color. Our features are based on computing directional gradients of outputs of V1-like mechanisms. Texture gradients are computed as differences in histograms of oriented filter outputs, and color gradients on histograms of a*, b* features in CIE L*a*b* space. Several types of classifiers ranging from logistic regression to support vector machines were trained. Performance was evaluated on a separate test set using a precision-recall curve which is a variant of the ROC curve. This curve can be summarized by its optimal F-measure, the harmonic mean of precision and recall. Results: (1) The precise form of the classifier does not matter—equally good results were obtained using logistic regression (weighted linear combination of features) as with more complicated classifiers. (2) Singly, brightness, texture and color yield F-measures of 0.62, 0.61, and 0.60 respectively. The optimal gray-scale combination of brightness and texture has an F-measure of 0.65 and addition of color boosts it to 0.67. These results indicate that the different cues are correlated but do carry independent information. By measuring inter-human consistency, the gold standard F-measure is 0.8, thus quantifying the gap left for more global and high-level processing.

http://www.cs.berkeley.edu/projects/vision/grouping

**TA116**

**Revisiting Ebenbreite**

Walter Gerbino (gerbino@units.it), Robert Volcic; University of Trieste (Italy) — Ebenbreite (Morinaga 1941) is a powerful factor of figure/ground organization. Regions bounded by parallel contours are perceived as figures more easily than regions bounded by non-parallel contours (Metzger 1953). Despite its power to generate elegant demonstrations, the crucial stimulus feature involved in...
Ebenbreite is unclear. Vertically-oriented stripes used in Morinaga-like patterns can involve two different transformations: (a) translation of a curved contour along a horizontal direction; (b) reflection relative to a curved axis, under a smoothness constraint. At small curvatures the stripes generated by the two transformations are similar; whereas they differ substantially at large curvatures. We performed two experiments to study the possible superiority of reflection over translation, following the general intuition that figural organization based on reflection Ebenbreite might be easier because of its compatibility with a simpler 3D percept. In the first experiment observers judged if a target stripe was present/absent in a pattern made of several stripes, which could be either translatory or reflective, depending on trial. In the second experiment observers searched for a stripe with translation Ebenbreite among distractors with reflection Ebenbreite, or vice versa. In both conditions we found a superiority of reflection over translation, despite the fact that also translation Ebenbreite is compatible with a 3D percept. Such a superiority might depend on the projective compatibility of reflection Ebenbreite with rotational symmetry around an elongation axis.

Acknowledgment: Support: MIUR-COFIN2000

TA117

The costs and benefits of grouping along a contour

Preeti Verghese (preeti@ski.org); Smith-Kettlewell Eye Research Institute, USA—Earlier work has demonstrated the benefits of grouping along a contour: patches in a roughly collinear string are easily detected amidst noise patches of random orientation. This study examines whether contour grouping interferes with the ability to detect changes in a roughly collinear string of patches.

The test patch was the end element of a 4 Gabor patch string and was either collinear with the string (0°) or was tilted by 15, 30, or 45° with respect to the string. The string appeared at a random location within a 2 degree square aperture centered on fixation. In a 2IFC task, observers chose the interval with a contrast increment on the test patch. The contrast of the other elements in the string was 50%.

When the string was presented by itself, increment thresholds were highest for the collinear configuration and decreased with increasing tilt of the test patch from the string. However, when the same high contrast string was presented among randomly-oriented noise patches thresholds showed the opposite trend: thresholds were lowest when the patch was collinear with the string and increased with tilt. Collinearity also helped when the string was presented alone at low (10%) contrast. The benefits of collinearity were much reduced when the test patch appeared in a known location, suggesting a role for uncertainty as well as for collinear facilitation.

These results are consistent with single unit responses in striate cortex of cats and macaques (Polat et al, Nature 1998; Kapadia et al, PNAS 1999) showing that collinear interactions are suppressive when the stimulus is clearly visible (high contrast string without noise), whereas the collinear string both facilitates and acts as a cue to the test patch under conditions of poor visibility (noise or low contrast).

Acknowledgment: NEI grant EY12038

TA118

The efficiency of contour grouping

James H Elder (jelder@yorku.ca), Yaniv Morgenstern, Ricardo Tabone; Centre for Vision Research, York University, Toronto, Canada—Purpose. Human observers are surprisingly good at finding smooth contours in clutter. Here we use a new ideal observer formulation for computationally tractable problems to measure the efficiency of contour grouping and to investigate the underlying perceptual mechanisms. Methods. Human observers are presented with a sequence of two images comprised of randomly-arranged, oriented elements. One of the images also contains an element sequence generated by a stochastic contour process whose parameters are derived from natural image statistics (Elder & Goldberg, JOV02). QUEST is used to estimate the complexity (number of elements in the display) at threshold performance for contour detection. A doublepass technique is also used to estimate observer consistency. Results. The computational complexity of the problem precludes a direct simulation of the ideal observer. Instead we use two sub-optimal machine observers to derive rigorous, tight bounds on ideal observer performance. Human efficiency, defined as the ratio of display complexity at threshold for human and ideal observers, is in the 25-50% range. Inefficiencies can arise from 3 sources: 1) internal noise, 2) systematic error in the internal model of the contour process, and 3) failure to consider all possible paths (algorithm error). We model internal noise as additive Gaussian error in the perceived location and orientation of the local line elements, and use the doublepass data to estimate these two noise parameters. Our main result is that this local noise can account for nearly all of the inefficiency in contour grouping. Discussion. Attribution of the majority of error to internal noise suggests that the underlying grouping algorithm is close to optimal. In particular, strictly local or greedy sub-optimal strategies can be ruled out.

Acknowledgment: This research was supported by CRESTech, GEOIDE and NSERC.

TA119

What limits thresholds for contours in noise – contour response strength or uncertainty?

Anthony M Norcia (amn@ski.org), Vanitha Sampady; Smith-Kettlewell Eye Research Institute, San Francisco, CA USA—Normal observers can detect extended contours defined only by long-range correlations in orientation, but contour detectability decreases as the level of background noise increases. In a psychophysical task, spatial noise could act by decreasing the signal from the contour elements (masking) or by increasing uncertainty as to which elements are relevant. To discriminate between these two views, we have used a direct measure of signal strength, the Visual Evoked Potential (VEP), to obtain thresholds for Gabor-defined contours. Circular contours (~7-11) comprised of 12 Gabor patches were presented at random locations in the presence of noisy backgrounds comprised of identical but randomly oriented Gabors. Contour elements were rotated on and off the implicit contour at 3.0 Hz and noise elements were rotated at 3.6 Hz. By tagging the contour and noise elements with different temporal frequencies, we were able to record contour responses in the presence of varying degrees of noise without contamination of the contour-element responses by responses to the noise.

Noise tolerance thresholds were measured for different degrees of orientation offset at a fixed spacing of the contour elements or at a fixed orientation offset for a range of contour element spacings. The addition of high-density noise eliminated the contour-specific response even though all the contour elements were still present and were unchanged in form. Contours whose elements had 0-10 deg orientation offsets were most resistant to noise. Contour-specific components were measurable at contour-element spacings up 9 wavelengths of the Gabor carrier (1.6 deg). The decrease in contour-specific responses with added noise is not consistent with uncertainty models. These reductions in signal strength are more easily explained by a masking effect. Thus explanations that rely exclusively on the observer being uncertain in the presence of noise are unlikely to be correct.

Acknowledgment: Supported by EY06579.
contours. Many investigators equate these principles.

In this talk, we will argue that, although they both enforce certain smoothness properties, good continuation and relatability are distinct principles, each required to understand visual segmentation and grouping phenomena. As it is usually defined only by examples, we first put forth a formal definition of good continuation: Contiguity vs. segmentation depends on the presence or absence of zero-order and first-order contour discontinuities. We will present data and demonstrations supporting this definition.

Relatability — which governs contour interpolation across gaps — differs in 5 ways from good continuation. Zero- and first-order discontinuities of segment visible arrays (good continuation) but are prerequisites for unit formation via relatability. Relatable edges must be connectable by a monotonic curve; also, they cannot bend through more than 90 deg. We will present demonstrations and data showing that good continuation follows neither the monotonicity nor 90 deg constraints. Finally, breaches of good continuation produce either separate objects or parts, whereas failures of relatability (in the absence of completion by surface spreading) produce distinct objects. Good continuation and relatability express related but distinct laws, applicable to different issues of perceptual organization.

Acknowledgment: Supported by NIH EY13518 to PJK and TFS

TA121
Contour grouping: is there something special about closed contours? Tal Tversky1 (tal@cs.utexas.edu), Wilson S Geisser2, Jeff Perry2; 1Department of Computer Science, University of Texas at Austin, USA, 2Center for Perceptual Systems, University of Texas at Austin, USA — PURPOSE: There is a body of literature claiming that “closure” helps strengthen low-level contour grouping. However, it is difficult to know whether closure effects are the result of a low-level closure mechanism, or the result of a low-level “good continuation” mechanism followed by a high-level decision process that picks between grouped contour elements. We attempted to design experiments with better control of decision factors.

METHODS: Using a two alternative forced choice procedure, we measured detection accuracy for closed and open contours made up of unconnected line segments. The closed contour was a circle passing through the origin and randomly rotated about the origin; the open contour was a randomly oriented ‘S’ whose center passed through the origin. The ‘S’ stimulus was identical to the circle in almost all aspects except closure. In one experiment, the target contours were embedded in a background consisting of randomly oriented and positioned line segments, and we varied the orientation jitter of the contour line segments. In a second experiment, there were no background elements and we varied the luminance contrast of the line segments. In a third experiment, we found better performance for closed contours.

RESULTS: For the first two experiments we found no significant closure effect. This is a departure from what has been found previously and is presumably the consequence of controlling for decision factors. For the third experiment, we found better performance for closed contours.

CONCLUSIONS: Closure effects are probably smaller than has been previously thought, requiring specialized conditions unlikely to occur in the natural world. We are exploring contour grouping models (based on natural scene statistics) to determine whether a low-level good continuation mechanism is sufficient to explain the observed closure effect.

Acknowledgment: Supported by NIH grant EY11747

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**Visuo-motor Control**

**Monday, May 12, 2003**

**4:30 – 6:30 pm**

**South Hall**

**Moderator:** Mary Hayhoe

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**TA122**

**Illusory positional shifts affect both perception and action**

Anna Ma-Wyatt1 (amw890@hotmail.com), Paul V McGraw2; 1Department of Psychology, The University of Western Australia, Australia, 2Department of Optometry, University of Bradford, UK — Purpose: It has been suggested that separate visual pathways exist for perception and action (e.g. Goodale and Milner, 1992). Much of the evidence for this notion is based on the fact that the visuomotor, or action system, is resistant to many visual illusions. However, many experiments showing a dissociation between perception and action required subjects to make a motor response which was more complex than the equivalent perceptual judgement. We investigated whether a simple motor response (ballistic pointing) was influenced by an illusory change in visual position. Methods: When a grating is drifted behind a stationary window, the window itself appears displaced in the direction of motion. We used this effect to create an illusory positional offset. Four identical patches, presented in a diamond formation, all drifted either up, down, to the left, or to the right. In the perceptual condition, subjects were asked to judge the position of a line relative to the intersection of the perceived position of the four patches. In the action condition, subjects were asked to point to the perceived intersection. Results: Subjects showed a positional bias in judging the perceived position of a line relative to the intersection of the perceived position of the four patches. In the action condition, subjects were asked to point to the perceived intersection. Conclusions: For a simple positional judgement, it is possible to demonstrate similar absolute errors for both perception and action, suggesting that a dissociation between the two systems is not a general finding and may be partially due to task demands.

Acknowledgment: PVM is supported by the Wellcome Trust, UK.

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**TA123**

**Look ahead fixations and visuo-motor planning**

Neil R Mennie1 (mmennie@cs.rochester.edu), Mary M Hayhoe1, Brian T Sullivan2, Carol Walhout2; 1Center for Visual Science, University of Rochester, USA, 2University of Edinburgh, UK — In studies of eye movements in natural tasks, fixations are tightly linked to the immediate action, with few fixations on irrelevant objects or locations (Land et al, Perception, 1999). Additionally, several studies have reported the frequent occurrence of “look-ahead” fixations. These are fixations on an object in the few seconds prior to a second fixation that guides a reaching movement to grasp the object. One possibility is that these fixations indicate that the subject is planning a reach, and fixating the object in order to acquire spatial location for guiding the next movement. We investigated this possibility in a toy construction task that required picking up and connecting components in a pre-determined sequence. We found that all of N subjects produce look-
Spatial memory use and coordination of eye, head, and hand movements. Mary M Hayhoe1 (mary@cvs.rochester.edu), Pilar Aivar2, Evan Gaines1, Jelena Jovanovicj; 1Center for Visual Science, University of Rochester, Rochester, USA, 2Erasmus University, Rotterdam, Netherlands—Despite evidence for limitations on memory across saccadic eye movements, a variety of recent results suggest that information about the spatial structure in a display is retained, and can facilitate visual search and saccade programming. We have demonstrated such facilitation of saccade programming from prior views in a 3-D virtual environment, in a task where observers copy a simple model. In this task, observers make large, coordinated movements of eye, head, and hand from right to left and back, across the display, in order to pick up the model components and place them in the copy. We examined the relative latency of eye, head, and hand for the movements following pickup, and following placement of a piece. We found that head and hand movements both precede the eye by 150-200 msec (head) or 200-400 msec (hand), depending on the direction of movement. This is a substantially longer lead time than is observed with single movements. Thus the advantage afforded by the use of spatial memory may be to allow early initiation of the hand and head movements, which are much slower than the eye. The importance of visual spatial memory is that it allows planning and consequently coordination of the movements of the different effectors. In addition, the head and hand latencies were well correlated on a movement-by-coordination of the movements of the different effectors. In this way, observers make any given trial the goal target could be to the left or right of the fixation target. The fMRI signal was always related to the horizontal location of the remembered goal relative to gaze. When eye movements reversed the remembered horizontal goal location relative to the gaze fixation point, a dynamic shift in cortical activity from one hemisphere to the other occurred. We conclude that in the human posterior parietal cortex, spatial goals for eye and arm movements are stored and remapped in eye-centered coordinates.

Acknowledgment: Supported by NIH grants EY05729 and RR09283

TA126
Grasping and representational momentum Anne-Marie Brouwer (anne-marie.brouwer@tuebingen.mpg.de), Volker H Franz, Ian M Thornton; Max-Planck-Institut fuer biologische Kybernetik, Deutschland—Observers tend to misremember the stopping point of a change in the direction of the change. We investigated whether this representational momentum effect is reflected in grasping. To do this, we presented 14 subjects with a sequence of 3 still images in which a pair of household pliers was seen to open or close in 1 cm steps. In a visual task, subjects indicated whether a fourth, probe image differed from the stopping point of the sequence. In a grasping task, subjects reached out and closed a virtual version of the third pair of pliers, just after the image disappeared. The subjects’ thumb and index finger were attached to robot arms which allowed us to provide haptic feedback and to measure the movement of the digits. When grasping identical versions of the third pliers, subjects opened their digits wider if the width of the pliers had been increasing compared to when the width had been decreasing. This is consistent with a build up of representational momentum. The direction of change (decreasing or increasing pliers width) had an effect equivalent to 4 mm physical variation in grasping. In the visual task, the pliers that were perceived as equal to the third ones tended to have a larger opening width when the width had been increasing than when it had been decreasing. This is also consistent with representational momentum. However, the visual effect was only significant for subjects who did the visual task first (p<0.01). For these subjects, the size of the effect was 1 mm pliers width.

Although subjects were asked to grasp the third pliers and got the appropriate haptic feedback, they apparently extrapolated the opening or closing of the pliers. This grasping effect does not appear to be directly related to the visual representational momentum effect, because the impact of direction was larger and more reliable in grasping than in perception and the effects were not correlated between subjects. http://www.kbp.tuebingen.mpg.de/~brouwer

TA127
Grasp effects of visual illusions: dynamic or stationary? Volker H Franz1 (volker.franz@psychol.uni-giessen.de), Frank Scharnowski2; 1University of Giessen, Giessen, Germany, 2Max-Planck-Institute for Biological Cybernetics, Tuebingen, Germany—In recent studies we found effects of visual illusions on the maximum grip aperture in grasping. Here, we ask whether these effects decay (or build up) during the execution of a grasp movement. Some recent studies suggest a decay (Glover & Dixon, Perception and Psychophysics, 64, 266-278, 2002), while the view of others is more consistent with a build up (Carey, Trends in Cognitive Sciences, 5, 109-113, 2001). We reanalyzed the data of different studies on the Ebbinghaus / Titchener illusion (Franz et al., Psychological Science, 11, 20-25, 2000; Franz et al., Experimental Brain Research, in press) which used very large sample sizes (26 and 52 participants). The hand aperture of each grasp movement was analysed at different, normalized time points. Special care was taken to avoid possible artefacts which might arise from the hand motion already touching the target object. Also, we corrected at each time point for the responsiveness of the hand aperture to a physical variation of size. Results show that the illusion effects are remarkably constant over time. This suggests that either the neuronal signals which cause the motor...
illusions are constant over time, or that the grasp trajectory is largely preprogrammed before the movement starts.

Acknowledgment: Supported by DFG grant Fa119/15-3 and by the Max-Planck Society.

TA128
FMRI confirmation of a neurological dissociation between perceiving objects and grasping them Metta M, A Gooch J, Thomas W James T, Jody C Culham G, Keith Humphrey D, David Milner A, University of Western Ontario, London, Canada, 2Vanderbilt University, TN USA, 3University of Durham, UK – Some of the most compelling evidence for the distinction between vision-for-perception and vision-for-action has come from studies of patient DF who developed visual form agnosia following an anoxic episode. DF is able to use visual information about the size, shape, and orientation of objects to control her grasping movements despite the fact that she is unable to perceive those same object attributes. On the basis of these results and some early structural MR data, we proposed that the anoxia had interrupted the normal flow of object form information into her ventral stream without affecting the processing of object form information by her dorsal stream. Recently we confirmed this idea in an fMRI experiment. New anatomical MR images showed that the lateral occipital cortex (LOC), a ventral-stream area implicated in object recognition, is severely damaged in DF. A comparison of activation with line drawings of objects and scrambled versions of the same drawings revealed no differential activation in this or the surrounding cortex. Objects with color and visual texture did result in significant but atypical activation in areas outside of LOC. In contrast, when DF grasped objects that varied in size and orientation, she showed relatively normal activation in the anterior intraparietal sulcus (AIP), a dorsal-stream area implicated in the visual control of grasping. These findings provide additional support for the idea that visual perception and the visual control of action depend on separate visual pathways in the cerebral cortex, and confirm the respective roles of the ventral and dorsal visual streams in these functions.

Acknowledgment: Supported by the CIHR (MAG, TWJ), the Wellcome Trust (ADM), and the CRC program (MAG)

TA129
When uncertainty matters: the selection of rapid goal-directed movements Julia Trommershauser, Laurence T Maloney, Michael S Landay; Dept. of Psychology and Ctr. for Neural Sci., New York Univ., New York, NY USA – We present three experiments that test the range of validity of a novel motor planning model (MEGaMove) based on statistical decision theory. In these experiments subjects had to rapidly touch a target region on a computer screen. Hitting the target within a prescribed time limit gained them a monetary reward. There were also one or more penalty regions on the screen that could partially overlap the target region. Hitting these regions incurred a specified monetary penalty. Late responses were also penalized. The model predicts that subjects Maximize Expected Gain in their average MOVEment end points (hence, “MEGaMove”).

In the first experiment the amount of penalty associated with a penalty region and the position of the penalty region relative to the target region were varied. Subjects followed the predictions of our model. Subjects shifted their mean movement end points away from the penalty region. This shift was larger for closer penalty circles and higher penalty values. The second experiment provided a direct test of the assumption that subjects use an estimate of their own motor variability in motor planning. The size of the target and penalty regions was varied, while the subjects’ motor variability remained constant. As predicted, subjects shifted their movement end points farther away from the penalty region for the smaller stimulus configuration (when scaled in units of the target size).

In the third experiment, stimuli included four rotated versions of a penalty/target configuration from the first experiment and four more complex configurations consisting of one target and two penalty regions. Subjects altered movement end points in direction and magnitude as predicted by our model in all configurations. Furthermore, end point variability remained as low as in the previous experiments. Thus, subjects were able to use an estimate of motor variability in planning their response in this novel and more complex situation.

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TA131  
Static scene analysis for the perception of heading: landmark identity and position information  
Annjudel Enriquez (annjudel@yahoo.com), George J Andersen, Craig W Sauer; Department of Psychology, University of California, Riverside – Recently we have shown that observers use a scene based analysis for the perception of heading in the absence of apparent motion (Hahn, Andersen, & Saidpour, in press, Psychological Science). In the following experiments we investigated the importance of objects as landmarks in performing heading judgments under those conditions and whether the information encoded is based on the object identity or the positions of the objects. 2 frame sequences of computer-generated scenes were presented that simulated a change in observer position through the scene. Participants judged whether they moved left or right from the initial position depicted on the first frame. Scences were presented with either a short inter-stimulus interval (ISI) of 50 ms to maximize apparent motion, or a long ISI of 1000 ms to eliminate apparent motion. In Experiment 1 we examined whether accuracy increased when a textured scene contained objects compared with textured scenes without objects. Accuracy increased with objects present in the scene, indicating that observers use objects as landmarks to infer observer motion. In experiment 2 we examined whether observers used object identity by preserving the locations of objects across frames but changing the object identity on half the trials. Greater accuracy in direction judgments occurred when object identity was not changed, suggesting that observers encode object identity to perform the task. Surprisingly, accuracy was above chance levels when object identity changed across frames, suggesting that observers also encoded position information of the objects independently of their identities. We conclude that objects serve as landmarks in determining heading, and that participants use both object location and identity when inferring the path of motion from static scenes.  
Acknowledgment: Supported by NSF BCS 0001758 and NIH EY012437.

TA132  
Visual control of locomotion without optic flow  
Jack M Loomis (loomis@psych.ucsb.edu), Andrew C Beall; University of California, Santa Barbara, USA – Using computer graphics techniques, we are able to place subjects in immersive virtual environments displayed only as scintillating random dot cinematograms (SRDC’s) with 1-frame lifetimes (Julesz, 1971). Thus, although each eye sees only a scintillating pattern of random dots of uniform density, the subjects experience moving about within room-sized virtual environments. Without training, subjects are immediately able to perform a wide range of complex spatial behaviors, including aiming toward targets, steering along curving paths, and intercepting moving objects, even though there is no optic flow correlated with the environments or actions.  
Formal experiments done so far deal with 2 forms of vehicle steering: steering a curving path and steering a straight path in the presence of lateral perturbations. Two viewing conditions have been compared for each task: dioptic stimuli with smooth optic flow produced by high contrast environmental features and SRDC’s with the same environmental features raised above the ground plane. The features were approximately matched for visibility in the two conditions. For the straight paths, the rms error of steering performance is 25% greater for SRDC’s, and for the curving paths, rms error is about 80% greater.  
The ease and accuracy with which subjects can perform complex spatial behaviors with SRDC’s signify that optic flow is not necessary for visually controlled locomotion. The suggestion is that optic flow normally acts through perceived flow in the control of spatial behavior. Furthermore, to the extent that subjects are utilizing aspects of optic flow to control behavior (e.g., splay rate), these appear to be aspects of the perceived flow instead.  
Acknowledgment: Supported by AFOSR grant F49620-02-1-0145.

TA133  
Path integration precision is doubled by the imagined proximity of previewed landmarks  
John W. Philbeck (philbeck@gwu.edu), Shannon O ‘Leary, Audra Lyn Blohm Leav; George Washington University, USA – Purpose: When navigating with vision, humans can determine their location by visually perceiving their distance and bearing relative to a landmark at a known location. When navigating without vision, positional uncertainty tends to increase with walked distance; if one believes a landmark is very nearby, however, one might disregard any uncertainty accumulated up to that point. If this happens, it should increase response precision in path integration tasks. This study tested that prediction.  
Method: Part 1: 36 participants binocularly viewed a single target cone at 2.4, 6.2 m in a well-lit room and attempted to walk to it without vision (5 repetitions per target). Part 2: using the same method, 12 participants walked 5 times to a previewed target at 6.2 m; 24 others saw a ‘landmark’ cone on the path at 4.2 m in addition to the 6.2 m target. 12 of these participants received auditory feedback about the landmark’s location as they passed (via pulsed noise bursts), while the rest saw both the landmark and target cones but received no feedback while passing the landmark. All participants wore hearing protectors to minimize uncontrolled auditory cues.  
Results: Response precision in Part 1, as measured by within-subject standard deviations (SD’s), averaged 9.2% of the target distance for all 3 groups. Precision for the no-landmark group was unchanged in Part 2, while SD’s for the 2 landmark groups dropped by nearly half to 4.7% of the target distance and did not differ between these 2 groups. All groups overwalked slightly (averaging +15 and +36 cm in Parts 1 and 2, respectively), with no group differences.  
Conclusions: When approaching the remembered location of a previewed landmark, blindfolded navigators behave as if their positional estimate has become more precise, even in the absence of environmental location cues. Apparently, remembered landmarks can reduce some of the positional uncertainty that accumulates when navigating by path integration.  

TA134  
Behavioral dynamics of avoiding a moving obstacle  
William H. Warren1 (Bill.Warren@brown.edu), Sun Di1, Brett R. Fajen2; 1Dept. of Cognitive & Linguistic Sciences, Brown University, USA, 2Rensselaer Polytechnic Institute – We are investigating the behavioral dynamics of visually guided locomotion in complex, dynamic environments. Previously, we developed a dynamical model of how people walk to stationary goals, avoid stationary obstacles, and intercept moving targets, based on human experiments in a virtual environment. Here we examine how people avoid moving obstacles. In the model, the direction of a goal acts as an attractor of one’s heading direction, whereas the direction of an obstacle acts as a repellor of heading. With a moving target, change in the target-heading angle is nulled, creating an attractor a constant angle ahead of the target; a moving obstacle may be avoided by treating this as a repellor. The path of locomotion is the resultant of all of the forces acting on the agent at each instant. In the present experiment, participants walked to a goal while avoiding a moving obstacle, whose initial position, speed, and trajectory were varied. Testing was done in the VENLab, a 40 x 40 ft virtual environment. Participants wore a head-mounted display (60 deg H x 40 deg V), while head position was recorded with a hybrid sonic/ inertial tracking system (50 ms latency). We analyzed the observed path and the time series of obstacle-heading angle to assess the conditions under which participants cut in front of or pass behind the moving obstacle. The aim of this research is to identify and model the locomotor “rules” for an individual human agent. This may allow us to predict interactions between people as well as crowd behavior in more complex situations. Locomotor paths can thus be shown to emerge on-line from the interactions between an agent and a structured environment.  
Acknowledgment: NIH EY10923, NSF LIS IRI-9720327
Mapping vision to action in the outfielder problem  Philip W Fink (Philip.Fink@brown.edu), Patrick S Foo, William H Warren Jr.; Department of Cognitive and Linguistic Sciences, Brown University, USA – What optical variables are used to guide fielders to catch flyballs and how are these variables mapped onto the action system? A variety of strategies have been proposed for how flyball catching is accomplished, typically entailing fielders maintaining some optic variable constancy (e.g. Optical Acceleration Cancellation, Chapman, 1968; Linear Optical Trajectory, McBeath et al., 1995). However, manipulations in experiments on flyball catching are constrained by the physics of projectile motion. In the present study, we avoid this difficulty through the use of virtual reality. Participants ran to catch virtual flyballs in the VENLAB (using a Cybermind HMD in a 12m x 12m room). By using virtual reality, the physics of flyballs were changed in a manner not possible in a physical environment (e.g. by introducing sudden accelerations to the ball trajectory). An interception model of flyball catching, mapping the available visual variables (e.g. velocities and accelerations of angles to the ball) onto actions variables (e.g. heading and velocity of the outfielder) will be presented, and the effect of different noise levels on the model will be discussed.

Acknowledgment: NIH EY10923

Maplets: local geometrical components of human cognitive maps  Gordon E Legge (legge@umn.edu), Sarah J Mason, Mark Brady, Nicholas Giudice, Erik J Schlitch; Minnesota Laboratory for Low-Vision Research, University of Minnesota, USA – The cognitive representation underlying human spatial navigation is often dichotomized into "route knowledge" and "survey knowledge." Motivated by concepts from studies of animal navigation, we propose a different form of underlying representation for human navigation. "Maplets" are small pieces of maps whose configuration information can be encoded from a single location using vision. The maplet representation of a building’s layout consists of a set of maplets each composed of a root node (corridor intersection) and the connecting links (branching corridors) to adjacent maplets. We have developed a computer algorithm that synthesizes global building layouts from a set of maplets, demonstrating that global layout information is implicitly retained in the maplet decomposition. Convergent evidence from two empirical studies, conducted for other purposes supports the psychological reality of maplets. In one experiment (Giudice et al., VSS 2002), human judges rated the accuracy of maps drawn by human subjects who learned building layouts by exploration. A maplet-matching score (computed by comparing the number of maplets in the subjects’ drawings to the actual maplet representation of the layout) correlated better with the judges’ ratings (R = .87 to .98) than did a global template matching method (R = .64 to .66). In a second experiment (Schlicht et al., ARVO 2001), subjects learned a building layout by free exploration. Then they drew a map of the layout and also performed a set of target-localization trials. The maplet-matching scores, derived from the subjects’ drawings, correlated (R = 0.7) with the accuracy of performance in the localization trials. Our computational and empirical results support the proposal that configurational information in human cognitive maps is stored in local maplets. Each maplet contains geometrical information that is accessible by visual inspection from within the maplet.

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Color  Tom Troscianko1 (tom.troscianko@bris.ac.uk), Roland Baddeley2, Carlos A Parraga3, Ute Leonards3, Jolyon Troscianko5; 1University of Bristol, 2University of Sussex, UK, 3University of Geneva, Switzerland, 4University of Oxford, UK – It is known that primate red-green color vision is efficient at encoding the presence of red or yellow fruit or leaves against a background of green foliage. However, our observations of monkey foraging behavior in Kibale Forest, Uganda during the dry season suggested that monkeys frequently ate green leaves on trees lacking any red object. They also showed preferences for specific trees. We asked whether the neural encoding of the green leaves of such trees allows discrimination from other trees, across marked differences in illumination due to time-of-day and weather effects. We obtained 80 images of two scenes, each containing several types of tree, throughout two days at intervals of 10-20 minutes, using a calibrated digital camera system described elsewhere (Párraga, Troscianko, and Tollehurst Current Biology 12, 483-487; 2002). The camera calibration allowed the decomposition of each pixel into LMS cone responses, and also luminance, red-green, and yellow-blue opponent responses. We averaged the values of these responses in five separate patches for images from Day 1, and six patches for Day 2. Our first analysis replicated the approach of Nascimento, Ferreira, and Foster (2002) JOSA A 19, 1484-1490, who suggested that ratios of cone responses across different patches should be invariant against changes in illumination. This turned out not to hold when one of the patches was plunged into shadow. Importantly, if similar ratios are taken of the opponent-channel responses, particularly the red-green channel which shows invariance to shadows, these new ratios are more invariant across illumination changes by an order of magnitude. We conclude that the red-green opponent system provides information about scenes containing green leaves which is strongly invariant across changes in illumination direction, spectral composition, and intensity. In other words, for scenes containing foliage, the color constancy problem is solved at the level of the retina.

Color selectivity in metacorrelation: asymmetrical and anisotropic  Dirk Beer (rdbeer@ucsd.edu), Donald I.A. MacLeod; University of California San Diego, USA – How is color represented in the cortex? Most evidence suggests that the well-defined code found in the retina and lateral geniculate nucleus, in which two “cardinal axes” of the color circle structure are encoded by just two parallel sets of signals (alongside a third for luminance), gives way in the cortex to a relatively messy and inscrutable organization where no such privileged axes exist. Here we use metacorrelation to investigate the cortical representation of color and brightness.

Using the BIGMAX stimulator we describe elsewhere, test discs of 1.1 deg
Luminance transients facilitate color vision. This enhancement may be related to psychophysical demonstrations that increase the response gain of blue-yellow V1 neurons after a brief delay. These results are consistent with the idea that luminance transients produce a multiplicative interaction between luminance and blue-yellow inputs. A masking ring devoid of color strongly suppressed only colorless test discs of similar luminance polarity; colored tests were little affected by colorless masks. But this selectivity for color difference was not symmetrical: colorless luminance test discs were effectively masked by colored rings, so long as the ring included an appropriate luminance modulation. Similar results were obtained in working around the two cardinal directions in the isoluminant plane. These observations suggest that test discs escaped masking, and were seen in roughly their proper color and luminance contrast, if they generated at least one cardinal-axis signal that exceeded the corresponding signal elicited by the mask.

As this interpretation predicts, no comparably sharp and asymmetrical selectivity for direction of modulation was found when working around the diagonal directions in color space. On this evidence, the cardinal directions do have a special status in the neural representation of color at the site of metacortex.

Acknowledgment: Supported by EY01711.

TA139 Luminance transients facilitate subsequent blue-yellow signals in individual macaque V1 neurons Gregory D Horwitz1 (horwitz@salk.edu), E.J. Chichilnisky2, Thomas D Albright1, 1The Salk Institute, HHWF; USA, 2The Salk Institute, McKnight Scholars Award; USA, 3The Salk Institute, HHMI; USA – The responses of some V1 neurons change nearly linearly with cone contrast whereas other neurons respond non-linearly. We studied color-opponent V1 neurons using a novel reverse correlation procedure that permits identification and characterization of a wide class of non-linear neuron. Previously we reported that the responses of blue-yellow neurons were non-linear and could be modeled as the product of a full-wave rectified luminance signal and a half-wave rectified blue-yellow signal (Horwitz et al. 2002 Soc. Neurosci. Abs. 720.8). Here we consider the temporal relationship between these luminance and blue-yellow signals. V1 neurons in awake, fixating monkeys were stimulated with randomly flickering colored checkerboard patterns. Stimuli preceding spikes were analyzed to assess stimulus selectivity. The average stimulus preceding a spike in blue-yellow neurons was, by definition, an increase in blue and a decrease in yellow. Principal components analysis on the ensemble of spike-triggered stimuli revealed a rectified luminance signal. Joint consideration of both response properties was consistent with a multiplicative interaction between luminance and blue-yellow inputs. The luminance signal reached its maximum ~10 ms before the blue-yellow signal. These results are consistent with the idea that luminance transients increase the response gain of blue-yellow V1 neurons after a brief delay. This enhancement may be related to psychophysical demonstrations that luminance transients facilitate color vision.

Acknowledgment: Supported by NIH Grants EY04440, EY13079; Australian NHMRC Grant 211247

TA141 Induction from patterned S-cone backgrounds: Receptoral or postreceptoral basis? Steven K. Shevell (shevell@uchicago.edu), Patrick Monnier; Visual Science Laboratories, University of Chicago, USA – BACKGROUND & PURPOSE Chromatic backgrounds alter color appearance. Background patterns that isolate S cones have been shown to cause particularly strong color shifts, which are larger than the shift from a uniform background at any chromaticity within the pattern (Shevell & Monnier, 2001). The S-cone patterns used in previous work were represented at both the receptive and postreceptoral levels. The question addressed here is whether the color shifts induced by S-cone-isolating chromatic patterns reflect activity at the receptive level (S-cone signals) or in a postreceptoral pathway (S/(L+M)). The results establish that patterns represented by postreceptoral signals, not S-cone excitation, mediate these large color shifts. METHODS Color appearance of a test field was measured using several background patterns composed of concentric circles alternating between two chromaticities. Pattern 1 had both S-cone and postreceptoral S/(L+M) variation, as in previous work. Pattern 2 had postreceptoral variation (as in Pattern 1) but no S-cone variation. Pattern 3 had S-cone variation (as in Pattern 1) but no postreceptoral S/(L+M) variation. The properties of Patterns 2 and 3 were achieved by adjusting the luminances of the two chromaticities. Color shifts induced by these patterns were measured using asymmetric matching. RESULTS Pattern 1 produced large shifts in color appearance, corroborating previous results. Similar shifts were produced by Pattern 2 (postreceptoral variation only) but not by Pattern 3 (S-cone variation only). CONCLUSION The large shifts in color appearance induced by S-cone patterns are mediated by signals in a postreceptoral S pathway. These results are consistent with a cortical neural mechanism with +S/-S spatial antagonism, as found in V1 (Conway, 2001) and which accounts for previously reported perceptual color shifts.

Acknowledgment: Supported by NIH grants EY-04802 & EY-07072

TA142 Infants’ spontaneous hue preferences are not due solely to variations in perceived brightness Davida Y. Teller1 (dteller@u.washington.edu), Andra L. Civan2, 1Departments of Psychology and Biophysics and Physiology, University of Washington, Seattle, WA, USA, 2Department of Psychology, University of Washington, Seattle, WA, USA – Purpose. In a classic study, Bornstein (1975) showed 4-month-old infants many pairings of monochromatic, isoluminant stimuli. The infants showed spontaneous looking preferences for red (630 nm) and blue (460 nm) over yellow (580 nm) and green (520 nm). However, to adults, with luminances matched, reds and blues look brighter than do yellows and greens. If infants see the same pattern of brightnesses, and prefer brighter appearing stimuli, then Bornstein’s spontaneous ‘hue’ preferences could be due solely to differences in perceived brightness. Will the classic hue preference pattern disappear if the stimuli are equated in adult brightness values? Methods. Stimuli were presented on a video monitor. Each of six chromatic stimuli from the edge of the color gamut (red, green and blue phosphors and three intermediate stimuli, yellow, purple and blue-green)
was paired with white (CIE x,y = .333, .333). The white stimulus was either matched to the chromatic stimuli in luminance (4.5 cd/m²), or in brightness as determined by average adult brightness matches in situ (6.1 to 21 cd/m²). A 0.45 cd/m² white surround was used.

Results. In general confirmation of Bornstein, blue, purple, and red were preferred to yellow, green, and blue-green. Preferences were virtually identical for luminance-matched and brightness-matched stimuli.

Discussion. These data reject the hypothesis that infants’ spontaneous hue preferences are due solely to adult-like variations in perceived brightness. The possibility remains that they are due to adult-like differences in perceived saturation. Studies with adult saturation-matched stimuli, and with chromatic surrounds, are in progress.

Acknowledgment: Supported by EY 04470

Control of Eye Movements

Tuesday, May 13, 2003
10:45 am – 12:15 pm
North Hall
Moderator: Larry Cormack

10:45 Stevenson, Mulligan, Cormack, TA143
11:00 Liston, Chukoskie, Krauzlis, TA144
11:15 Vishwanath, Kowler, TA145
11:30 Sommer, Wurtz, TA146
11:45 Connolly, Goodale, Gallt, Munoz, TA147
12:00 DeAngelis, Wei, Angelaki, TA148

TA143

Attention adds a long latency component in eye movement correlograms Scott B Stevenson1 (SBStevenson@uh.edu), Jeffrey B Mulligan2, Laurence K Cormack3; 1University of Houston College of Optometry, USA, 2NASA-Ames, USA, 3University of Texas at Austin, USA—WHY: Oculomotor tracking has both reflexive and voluntary aspects in most cases. Previous studies of how effort and attention modify tracking responses have employed a single target with varying instruction. Here we report experiments with two, independently moving targets with an instruction to track one or the other. A reverse correlation technique was used to measure the tracking responses to both targets so that the effect of attention and effort could be compared more directly. HOW: Each eye saw two concentric rings, viewed hemispheric through the optics of an SRI dual-Purkinje binocular eye tracker. Integrated velocity noise (low pass to 10 Hz) was added to the targets to generate random 4-D walks. Eye motion was sampled binocularly at 120 Hz in synchrony with the monitor frame rate and used to calculate both version and vergence velocity. These velocities were correlated to the ring velocities to yield “eye movement correlograms”. WHAT: Both targets contributed significantly to vergence and version, despite the effort to track just one. Both attended and unattended targets produced short latency responses (onset at 70-80 ms for H and V version; 90-110 ms for H and V vergence). The attended target showed additional, longer latency responses (onset at 100-110 ms for H and V version; 150-200 ms for H vergence). This effect was most evident with H vergence and was generally absent with V vergence. SO WHAT?: Because different visuo-motor subsystems require more or less processing and involve more or fewer synapses, there are latency differences in their responses to target motion. The eye movement correlogram may reveal these various modules as distinct components and allow a dry dissection of the visual processes involved in oculomotor control. The current results show that voluntary, attentive tracking is associated with a relatively long latency response component in addition to a shorter latency, reflex component.

Acknowledgment: Supported by EY12986

http://www.opt.uh.edu/research/ssstevenson/index.html

TA144

Max rules: modeling the where and when of saccadic decisions Dorion B Liston (dliston@salk.edu), Leanne Chukoskie, Richard J Krauzlis; Systems Neurobiology Lab, Salk Institute, La Jolla, CA, USA—Purpose: Saccadic eye movements provide discrete responses at easily measured latencies, facilitating study of the underlying decision process. Linear rise-to-threshold models of saccadic decisions (i.e. race model, LATER) have been very successful at describing latency (1/rate) distributions, but do not account for the accuracy (% correct) of saccadic choices. We have extended the race model and incorporated predictions derived from probability theory to account for the latency and accuracy of saccadic decisions.

Methods: A macaque observer fixated a central fixation cross on a random noise background (mean 41, sd 9 cd/m²). Two bounding boxes centered at 6 on either side of fixation demarcated possible target locations. After a random interval, two gaussian-blurred disks were added to the background, with a small luminance increment (0 .48 .97 1.45 1.94 cd/m²) added to one disk. The monkey was rewarded for making a saccade to the brighter disk. We measured saccadic latency distributions and percent correct for each signal strength.

Results: We modeled the decision process by applying a max rule to the rates drawn from two distributions, each representing one saccade goal. The shapes of the correct and incorrect latency distributions as well as their relative proportions were well fit. As signal strength increased, the monkey’s proportion correct increased and saccadic latency decreased; rates associated with correct responses increased with signal strength and rates for incorrect responses remained constant.

Conclusions: By including a max rule, our extension of the race model accounts for both the latency and percent correct of saccadic choices. The max rule incorporates the idea that the overt saccadic choice reflects only one of the multiple saccades prepared during visual discrimination. This version of the race model may be useful in determining how saccadic decisions are affected by task parameters such as signal strength and prior probability.

Acknowledgment: Supported by: McKnight & NASA OBP-R-07-0135-0106 (RJK) and NSF GRFP (DL)

http://www.snl.salk.edu/~dliston/afc_model/

TA145

Saccadic localization is affected by cues to 3D shape Dharanjai Vishwanath (dharanjai@john.berkeley.edu), NJ Eileen Kowler, Dept. of Psychology, Rutgers University, NJ—For a single saccade launched to an eccentric target, the default landing position is assumed to be based on a averaging of visual signals that yields the COG of a distributed 2D retinal representation of the target. In natural viewing, a saccade is usually generated as part of a larger saccadic sequence, and the targets are typically 3-dimensional objects whose projected retinal shapes can vary significantly depending on the vantage point from which the object is viewed. In this study, saccadic localization of 2D and 3D targets was tested using a naturalistic sequential scanning task. For 2D targets, saccades landed near the 2D COG with a high degree of accuracy (mean errors < 5% of saccade size), even for a target with well-defined component parts and with the COG located outside its boundary. For computer-generated images of 3D objects, landing positions of saccades deviated systematically from the COG of the 2D retinal image in the presence of cues such as perspective, shading, context, and shape. The most surprising finding was the observed shift in saccadic landing position toward the projected 3D COG of the shape. The 3D COG may be a more advantageous landing position given that it will coincide with the apparent center of the 3D...
object. Individual differences in a perceptual task devised to estimate perceived depth in the displays were correlated with saccadic performance in 4 out of 5 subjects. We conclude that the default landing position for saccades is not generated exclusively by visual representations based on the configuration of the 2D retinal image, but instead may have access to depth-scaled visual representations, of the sort known to be present as early as V1.

**TA146**

The frontal eye field sends predictively remapped visual signals to the superior colliculus

Marc A Sommer (mas@lsr.nei.nih.gov), Robert H Wurtz; Lab. Sensorimotor Research, NEI, NIH, Bethesda, MD, USA—We perceive a stable visual world even though saccades often move our retinas. One way the brain may achieve a stable visual percept is through predictive remapping of visual receptive fields: just before a saccade, the receptive field of many neurons moves from its current location ("current receptive field") to the location it is expected to occupy after the saccade ("future receptive field"). Goldberg and colleagues found such remapping in cortical areas, e.g. in the frontal eye field (FEF), as well as in the intermediate layers of the superior colliculus (SC). In the present study we investigated the source of the SC’s remapped visual signals. Do some of them come from the FEF? We identified FEF neurons that project to the SC using antidromic stimulation. For neurons with a visual response, we tested whether the receptive field shifted just prior to making a saccade. Saccadic amplitudes were chosen to be as small as possible while clearly separating the current and future receptive fields; they ranged from 5-30 deg. in amplitude and were directed contraversively. The saccadic target was a small red spot. We probed visual responsiveness at the current and future receptive field locations using a white spot flashed at various times before or after the saccade. Predictive remapping was indicated by a visual response to a probe flashed in the future receptive field just before the saccade began. We found that many FEF neurons projecting to the SC exhibited predictive remapping. Moreover, the remapping was as fast and strong as any previously reported for FEF or SC. It is clear, therefore, that remapped visual signals are sent from FEF to SC, providing direct evidence that the FEF is one source of the SC’s remapped visual signals. Because remapping requires information about an imminent saccade, we hypothesize that remapping in FEF depends on corollary discharge signals such as those ascending from the SC through MD thalamus (Sommer and Wurtz 2002).

**Acknowledgment:** Supported by the NEI.

**TA147**

fMRI activation related to preparatory set is correlated with saccade latency in human frontal eye fields but not in the supplementary motor area

Jason D Connolly1, Melvyn A Goodale 2, Herbert C Coltz3, Douglas P Munoz2, 1University of Western Ontario, London, Ontario, CANADA, 2Queens University, Kingston, Ontario, CANADA — Variation in saccade latency in response to identical sensory stimuli has been attributed to variation in preparatory set. Here we report the first evidence for a relationship between saccade latency and set-related activity in the human frontal eye fields (FEF). Event-related fMRI was used to examine the activation time-courses during a preparatory gap period (2 sessions of 144 trials with 5 subjects), during which no visual stimulus was presented and no saccades were made. The subject simply anticipated the appearance of a flashed peripheral target. Each trial began with the presentation of a central fixation cue (3 s), followed by a green (pro-saccade) or red (anti-saccade) central instructional cue (3 s). This was followed by a 0 (no gap) or 2 s (gap) period of darkness, followed by appearance of a flashed peripheral target (100 ms). Saccade direction and latency were recorded during scanning for each subject. 2-S gap trials were sorted according to short (top 25%) vs. long (bottom 25%) saccade latencies. Examination of the time-courses of activation in the FEF for 2-s gap trials showed a greater build-up in activity during the gap period for short as compared to long latency saccades. In contrast, the supplementary motor area (SMA) exhibited preparatory activity that was not different for short- and long-latency saccades. Replicating our previous work, activation in the intraparietal sulcus (LIP+) did not show preparatory build-up during the gap. These data provide evidence that the FEF contributes to the generation of preparatory set and that such signals may underlie the observed behavioral variability. Moreover, the differences in the pattern of activation we observed in FEF, SMA, and LIP+ demonstrate a functional dissociation between these three primary human oculomotor areas.

**Acknowledgment:** Supported by CIHR and CRC grants to MAG and DPM.

**TA148**

Does the oculomotor system make use of high-level visual cues to viewing distance?

Gregory C DeAngelis (gregd@cabernet.wustl.edu), Min Wei, Dora E. Angelaki; Washington University School of Medicine, St. Louis MO USA — Depth judgments that require knowledge of viewing distance are strongly influenced by both vergence angle and by the pattern of vertical disparities across large visual fields. Given the established importance of disparity fields in depth perception, we hypothesized that the oculomotor system might also make use of high-level monocular and binocular cues to viewing distance. To address this hypothesis, we investigated how compensatory eye movements during translation (translational VOR) scale with viewing distance. Monkeys viewed random-dot stereograms with which we independently manipulated vergence angle, the vertical disparity field, relative horizontal disparities, and texture cues to viewing distance. Stereograms simulated a textured wall or pyramid at different distances, with stimuli rear-projected on a fixed screen 32cm in front of the animal (subtending 85 x 68 degrees). In a control condition, a dot field was projected onto a moveable screen at different distances from the animal. For all of these visual conditions, 5-10 cycles of left/right motion of the animal (at 5 Hz) were interleaved with 2-3 cycles in complete darkness. Only cycles for which fixation and vergence were well-controlled were admitted into analysis. For each stimulus condition, the relationship between tVOR gain and viewing distance was quantified by linear regression. As expected from previous work, tVOR gain depended strongly on vergence angle. Vertical disparity and texture cues had a statistically significant effect on tVOR gain, but these effects were ten-fold weaker than the effect of vergence angle. By contrast to the large effects that vertical disparities can have on depth judgments, our results suggest that the oculomotor system relies far less on high-level cues to viewing distance than does the perceptual system.

**Acknowledgment:** Supported by grants from NIH (EY12814 and DC04260).
TA149

Linear and non-linear responses to form coherence in extrastriate cortical areas

Oliver Braddick1 (oliver.braddick@psy.ox.ac.uk), Justin O’Brien2, Geraint Rees3, John Wattam-Bell4, Janette Atkinson4, Robert Turner2;

1 Dept Experimental Psychology, Oxford University, UK, 2 Human Sciences, Brunel University, Uxbridge, UK, 3 Institute of Cognitive Neuroscience, University College London, UK, 4 Visual Development Unit, Psychology Dept, University College London, London, UK – Sensitivity to global form coherence provides a possible psychophysical measure of ventral stream function, both in normal vision and in neurodevelopmental anomalies. We have identified extrastriate cortical areas which show a differential fMRI response to form coherence, tested by the contrast between arrays of line segments aligned to concentric circles, vs randomly oriented segments (Braddick et al, Current Biology, 2000). To understand the role of these areas in detection of coherent form, we need to know how their activity varies quantitatively with form coherence.

We have tested, in a blocked fMRI design, BOLD responses to graded levels of form coherence (0, 33, 66 and 100%). Foci where signal varied quantitatively with % coherence were found bilaterally in the middle occipital gyrus (MOG), the lingual/fusiform area (LF) and the posterior intraparietal sulcus (IPS). In MOG and the more lateral part of LF, the response showed a monotonic, approximately linear increase with stimulus coherence, analogous to the results of Rees et al (Nature Neuroscience, 2000) for varying motion coherence in area V5. However, IPS and a medial part of the LF region, showed non-monotonic responses, with a higher BOLD response for 66% than for 100% coherence. Both results were consistent bilaterally.

The linear responses imply that MOG and LF may be involved in encoding and transmitting the information used to detect form coherence, either in parallel or in a sequence which does not involve any non-linear transformation. Non monotonic signals must play a different role and may reflect a contribution of attentional processes which need to be engaged more strongly when the coherent form becomes less clear. The anatomical relationship between IPS and medial LF suggests that such processes may include descending modulation of relatively early stages in the form processing pathway.

Acknowledgment: Supported by: Programme grant G7908507 from the Medical Research Council, and Wellcome Trust support for the Functional Imaging Laboratory

TA150

Sensitivity to direction of gaze in human posterior parietal cortex

Andrew T Smith1 (a.t.smith@rhul.ac.uk), Adrian L Williams2, Krishna D Singh3, Royal Holloway, University of London, UK, 2 Aston University, UK – Visual location is initially encoded in retinotopic coordinates but is later converted to a geocentric frame of reference, allowing stable perception despite eye movements. In primates, the first stage of the transformation involves neurons (in various areas) that have fixed receptive fields in retinotopic space but responsiveness that is strongly modulated by eye position. We provide evidence for the existence of such neurons in the human posterior parietal cortex. An MR adaptation paradigm was used. A circular, flickering, checkerboard pattern (diam. 10 deg) was presented in an otherwise-dark field. A fixation spot was provided in the middle of the pattern. Functional imaging was performed with a 1.5T MR scanner (GE Signa), using a purpose-built optical system to provide a large (80 deg) image. After an initial dark period to establish baseline activity, the stimulus appeared on the horizontal meridian at an eccentricity of 30 deg from the centre of the screen. The observer moved the eyes so as to foveate the fixation spot. The pattern remained at that location for 3 mins, during which time substantial BOLD signal adaptation occurred. It then disappeared and immediately reappeared at the same eccentricity on the opposite side. The observer made a single, large (60 deg) eye movement to re-establish fixation. Voxels that were sensitive to gaze direction were identified by correlating the activation timecourse with a model adaptation rebound response. Because retinal stimulation is invariant (except during the transition), there should be no rebound from adaptation in strictly retinotopic neurons. Rebound indicates a change in the active neuron population, reflecting sensitivity to gaze direction. A cluster of voxels showing strong rebound was observed immediately anterior to the parieto-occipital sulcus, close to the medial surface (possibly LIP; Sereno et al. Science 2001), suggesting that this region is sensitive to the geocentric location of stimuli.

Acknowledgment: Supported by The Wellcome Trust

TA151

Responses to glass patterns in macaque V1 and V2

J A Movshon (movshon@nyu.edu), M A Smith, A Kohn; HHMI and Center for Neural Science, New York University, USA – We have previously shown that the responses of V1 to dynamically presented Glass patterns are well predicted by a quasi-linear model of spatial summation within the receptive field (Smith et al., 2002, J Neurosci). We have now extended these observations to neurons in V2, recorded in opiate-anesthetized macaque monkeys.

As in V1, V2 neurons respond most selectively to translational Glass patterns when dot-pair orientation matches the best orientation measured with gratings, and when dot spacing is roughly half the period of the best spatial frequency. Also as in V1, neuronal selectivity decreases in a predictable way when the dot spacing is made smaller or larger than optimum. Perhaps because their receptive fields are larger, V2 neurons respond somewhat better to Glass patterns than V1 neurons, but rarely as well as they respond to gratings.

To explore the possible role of the receptive field surround in shaping responses to extended forms defined by Glass patterns, we measured the responses of some V2 cells to Glass patterns defining complex forms like radial and circular patterns. We arranged these forms so that the classical receptive field stimulus was always similar to the optimal translational pattern. Responses to all stimuli of this kind were very similar to the response elicited by a simple translational pattern.

We conclude that a) V2 receptive fields, like their V1 cousins, respond to Glass patterns that “match” the classical receptive field, and b) embedding the optimal local pattern in different global forms made no discernible difference to neuronal response. V2 neurons do not appear to be the neural substrate of the mechanisms, inferred from psychophysical experiments, that give selective response to global form in Glass patterns.

TA152

Cooperative synchronized assemblies and orientation discrimination

Jason M Samonds (jason.m.samonds@vanderbilt.edu), John D Allison, Heather A Brown, AB Bonds; Vanderbilt University, USA – There is no clear link between the broadly-tuned responses of single neurons and the fine behavioral capabilities of orientation discrimination. We have examined whether the joint activity of synchronized cells with similar preferred orientations would support finer discrimination than found in the rate code of single cells. We recorded from small populations of cells with a multi-electrode array in Area 17 of three cats (22, 25, and 29 cells) that were paralyzed and anesthetized with Propofol and N2O. Analysis of joint firing provides a substantial advantage (i.e., cooperation) in fine angle discrimination (4 degrees). This advantage increases from 50-300% as the population of an assembly is increased from 2-6 cells. The improvement of discrimination from cooperation accelerates with respect to the number of cells, yielding efficient encoding of orientation with fewer cells or in less time than from independent coding. The advantage provided by the joint activity of 6 cells grows from 75-540% as the orientation discrimination task is reduced from 10 to 2 degrees, which suggests that cooperation could potentially be a mechanism that supports higher acuity. There is almost no significant difference between the responses to 2-degree variations in individual responses making it unreasonable to achieve this level of discrimination by simply examining
large populations of cells independently. The cooperation is measured at a temporal resolution of 3-6 ms and incorporates another 3-6 ms of discharge history, which corresponds to the time scale of the orientation-dependent synchrony we find among the cellular assemblies. The results provide quantitative evidence that supports a role for synchrony in visual perception.

Acknowledgment: Supported by National Eye Institute Grant RO1EY-03778-19

TA153

Global interaction appears first in the temporo-occipital cortex Síno Vanni1,2, (suvanni@neuro.hut.fi), Michel Djoit3, Jan Warnking1, Christoph Segebarth3, Jon Bullier1, 1Brain Research Unit, Leu Temporal Laboratory, Helsinki University of Technology, Finland, 2Centre de Recherche Cerveau & Cognition, CNRS-Université Paul Sabatier, Toulouse, France, 3Unité Mixte INSERM, Université Joseph Fourier U438 -RMN Bioclinique, Grenoble, France – Psychophysical evidence suggests that information is integrated across the visual field early, and physiological data and models suggest that global information might have an important role in directing early cortical processing. In order to test for such early effects of global interactions on local processing, we tried to determine where and when the responses to two different visual stimuli are combined together in the human cortex. We showed two checkerboard patterns either simultaneously or one at the time, first in the left lower visual quadrant, and then at symmetrical positions in the left and right lower quadrants. Visual evoked potential (VEP) and functional magnetic resonance imaging (fMRI) data was acquired separately, but with identical stimulus parameters, and the retinotopic areas were mapped separately with fMRI. We acquired the position and orientation of the VEP sources in the retinotopic areas directly from fMRI, whereas other sources were modelled from the VEP data. Area V1 activated first, starting at 50 ms, and a temporo-occipital site located in the LOC/ V5 region followed soon, only about 10-15 ms after V1. Interaction was estimated by comparing the VEP source amplitude for the two simultaneous patterns to the sum of the single pattern responses. For the left visual field stimuli, the earliest interaction appeared at 80 ms in the right temporo-occipital region. When patterns were presented in two different hemisfields, interaction appeared again first in the temporo-occipital region, bilaterally, and started at about 100-110 ms latency. The retinotopic areas (V1, V2, V3, and V3a), as well as other sources, showed linear summation of responses for the two patterns at these latencies, and interactions appeared later. According to our data, the earliest global interactions emerge in a temporo-occipital region located near V5 and LOC, starting 30 ms after the first afferent volley reaches the cortex.

Acknowledgment: This work was supported by European Commission grant MCFI-2000-01134 from Quality of Life and Management of Living Resources –program.

TA154

The most reliable period for temporal cortical neurons David Sheinberg, (David_Sheinberg@brown.edu); Department of Neuroscience, Brown University, USA – There is a popular belief that the sensory response of single cells throughout visual cortex is highly variable from trial to trial, and that this variability places a fundamental limit on the information processing capacity of individual neurons. Often this variability is characterized by recording the activity of a cell during multiple repetitions of a particular stimulus condition, and comparing the mean number of action potentials occurring in each repetition to the variance of these counts. An obvious question to be addressed before conducting such an analysis is asking what actually constitutes a “trial”? How critically does the trial to trial reliability of a single cell depend on the time window within which spikes are counted? Recent data from primate V1 (Müller et al., 2001) suggest that a relatively short epoch surrounding the cell’s onset transient is both selective and reliable. Here we address this question by examining the activity of visually driven cells located in the temporal cortex of the monkey during both fixation and object identification. We find that for this population of cells, the choice of time windows is critical. Cells that appear to respond predictably are indeed quite reliable – with mean to variance ratios significantly in excess of one (as would be predicted by a Poisson process). However, this period of reliability is limited to short intervals – on the order of 75 to 100 milliseconds. Furthermore, for most cells, reliable responses are evoked for only a small subset of test patterns. We suggest that this period of maximal reliability, which generally occurs within 200 milliseconds of stimulus onset, is also time period over which these cells are most critical for signaling the presence of well known visual patterns.

Acknowledgment: This research was supported by the Max Planck Institute, the Alfred P. Sloan Foundation, and the James S. McDonnell Foundation

TA155

It may be easier to see two things at the same time! Shaul Hochstein (shaul@vms.huji.ac.il), Einat Shneor; Neural Computation Center, Hebrew University, Jerusalem, Israel – According to Reverse Hierarchy Theory (Hochstein & Ahissar, Neuron, 2002), high level cortical regions are responsible for pop-out - rapid detection of an element that differs greatly from surrounding elements in a single dimension such as color or orientation. With large-receptive field attention spread across the entire array, subjects detect presence or absence of targets with response times that do not depend on the number of distractor elements. We now asked what will be the speed and accuracy of detecting 2 such elements simultaneously. Subjects viewed a briefly presented 8x8 array of pink lines oriented at 55 degrees (or 60 deg.) followed by a masking stimulus after a variable Stimulus-to-mask Onset Asynchrony. On some trials, 1 or 2 of the elements were replaced by a pale green line of the same orientation, a pink line of orientation 35-40 degrees (or 30 deg.), or a line with both these changes. Subjects reported the number of odd lines, and their nature. Surprisingly, we found that subjects were more accurate at detecting-and-identifying 2 targets than single targets - for all types of odd elements. In addition, it was easier to report presence of two odd elements - one with an odd color and one with an odd orientation - than to report the presence of one odd element which differed from the distractors both in color and orientation. These results suggest that oddity is detected as a single whole so that arrays with a pair of targets are perceived as distinct unitary structures. The interdependence of detection of two pop-out elements supports the Reverse Hierarchy Theory notion that pop-out depends on high-level large receptive fields.

Acknowledgment: Support: Israel Science Foundation Center Grant #8009 and US-Israel Binational Science Foundation

TALKS

Tuesday, May 13, 2003 4:30 – 6:00 pm

Attention I

Tuesday, May 13, 2003

4:30 Hochstein, Shneor, TA155

4:45 Scholl, Nolte, Pasheva, Sussman, TA156

5:00 Strayer, Dreuss, Johnston, TA157

5:15 Dickinson, Chen, Zelinsky, TA158

5:30 Carrasco, Giordano, McElree, TA159

5:45 van Ee, van Dam, Brouwer, Korssten, TA160
Inattention-blindness behind the wheel

David L. Strayer (strayer@psych.utah.edu), Frank A. Drews, William A. Johnston; Department of Psychology, University of Utah, USA—Eighty-five percent of the 137 million cellphone users in the United States use their phones while driving. We report four experiments that assessed the effects of hands-free cell phone conversations on simulated driving. Our study used a car-following paradigm and found that these conversations impaired drivers' ability to react to cars and pedestrians in front of them. Our results indicate that the extent to which this impairment can be attributed to a withdrawal of attention from the visual scene, yielding a form of inattention blindness. To examine both explicit recognition memory and implicit perceptual memory for objects presented in the visual field while driving, we performed a series of experiments. Rejected items in Exp 1 were marked in red as observers searched for an object among Q distractors in two target (present vs. absent) and set sizes (31 or 46 items) conditions. Exp 2 kept the color marker but varied set size between 6 and 46 items in order to determine at what distractor memory load external marking benefits are expressed. Exp 3 used an "eraser" marker to remove rejected items, thereby enabling us to further explore the relationship between set size and marking. Exp 4 examined the effect of onsets vs. offsets by either adding or removing a box enclosing each marked item (i.e., items in the onset condition appeared initially without boxes but then box markers were added during search, whereas items in the offset condition appeared initially in boxes with these box markers then removed during search). For each experiment, search efficiency in the marked conditions was compared to a no-mark control condition. From these comparisons, we were able to estimate the effectiveness of internal marking during search. If the internal marking process was perfectly effective (i.e., perfect memory), no advantage should result from external marking. Our data clearly reject this hypothesis. Although the benefit derived from external marking varied with the marker type and the search manipulations, search was generally more efficient with marking than without. The implications of these results for models of memory during search are discussed.

Acknowledgment: This work was supported by NIMH Grant No. R01 MH63748 and NSF Grant No. ITR 0082602.

Can covert attention eliminate temporal disparities in the visual field?

Marisa Carrasco (marisa.carrasco@nyu.edu), Anna Marie Giordano, Brian McElree; New York University, USA—Background: 1) In addition to improving discriminability, covert attention accelerates the rate of visual information processing (Carrasco & McElree, 2001). 2) Contrast sensitivity is better along the horizontal than vertical meridian and better at the South than North location. These asymmetries are more pronounced as eccentricity increases. Covert attention improves discriminability at all locations to a similar degree (Carrasco et al., 2001, 2002). 3) Recently we have found that information accrual is faster: (a) at far than near eccentricities, (b) at the horizontal than vertical meridian, and within the vertical meridian at the S than N location. Goal: We investigated whether covert attention affects the rate of visual information processing as a function of: (a) eccentricity (4 or 9 ), (b) location at a given eccentricity (cardinal and intercardinal points at 4 or 9 ). Methods: We collected time-course functions for orientation discrimination with the response-signal speed-accuracy trade-off (SAT) procedure. Each trial began with a cue (67 ms), which was either informative (dot indicating the target location) or neutral (a dot at fixation). After a 53 ms ISI, Gabor patches with 0 or 7 distracters appeared for 40 ms. The target and distracters were presented at 8 equidistant locations from fixation at 4 or 9 eccentricity. A tone sounded at 1 of 7 SOAs, ranging from 40 to 2000 ms, prompting observers to respond. Results: Covert attention accelerated information accrual: (a) similarly for far and near eccentricities, (b) more on the vertical than the horizontal attention is directed elsewhere.

http://www.psych.utah.edu/AppliedCognitionLab

Explicitly marking rejected distractors in an overt visual search task

Christopher A. Dickinson (cddickin@ic.sunysb.edu), Xin Chen, Gregory J. Zelinsky; State University of New York at Stony Brook, USA—Are rejected distractors marked in a visual search task and, if so, what are the limitations of this marking process? To address these questions, we introduce a technique for explicitly marking display locations visited by gaze during overt search. Each display item fixed for at least 200 ms was visibly marked following the saccade away from that item. The stimuli in this initial series of experiments were small (0.35 ) gray Os and Qs presented on a black background. Marker type was manipulated between experiments. Rejected items in Exp 1 were marked in red as observers searched for an O among Q distractors in two target (present vs. absent) and set sizes (31 or 46 items) conditions. Exp 2 kept the color marker but varied set size between 6 and 46 items in order to determine at what distractor memory load external marking benefits are expressed. Exp 3 used an "eraser" marker to remove rejected items, thereby enabling us to further explore the relationship between set size and marking. Exp 4 examined the effect of onsets vs. offsets by either adding or removing a box enclosing each marked item (i.e., items in the onset condition appeared initially without boxes but then box markers were added during search, whereas items in the offset condition appeared initially in boxes with these box markers then removed during search). For each experiment, search efficiency in the marked conditions was compared to a no-mark control condition. From these comparisons, we were able to estimate the effectiveness of internal marking during search. If the internal marking process was perfectly effective (i.e., perfect memory), no advantage should result from external marking. Our data clearly reject this hypothesis. Although the benefit derived from external marking varied with the marker type and the search manipulations, search was generally more efficient with marking than without. The implications of these results for models of memory during search are discussed.

Acknowledgment: This work was supported by NSF #BCS-0132444.

Talking on a cellular telephone dramatically increases ‘sustained inattentional blindness’

Brian J Scholl (brian.scholl@yale.edu), Nicholas S Noles, Vanya Pashcheva, Rachel Sussman; Yale University, USA—In daily life attention is constantly spread not just across computer displays, but across several modalities, tasks, and objects, and it is unclear how attention operates in such realistic situations. Here we report a striking effect of sustained inattentional blindness (SIB) induced by one particularly relevant attention-demanding task: talking on a cellular telephone. Much research has shown that talking on a cellphone will slow responses, increase performance errors, and degrade detailed visual memory. But while some traffic accidents are no doubt caused by such factors, many have a different cause: Why did I hit the other car? Because I didn’t ‘see’ it! Here we report a first test of the impact of cellphone use on visual awareness. Observers viewed a dynamic display containing many moving items with various features, and were given a ‘multiple object tracking’ (MOT) task. Observers completed 3 trials, then on the 4th trial an unexpected event (UE) occurred: a new salient object suddenly entered and passed across the display, fully visible and in motion for 5 s. Observers were then probed in several ways for their awareness of the UE, and as in other studies many observers – 30% — were ‘intentionally blind’, and completely failed to perceive the UE. Another group of observers completed the identical task, but also had a cellphone conversation with a confederate during the experiment. These observers were no less accurate at the overt MOT task, but their level of SIB skyrocketed to 90%! The nature of this impairment was refined in several additional controls, in which subjects had to talk but not listen to the confederate, listen but not talk, or mindlessly shadow a list of words. The massive jumps in SIB caused by the cellphone conversations and other cognitively engaging controls suggests a sobering conclusion: that visual ‘awareness’ is particularly impaired by cellphone conversations, above and beyond any smaller effects on visual performance.

Acknowledgment: (BJS was supported by NSF #BCS-0132444.)
Learning & Plasticity I

Tuesday, May 13, 2003
4:30 – 6:00 pm
South Hall
Moderator: Jozsef Fiser

4:30 Yu, Klein, Levi, TA161
4:45 Gold, TA162
5:00 Fiser, Aslin, TA163
5:15 Bavelier, Green, TA164
5:30 Eckstein, Plum, Shimozaki, TA165
5:45 Tanaka, Miyachi, Inamura, Misaki, Matsumoto, Tashiro, TA166

TA160
Bistable stereoscopic 3D percepts: Will-power, flip frequency, eye movements and blinks Raymond van Ee (r.vanee@phys.uu.nl), Loes C.J. van Dam, Gijz J. Brouwer, Nienke J.H. Korsten; Utrecht University The Netherlands – Conscious perception can be influenced by the observer’s intention. Insights in conscious perception stem mainly from binocular rivalry studies in which the alternative percepts flip without clear voluntary control. We studied voluntary control in perception by exposing the visual system to a novel ambiguous 3D stimulus. In our paradigm observers estimate the orientation of a grid in 3D space (a metrical task). Perspective- and disparity-specified grid orientations can be independently varied across stimulus presentations, enabling us to do quantitative signal processing analysis. We have previously reported that observers are able to attentively select either a perspective- or a disparity-dominated percept when the two specified orientations had opposite signs (van Ee et al., Journal of Vision, 2002, 2, 597-607). Here we measured (i) the duration that an observer is able to voluntarily keep one percept over the alternative percept and (ii) the normal percept-dominance duration when the observer does not try to keep one over the other percept. We examined the increase in percept-dominance duration due to voluntary control, for both our stimuli and the classical binocular rivalry stimuli (horizontal/vertical bars and the house/face). Although spontaneous flips could not be prevented, we found a clear increase in percept-dominance duration for our stimulus relative to the classical stimuli. For a number of subjects the increase was almost ten-fold. We also measured eye movements and found that perceptual flips were neither correlated with eye movements, nor with blinks. Thus, will-power seems to have a relatively large influence in our bistable stimulus providing conditions for well-controlled conscious perception experiments.

http://www.phys.uu.nl/~vanee

Acknowledgment: Supported by National Institute of Health grants R01EY01728 and R01EY04776

TA162
Dynamic classification images reveal the effects of perceptual learning in a hyperacuity task Jason M Gold (jgold@indiana.edu); Department of Psychology, Indiana University, Bloomington, IN, USA – Purpose: Performance in hyperacuity tasks often improves with practice. One possible mechanism for this effect is an improvement in the spatial tuning of observers’ templates. Here, I use response classification to measure trial-by-trial changes in observers’ templates with practice in a vernier acuity task. Methods: 3 observers discriminated between 2 vertical line segments in which the entire top half was shifted by 1 pixel (~20”) to the left or right. On each trial, a vernier stimulus was chosen randomly and presented in high contrast Gaussian white noise. Each observer participated in 1000 trials/day over the course of 10 days. Contrast thresholds were measured during each session with a staircase that maintained ~71% correct performance throughout the session. Results & Conclusions: Practice reduced thresholds by a factor of ~1.5 over the course of the experiment. A series of N classification images was computed using the noise shown on trials N through N+2,000 (where N ranged from 1 to 8,000). The result was a classification movie that revealed the changes that took place in an observer’s linear template over time. When viewed in rapid succession, the series of images showed a stable template slowly emerging from a background of noise. This effect was quantified by cross-correlating each human classification image with the classification image for a model observer that a) assumed both the bottom and top halves of the vernier stimuli were shifted by 1 pixel in opposite directions; and b) was subject to a modest amount of spatial uncertainty. The correlation between the human and model classification images increased systematically by a factor of ~1.5 over the course of the experiment. I am currently using double-pass response consistency and spatial jitter to measure any reductions in multiplicative internal noise and/or spatial uncertainty that may have contributed to the changes that took place in the classification images over time.

http://vislab.psych.indiana.edu/~jgold/html

Conclusion: Covert attention improves visual temporal dynamics to the same degree at different eccentricities, but it speeds up information accrual more at the least privileged locations, i.e. along the vertical meridian, thus eliminating temporal asymmetries at a given eccentricity.

Methods: The stimulus was a Gabor patch presented either at the visual fovea (6 cpd) or at 5 deg temporal or nasal periphery (0.75 cpd). Contrast thresholds were measured with a 2AFC staircase method.

Results: (1) Among five observers who practiced foveal contrast detection and discrimination at 0, 0.3, 0.47, and 0.63 contrasts, four showed significant improvement over 4-5 days (2 hrs/day). The fifth observer started with very low thresholds and practice did not further improve performance. (2) Practice induced improvement for discriminating a vertical, 0.47 contrast foveal Gabor only partially transfers to discrimination of a horizontal Gabor, for Gabors with spatial frequency +/-1 octave away, and for Gabors at lower (0.30) and higher (0.74) contrasts, with other stimulus conditions identical. (3) Practice also improved contrast discrimination in the visual periphery. Improvement in one hemi-field only partially transfers to the other hemi-field of the same eye. (4) Practice produced much less learning in detection than in high-contrast discrimination under comparable practice conditions. Practicing detection with additional Gabor flankers did not facilitate learning in detection with no flankers when both conditions were run together.

Conclusions: (1) Practice improves contrast discrimination in both foveal and peripheral vision. (2) Learning is partially general, partially specific to the stimulus spatial frequency, orientation, contrast, and retinal location, indicating that both low-level (gain) and high-level (strategy) learning is involved. (3) Contextual stimuli do not affect perceptual learning of contrast detection.
TA163
Element predictability not high occurrence frequency determines feature learning from multi-element scenes
Joséf Fiser
Center for Visual Science, University of Rochester, USA—Previous studies have demonstrated that humans, by mere exposure, can become sensitive to clusters of elements (objects) from multi-element visual scenes. However, a key question in object recognition—which of several statistics of the scene (e.g., element relative frequency or conditional probability) humans prefer for breaking complex unfamiliar objects into subparts—has not been investigated before. We addressed this question by presenting naïve observers with 184 unfamiliar artificial multi-element scenes, where the occurrence frequency and conditional probability (predictability) statistics were different across the participating elements. Subjects passively viewed each scene for 2 second during a familiarization session. Each scene consisted of 7 geometric shapes positioned apparently randomly on a 5x5 grid. However, each scene was generated with one of two consistent 6-tuples (six elements always appearing in a given configuration) and a noise element so that the participating elements of the 6-tuples had different occurrence frequencies and predictabilities. In particular, some elements of the 6-tuples appeared 1.5 times more often during familiarization, but were less predictive of neighboring elements, while some less frequent elements predicted their neighbors better. A 2AFC post-exposure test revealed that subjects remembered the embedded shape-pairs of the 6-tuple with lower element occurrence but higher predictability better than shape-pairs with higher element occurrence and lower predictability [(t(29)]=2.25, p<.05]. This result provides direct evidence that, other dimensions being controlled, encoding the sub-features of a larger coherent visual structure is determined by the predictability between elements rather than their higher occurrence frequency in the scenes. Moreover, elements with lower predictability in the structure serve as breakpoints for "chunking" the object structure into parts.

Acknowledgement: Supported by NSF SPR-9873477 and by NIH T32 EY07125-13

TA165
The efficiency of the use of feedback in perceptual learning
Miguel P Eckstein
Department of Psychology, UC Santa Barbara, US—Introduction: Many studies have shown how feedback can improve perceptual learning (e.g., Herzog and Fahle, 1997). Less is known about how well humans use feedback. To investigate this question, we use an experimental paradigm (rapid perceptual learning, RPL; Abbey et al., 2001; Eckstein et al., 2002) in which an ideal observer learns from trial to trial. The framework allows us to compare the amount of learning with and without feedback in the human observer to the maximal possible learning assessed by the ideal observer. Methods: In the pre-RPL paradigm a learning set consisted of 8 trials. One out of the 26 letters from the English alphabet was randomly chosen and remained as a target throughout a learning set. On each trial, the target letter appeared randomly in 1 out of 8 locations embedded in image noise. The observers had to localize the target on each trial and identify it on the last trial of the learning set. There were two blocked conditions: 1) no feedback, 2) feedback about the target location provided with a post-cue following the observers’ localization response (post-cue feedback). Observers participated in 1200 learning sets. Results: Human localization performance across the 8 learning trials increased significantly for both conditions (averaged across conditions and observers = 8%). Learning was greater for the feedback condition than the no feedback condition consistent with previous studies. Overall human efficiency (i.e. the squared ratio of the ideal observer contrast threshold and the human contrast threshold) decreased (~7%) from the first to the last learning trial for both conditions suggesting that humans learn less than the ideal observer. Efficiency for the feedback condition reached its lowest point in the 2nd learning trial suggesting that the ideal observer learns faster with feedback than humans. Conclusion: Humans use feedback in a perceptual learning task is imperfect and slow compared to the ideal observer.

Acknowledgement: NIH-ROI 53455, NASA NAG 9-1157, NSF 0135118

TA166
Transfer of long-range interaction across the visual hemifield by reversed visual input
Yasuto Tanaka1 (ytanaka@po.crl.go.jp), Satoru Miyachi2, Tosihide Inariuoka3, Masaya Misaki4, Eriko Matsumoto5, Takara Tashiro6; 1Brain Information Group, Kansai Advanced Research Center, Communications Research Laboratory, Japan, 2Department of Psychology, Faculty of Letters, Osaka City University, Japan—The reversal of the retinal image using prism spectacles induces disruption of sensory-motor coordination. Although several studies report that harmonious visuomotor behavior is recovered after prism adaptation, the mechanism involved in the adaptation is largely unknown. Here we study large-scale visual plasticity between left and right hemifields using Gabor patches and left-right reversed prisms. Experiments were carried out for 5 days. Before the prism adaptation, the long-range interaction was achieved by a temporal cuing method. Temporally primed visual signals (peripheral crosses at 7.2 deg., duration=100ms) preceded vertically collinear 3 Gabors by 300-600ms. The Gabor stimuli (sigma=6 lambda=0.2 deg., 100ms) were presented binocularly at 3 deg. leftward from the central fixation spot. The flanker (C=0.4)-to-target distance was 6 lambda. The practice with temporal cues for 30min generated extended long-range facilitation to 9-12 lambda over days (threshold reduction=0.23±0.08 log units; 5 subjects). Before the adaptation, no transfer was observed at the opposite visual field. After two days of adaptation, the extended long-range facilitation was found not only at the practiced visual field but also at the opposite side (distance=3 deg., 0.14±0.05 log units; 2 subjects). This transfer persisted over the subsequent 3 days of adaptation and preserved after putting off the prisms. No transfer was found using up-down reversed prisms (1 subject). Control observers without prisms (2 subjects) showed no transfer. The transfer of the long-range interaction across the hemifield by prism adaptation demonstrates large-scale plasticity in early visual system induced by reversed retinotopic input. There is no commissural

Acknowledgement: NIH-ROI 53455, NASA NAG 9-1157, NSF 0135118
connection in V1 between the practiced area (left visual field) and the tested area (right visual field), thus the results suggest that the learning effect transferred through higher cortices (i.e. the parietal cortex) and projected backward to V1 during the adaptation.

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**Motion I**

**Tuesday, May 13, 2003**

6:15 – 7:45 pm

**North Hall**

**Moderator:** Frans Verstraten

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**TA167**

fMRI reveals the neuronal substrate underlying form and motion processing in transformational apparent motion

Peter U Tse, (Peter.Tse@dartmouth.edu); Dartmouth College, Hanover NH 03755 USA – Transformational apparent motion (TAM) occurs when a figure changes discretely from one configuration to another overlapping configuration. Rather than an abrupt shape change, the initial shape is perceived to transform smoothly into the final shape as if animated by a series of intermediate shapes. Here fMRI has been used to determine the neurophysiological substrate of this motion illusion.

In the past, fMRI has been used both to locate areas of the human brain involved in processing form and to locate areas involved in processing motion. Relatively few studies, however, have examined how the form and motion processing streams interact. For this purpose, Transformational Apparent (Tse, Cavanagh, and Nakayama, 1995, 1998) is an ideal stimulus probe, because the direction of motion that is perceived depends on the form relationships that exist between successive stimuli (Tse and Logothetis, 2002).

In two experiments, TAM stimuli and control stimuli that were similar in low-level properties, but which did not give rise to the perception of TAM, were blocked. The BOLD signal was measured using a 1.5T GE scanner. Voxel volume was 3.75x3.75x5mm in 25 horizontal slices collected using single-shot T2* weighted gradient-recalled EPI sequences.

When TAM and non-TAM stimuli were contrasted using the General Linear Model, there was significantly more BOLD signal in the following results: areas 18 and 19, area MT+, and area 7 in the superior parietal lobule and precuneus. These data are consistent with models that place a stage of texture and form analysis in extrastriate cortex before motion processing in area MT+.

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**TA168**

Apparent motion is less apparent with attention

Yaffa Yeshurun (yeshurun@research.haifa.ac.il); Liat Levy, University of Haifa, Israel – Can spatial transient attention affect apparent motion? To answer this question we used two different tasks that involved apparent motion displays. The first display was composed of a short line segment appearing successively in two spatial locations with a varying ISI. The task required observers to rate the quality of motion. The second display included a rectangle composed of small dots. The rectangle also appeared in two spatial locations successively, with a varying ISI, but the order of locations ensured that the rectangle appeared to be moving upward on half the trials and downward on the other trials. Observers were asked to indicate the direction of motion. To manipulate transient attention these two tasks were coupled with peripheral precueing: On the “cued” trials a peripheral cue indicated the location of the apparent motion target prior to its appearance, allowing observers to direct their attention in advance to the target location; on the “neutral” trials a neutral cue specified that the target could appear in any one of the possible locations. In both tasks, the target could appear in one of several locations at the periphery, and stimuli durations ensured that eye movements could not occur between cue onset and target offset.

The results indicate, for both tasks, that the perception of motion was weaker when observers attended the target location. Observers gave lower quality rates and were less accurate in judging the direction of motion on the cued than the neutral trials. In addition, there is an indication that the ISI at which motion perception is strongest is longer when observers attend the target location. These findings are consistent with previous findings regarding attentional effects on temporal processes (e.g., lower temporal resolution, longer visible persistence, and longer duration estimation) and can be accounted for by an attentional mechanism that favors parvocellular over magnocellular neurons.

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**TA169**

Second order motion is not second-class: A new illusion in Motion Perception

Thomas A Carlson (carl0395@umn.edu), Paul Schrater, Sheng He; Department of Psychology, University of Minnesota – The current study introduces a new illusion in motion perception. The stimulus is a moving object that is composed of a textured center and a dynamic surround. When viewing this stimulus, subjects perceive the textured center as moving slower than the dynamic background (i.e. a perceptual lag). In a series of experiments, we investigated the possible underlying mechanism behind this phenomenon. The motion of the slow moving textured center can be decomposed into a first order motion signal (motion of the center texture) and a second order motion signal (the moving boundary between the textured center and the dynamic noise).

Potentially, the illusion could arise from a failure of first order motion system to properly estimate the velocity, a failure of the second order motion velocity estimate, or some combination of the two. Subjects performed a velocity-matching task for three types of moving stimuli: motion of the texture (first order), motion of the boundary (second order), and motion of both the texture and the boundary (combination of first order and second order). Subjects were found to be accurate in the velocity estimation of the first order stimuli. In the second order condition, subjects perceived the stimulus to be moving substantially slower than the true velocity. The perceived velocity of the stimulus with combined first and second order motion signal was found to be in between the two. The results of our experiments suggest that to compute perceived velocity, our visual system integrates first and second order motion information when both are available. Interestingly, this motion cue combination occurs even when the second order motion signal provides inaccurate velocity information. Given both an accurate first order velocity estimate and an inaccurate second-order velocity estimate, the second order motion signal is not treated as second class.

**Acknowledgment:** This research is supported in part by the James S. McDonnell Foundation

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**TA170**

The cogwheel illusion

Stuart Anstis (sanstis@ucsd.edu); Psychology Dept, UCSD, La Jolla, CA – When a toothed cogwheel – a circle with 12 inward pointing radial teeth – is moved rapidly along a clockwise circular path without rotation (like the circling sponge that remains upright in the hand of a window cleaner), it appears to rotate counterclockwise. We
measured how this illusion is affected by motion amplitude, tooth length, and Michelson contrast. At low contrast the pattern appears to reverse and rotate clockwise. Conclusion: The trajectories of the inner tips of the moving teeth stick out into the empty middle of the circle. They are more perceptually salient than the rest of the figure, and they actually move counterclockwise. The motion of these salient tips propagates to the rest of the figure. At low contrast the T junctions, where the teeth join the circle, become more salient than the tips of the teeth.

Acknowledgment: Grant from the UCSD Senate
http://psy.ucsd.edu/~sanstis

| TA171 | What makes local dots turn into moving global surfaces? | Frans Verstraten$^1$ (f.verstraten@fss.uu.nl), Ryota Kanai$^2$, Chris Paffen$^1$, Walter Gerbino$^2$; $^1$Universiteit Utrecht, Helmholtz Research Institute, Psychonomics Division, the Netherlands, $^2$University of Trieste, Department of Psychology, Italy – Visual processing involves processing stages in which local features are initially analyzed and combined to construct integrative representations of the visual environment in terms of objects and surfaces. In the case there are multiple cues for integration, conflicts may arise and the visual system has to come to a acceptable solution. Here we are interested in this process in the domain of visual motion perception. For the case of visual motion it is known that at least two distinct – local and global – processing stages are involved. First, motion is analyzed by local motion filters selective for spatio-temporal orientation. Next, these local motions are integrated by combining the signals arising from a common visual object or surface, while segregating those arising from different objects or surfaces. The question is how? We looked at two surface grouping strategies. Our stimuli consisted of dots which were changing their direction periodically over a short distance at a constant velocity. Oscillating dots were used because they consist of two components, sustained motion signals and transient direction changes (feature-based and synchrony-based grouping strategies, respectively). This stimulus allows us to vary the relative strength of the two grouping strategies. The results show that when the timing of the direction changes is random (zero synchronicity between the dots), the configuration results in a compelling percept of streaming motion transparency that cannot be distinguished from continuous motion transparency. As the synchronicity of the dots’ direction changes increases, the percept of streaming motion transparency changes drastically towards a percept of globally oscillating surfaces, that is, a pair of global surfaces is moving back and forth. The experiments also show that local signals, inconsistent with a surface interpretation, are prevented from further visual processing required for conscious perception of the dots.

Acknowledgment: NWO Pionier
http://www.fss.uu.nl/psn/tecb/

| TA172 | Spatiotemporal integration of motion across saccades | David Melcher (melcher.david@hsr.it), Concetta Morrone; S. Raffaele University, Milan, Italy – Humans make saccadic eye movements several times per second, on average, radically displacing the retinal image of objects from one view to the next. Why, then, is the world perceived as stable? In this study, the temporal integration of two brief motion pulses (150 ms) embedded in noise (10 s) was examined, both with maintained fixation and across eye movements. Motion coherence sensitivity was measured in a direction discrimination task as a function of the temporal delay between the two brief motion signals. When the subject made a 12 saccade from above to below the motion patch, temporal integration of motion continued across saccades, despite the fact that the retinotopic position of the stimulus changed as the result of a saccadic eye movement. This spatiotopic integration of motion occurred even when each brief motion stimulus was, by itself, below the threshold of conscious detection. Motion integration was not compulsory over the entire visual field, but depended on where the observer was looking and attending. These results suggest that the suppression of visual information during eye movements, combined with the integration of information about features of an attended object across eye movements, may be responsible for the perception of a stable world.

Acknowledgment: MIUR, COFIN 2002

| TA173 | Context dependent learning in contrast discrimination: effects of contrast uncertainty | Dov Sagi$^1$ (Dov.Sagi@Weizmann.ac.il), Yuad Adini$^1$, Mishia Tsodyks$^2$, Amos Wilkonsky$^1$; $^1$The Weizmann Institute of Science, Dept. of Neurobiology, Brain Research, Rehovot, Israel, $^2$Technion, The Bruce Rappaport Faculty of Medicine, Haifa, Israel. – Performance on perceptual tasks improves with practice. However, contrast discrimination thresholds show a remarkable stability when a large range of contrasts (0-0.6) is practiced. There are two known exceptions: (a) when the practiced target is surrounded by flankers (Adini et al, Nature 415, 790-793, 2002), (b) when practicing with a single base contrast (Yu et al, VSS 2002). The improvement can be explained by increasing the gain of contrast transduction and/or by optimization of discrimination strategies applied to the specific contrast level(s) used during practice. To separate between the two accounts we measured contrast discrimination thresholds before and after learning in conditions where the observers could not predict the target contrast (contrast uncertainty). Learning effects based on plastic changes in the basic sensory mechanism, but not on contrast specific strategies, are expected to survive such an experimental manipulation. The pre-learning tests (using Gabor signals) showed the expected stable performance with typical threshold vs contrast functions for both the certain and the uncertain contrast conditions. Next, observers were trained with contrast discrimination using a constant base (pedestal) contrast (0.5). Discrimination thresholds were almost halved during practice. However, this improvement was found to be specific to the trained condition and post-training tests with contrast uncertainty showed no improvement. A second group of observers practiced the full contrast range with the target embedded in a chain of flankers, showing the expected improvement in contrast discrimination. This learning effect was found to transfer to the post-learning test with contrast uncertainty. The results imply that contrast transduction is modified when contrast discrimination is practiced with flankled targets. Without flankers, learning may involve improvement of decision strategies, depending on the information available to the observer.

Acknowledgment: Supported by BRF/ISF
http://www.weizmann.ac.il/~masagi/vss03

| TA174 | Context dependent learning in contrast discrimination: effects of contrast uncertainty | Vadim Mednick, Nakayama, Stickgold, TA178

Learning & Plasticity 2

Tuesday, May 13, 2003 6:15 – 7:45 pm

South Hall

Moderator: Rene Marois
TA174

Attentional learning: learning to bias sensory competition
Zoltán Vidiyanszky1 (vidiyanszky@ana.sote.hu), Wonyeong Sohn2, 1Vision Research Laboratory, Neurobiology Research Group, Hungarian Academy of Sciences, Hungary, 2Laboratory of Vision Research, Rutgers University, USA – Visual attention can bias the competition between different visual stimuli - resulting in a simultaneous facilitation of attended, and suppression of unattended input. This study addressed whether there is attentional learning, i.e. can one learn to more strongly bias the competition between different visual stimuli?

Using transparent, bivectorial motion adaptors, we studied the plasticity of attentional modulation of the motion aftereffect (MAE). During adaptation, 70% of the dots, the MAE of which was measured, were colored red and moved along 0°. The rest of the dots were green and alternated direction every 4 s between +90° and -90°. Before and after learning, observers performed two test sessions. The test contained adaptation periods during which observers attended to the luminance of one or the other dot field in order to detect occasional brief luminance increases. The difference in the MAE duration between these two conditions was used as the index of the strength of attentional modulation. During the learning phase (seven one-hour sessions), observers always performed the luminance detection task over the dots with alternating motion directions.

We found a strong direction specific learning effect on the attentional modulation of motion processing. When the same bivectorial motion display was used during learning and test, the magnitude of attentional effects increased significantly with learning. However, learning had an opposite, suppressive effect on attentional modulation when the surface that was unattended during learning was made to move in the opposite direction during test. Our results provide strong evidence for attentional learning, a phenomenon that allows one to bias sensory competition more strongly as a result of practice. The fact that attentional learning effects are specific for the properties of the unattended stimuli implies that the plasticity of the mechanisms of attentional suppression plays an important role in attentional learning.

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TA175

Optimal learning rates for unbiased perception
Benjamin T Backus (backus@psych.upenn.edu); Department of Psychology, University of Pennsylvania, USA – One goal of a perceptual system is to make unbiased estimates. But biological perceptual systems cannot remain accurate without active processes to keep them calibrated (Helmholtz 1910; Welch 1986; Bedford 1999). Recent theory has described adaptations that achieve other goals, including the optimization of early sensory processing (Grzywacz & Balboa 2002), information transfer between stages of processing (Barlow 1990, Wainwright 1999), and evolutionary fitness (Geisler & Diehl 2002). Here we examine the optimal strategy for minimizing bias in a perceptual system that accumulates bias over time, and especially the case in which two methods are available for estimating a single scene parameter. In this situation, the rates at which independent, discrepant estimators should be moved towards the system’s best estimate are proportional to estimator variances (Gahramani, Wolpert & Jordan 1996). We show that the rate at which an estimator accumulates bias (modeled as the diffusion constant in a random walk) must also be taken into account: minimizing system bias requires that learning rates be higher for estimators that accumulate bias more quickly. Since learning rates are set by the system, we suppose they are near optimal. The theory seems useful. For example, under Bayes’ theorem, prior belief is equivalent to estimation from data, and we now can unify two previously distinct forms of adaptation: Wallach’s informational discrepancy (response to conflict between two data-based estimators), and Gibson’s normalization (modeled as response to conflict between an estimator and a prior). A data-based estimator often has lower variance than a prior, making it closer to the system’s best estimate; but it also accumulates bias faster, so the system gives it a higher learning rate. Consequently, the data-based estimator moves towards the prior rather than vice-versa. The framework is also useful for predicting sites of adaptation and certain adaptation aftereffects.

Acknowledgment: Funded by the University of Pennsylvania http://www.psych.upenn.edu/backuslab/ivss/2003/backus.html

TA176

Attentional modulation of scene learning in the parahippocampal place area and of face learning in the fusiform face area
Marvin M Chun1 (marvin.chun@vanderbilt.edu), Doo-Joon Yi2, Todd A Kelley2, René Marois3, 1Dept of Psychology, Vanderbilt University, TN, USA, 2Dept of Psychological and Brain Sciences, Johns Hopkins University, USA – The nervous system must resolve a trade-off between stability of existing neural connections and plasticity to encode new information. Selective attention may control learning so that only behaviorally-relevant, attended stimuli induce changes in neural circuitry.

We tested this hypothesis using fMRI measurements of scene learning in the parahippocampal place area (PPA, Epstein & Kanwisher, 1998) and face learning in the fusiform face area (FFA, Kanwisher, McDermott, & Chun, 1997). As an index of learning, we measured adaptation, namely, reduced activation to repeated vs. novel images (Grill-Spector et al., 1999). To manipulate attention, we used overlapping scene and face images (O’Craven et al., 1999), and asked subjects to attend to either scenes or faces in a 1-back matching task. When scenes were attended, significant adaptation was observed for the attended repeated scenes in the PPA, while no adaptation was observed for unattended repeated faces in the FFA. Conversely, when faces were attended, no adaptation was observed for the unattended repeated scenes in the PPA, while significant adaptation was observed for the attended repeated faces in the FFA. A control experiment ruled out alternative explanations based on signal level reductions due to inattention. These results suggest that attention governs when neuronal representations will exhibit plasticity to repeated perceptual input.

Acknowledgment: Supported by a Vanderbilt University Discovery Grant

TA177

How can subliminal perceptual learning be active?
Aaron R Seitz1 (aseitz@lums.harvard.edu), Takeo Watanabe1, 1Harvard Medical School, USA, 2Boston University, USA – In our previous studies (Watanabe et al., 2001, Nature; 2002, Nat Neurosci), subjects performed an attentionally demanding letter identification task in the fovea while sub-threshold coherent motion was presented in the periphery. Repetitive exposure improved performance specifically for the exposed sub-threshold motion direction. This showed that perceptual learning occurs as a result of exposure to a subliminal feature, and therefore, without attention directed to the feature.

This raises an important question: Does such subliminal learning occur only as a result of purely passive processing of a stimulus? To address this question, during exposure we presented four different directions of motion an equal number of times, but the direction of interest (DOI) was paired with the task targets. If learning is purely passive, thresholds should improve equally for all the presented directions. On the other hand, if learning is formed only on a feature to which attention is directed, no improvement should be found for any presented direction. Contrary to these hypotheses, the threshold improved for the DOI, which was paired with the task targets, but not for the other directions, which were paired with distractors.

While the results are at odds with the passive learning hypothesis as well as the focused attention hypothesis, they are consistent with classic
conditioning data, in which arbitrary features are learned when paired with rewarding or noxious stimuli. We propose a model in which diffuse reinforcement learning signals perform an important role, complementary to focused attention, in subliminal perceptual learning. In reinforcement learning a reward signal allows the correlation of the neural response with task performance to be learned. In contrast, focused attention allows knowledge to bias the neural response and involves cortical processing.

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TA178
Perceptual learning after a nap: The Mini-Me of Sleep Sara C. Mednick1, Ken Nakayama2, Robert Stickgold2;
1Psychology Department, Harvard University, USA, 2Harvard Medical School, Harvard University – Learning on a variety of perceptual and motor tasks requires a night’s sleep. In the present research we add a new dimension to our understanding of sleep-dependent learning by demonstrating a special role for daytime napping. We have previously shown that repeated, within-day testing on a texture discrimination task (TDT) (without sleep) produced retinotopically specific deterioration in performance; but an hour nap restored performance to baseline for two subsequent testing sessions. In the current study, we investigated two questions: 1) Whether deterioration accumulates over the inter-test interval or from stimulus exposure during testing; 2) Whether longer naps that include both slow wave sleep (SWS) and rapid eye movement (REM) sleep produce improvement beyond baseline performance. All subjects performed the TDT in the morning and evening of day one (tests 1 & 2), and once the following morning (test 3). Some subjects took a nap with EEG recording (60 – 100min) between tests 1 and 2. In the non-nappers, we found that performance deteriorated similarly when tests were separated by 8hrs as by 2hrs. Thus, stimulus exposure rather than inter-test interval produces TDT deterioration. In the nappers, we found significant TDT learning and the learning was significantly correlated with the product of SWS & REM durations in the nap. Our findings demonstrate that a daytime nap containing both SWS and REM is effective for task-specific learning, similar to findings for nocturnal sleep-dependent learning. Further, without a daytime nap, visual discrimination deteriorates with repeated exposure to a stimulus.

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TA180
Comparing the temporal dynamics of intra- and cross-modal attention switching. Luis A Lesmes1 (lulesmes@hotmail.com), Zhong-Lin Lu2, Barbara A Dosher2, George Sperling2; 1Laboratory of Brain Processes (LOBES), Univ. of Southern Calif. USA, 2Dept. of Cog. Sci., Univ. of Calif., Irvine – The time courses of attention switching between and within auditory and visual modalities were measured with a sensitive attention reaction time paradigm based on rapid serial presentation (1). In each trial, one digit stream and one letter stream were presented at 6 items/s. Observers identified a cue stimulus (2 or 9) embedded in a digit stream, switched to a letter stream, and then reported the following 4 letters and the identity of the cue. In intra-modal visual to visual (VV) and auditory to auditory (AA) conditions, the streams were presented at different foveal locations or in different ears. In cross-modal visual to auditory (VA) or auditory to visual (AV) conditions, the cue was in one modality and the letters in the other. Payoffs encouraged the report of early letters following the digit cue. The time course of switching is measured by the probabilities of reporting items in particular locations. For the cross-modal conditions, the report began with items simultaneous with the cue. In the intra-modal conditions, the report began with items immediately following the cue, but rarely included the simultaneous item. This time-course advantage for cross-modal relative to intra-modal switching is reflected in the medians of the temporal location of the items reported: 91 ms for VA and 125 ms for AV; 320 ms for VV and 305 ms for AA. We conclude that attention switching between two sensory modalities is approximately 200 ms faster than attention switching within a single sensory modality. A reanalysis of the data in terms of stimulus position relative to the first-reported item, effectively compensating for the overall temporal shift of the whole response ensemble, reveals that although cross-modal cuing is faster than intra-modal cuing, the full report distributions can be accounted for by a single attention gate which opens with different delay distributions.


Acknowledgment: Supported by AFOSR
Rapid visual search during slow attentional shifts

Todd S Horowitz1,2, (todd@search.beth.harvard.edu), Randall S Birdrond1, Jeremy M Wolfe1,2, 1Brigham & Women’s Hospital, 2Harvard Medical School, United States—We had observers perform an attentional gating task (Shift & Sperling, 2002) that required them to monitor a central 9.4 Hz RSVP stream for a cue digit. The identity of the digit instructed them to shift attention to one of two flanking streams and report the first letter they saw in that second stream. Attentional reaction time (ART) was defined as the interval between the cue and the reported letter. The average ART was 443 ms. We assume that observers attend to the cue stream, then make a voluntary attentional shift to the flanking stream. Are other attentional resources available during this shift? We assessed this by presenting a brief visual search task sometime during the gating task. Assuming a unitary spatial attention resource, one would predict that search performance would be severely impaired during the shift from one stream to the other. The search task required observers to report whether or not a target was present among distracting letters in a 4-item array. The search array was presented at the same eccentricity as the flanking RSVP streams for 107 ms and then masked. The SOA between the cue in the central RSVP stream and the search array varied from -427 ms to 427 ms. There was no dual-task cost on the attentional gating task. Search d’ was reduced in the dual task case relative to a single task control condition. Is this a simple dual-task cost or interference between attentional gating and search? The critical search trials are those that appear after the cue digit but before the reported letter in the flanking stream (0 < SOA < ART). We compared performance on these critical trials to control trials where the search task appeared either before the cue digit (SOA < 0) or after the reported flankng stream letter (SOA > ART). Search during the attentional shift (d’ = 1.20) was not impaired relative to control (d’ = 1.13). We conclude that it is possible to perform visual search while concurrently executing a volitional shift of attention.

Acknowledgment: Supported by AFOSR

The temporal dynamics of attention in a spatial cueing task revealed by classification movies

Kelly Y Chen (chen@psych.ucla.edu), Miguel P Eckstein, Steven S Shimozaki; Department of Psychology, UC Santa Barbara, LIS – Behavioral studies using reports of target items after a cue from a rapidly presented stream of potential targets (i.e., RSVP, Weichselgartner & Sperling, 1987) and studies measuring event related potentials (ERP, Hillyard et al, 1998) both indicate a time course of attentional gating of about 100 ms. In the present study, the temporal dynamics of attentional shifts to a peripheral cued location were examined in a contrast discrimination task. In particular we assess the earliest time from cue onset in which information can be used at the attended location. We estimate this use of information by the spatiotemporal analog of the classification image technique (classification movie, Xing and Ahumada, 2002). Methods: Two observers had to detect the presence of a Gaussian (stddev= 8.2 min) contrast increment (yes/no task; 50% probability of target presence) embedded in a temporal sequence of independent frames of spatially uncorrelated noise (frame rate= 401/s) displayed for 450 ms. The target was randomly located in one of eight locations equidistant from fixation at an eccentricity of 4.6 deg. A 100% valid simultaneous cue indicated the probable location of the target. The noise fields at the cued location on the signal absent trials (false alarms and correct rejections) were used to estimate the spatial perceptual filters of the observer at the cued location at different temporal intervals from cue onset (classification movies). Results: Observers showed significant estimated perceptual filters at the cued location within 25-50 ms. Conclusions: Our results suggest the use of information at an attended location begins 25 to 50 ms after a peripheral cue to shift attention, earlier than estimates from previous studies.

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Detecting patterns of covert attention shifts in psychophysical tasks using microsaccades

Ziad M Hafed (zhafed@cim.mcgill.ca), James J Clark; Center for Intelligent Machines, McGill University, Canada—When a person’s gaze is fixed, his attention can shift covertly about the visual field. In a recent paper (Hafed and Clark, 2002), we proposed a direct measure of covert attention, one based on the detection and analysis of microsaccades. Here we show how this measure can allow us to uncover new patterns of covert attention shifts that are unobservable using current approaches. We ran a simple task in which trials consisted of the onset of a peripheral stimulus 17 deg to the right or left of fixation followed by a foveal stimulus. All stimuli were 2.5 deg in size, and their colors were red, yellow, green, or blue. The stimulus onset asynchrony between the peripheral and foveal stimuli was randomly chosen from among 0, 50, 100, 150, & 500 ms. Subjects were instructed to maintain fixation and to make speeded same/different judgments on the colors of the peripheral and foveal stimuli. Eye movements were monitored, and microsaccade detection and analysis were as in (Hafed & Clark, 2002). We observed the occurrence of three epochs of ‘microsaccadic responses’ (and therefore of ‘attention shifts’) in our task: one related to peripheral events, one related to foveal events, and one related to response execution. In particular, microsaccade analysis revealed attention shifts to the peripheral stimulus and back after this stimulus’ onset, followed by attention shifts to the peripheral stimulus and back after the foveal stimulus’ onset, followed finally by an attention shift to the peripheral stimulus that was tightly synchronized with manual response execution. This final shift is hard to uncover using current approaches. We conclude that the accessibility to covert attention shifts that microsaccade analysis allows has tremendous implications on the study of how humans employ covert attention when interacting with their visual environment.


Acknowledgment: Supported by NSERC, Canada and IRIS, Canada

A linear cue combination framework for understanding selective attention

Richard F Murray (murray@mail.cps.utexas.edu), Allison B Sekuler2, Patrick J Bennett2; 2Center for Perceptual Systems, University of Texas at Austin, U.S.A. 2Department of Psychology, McMaster University, Canada—We can base visual judgements on selected parts of a scene, and ignore other parts. This ability is called selective visual attention. Sometimes selective attention is imperfect, which raises the question of how attended and unattended stimulus elements together determine observers’ responses, and the related question of how to measure intermediate degrees of selective attention. Using a linear cue combination framework, we develop a measure of selective attention, *attentional weight*, that describes the relative weight observers assign to attended and unattended stimulus elements. We describe a method for measuring attentional weight by measuring the correlation between the strength of attended and unattended elements and observers’ responses. We use this method to test whether observers can direct selective attention according to contrast polarity when judging global direction of motion or global orientation. We find that when observers try to judge the global direction or orientation of black or white stimulus elements, their responses are influenced by elements of the opposite contrast polarity. The attentional weight assigned to opposite-polarity distractors is typically 65% of the weight assigned to targets in the motion task, and 25% in the orientation task. Thus observers have only a limited ability to direct attention according to contrast polarity. Finally, we test a key assumption of the cue combination approach, namely that selectivity is the same for attended and unattended elements, and that observers simply assign less weight to unattended elements. We do this by using reverse correlation to measure directional selectivity for attended and unattended motion signals in random dot cinematograms. We find that selectivity is the same.
Perceptual binding of letters into words is low temporal resolution

Alex O Holcombe (holcombe@post.harvard.edu); University of California San Diego, USA — For cases such as stereodepth, edges, and motion direction, our percepts afford conscious access to high temporal frequency information. For example, percepts of motion direction are accurate even for gratings drifting at 20 Hz- indicating the binding of information from intervals of less than 50 msec. But other judgements, such as which spatially separated colors and orientation are presented simultaneously, are only accurate at slower than 5 Hz (Holcombe & Cavanagh 2001). Why the difference? Investigation of the perception of words should help decide between competing theories. Words are identified late in visual processing, leading one theory to predict temporal resolution will be low. Yet we have lifelong experience with processing words in rapid series, leading another theory to predict temporal resolution will be high.

METHODS: To measure the temporal resolution of binding letters into words, in each trial two four-letter strings alternated in the same location for several cycles. Observers discriminated between two pairs of letters strings which were indistinguishable at high temporal frequencies, e.g. observers discriminated (2AFCh) "tank" alternating with "mope" from "tape" alternating with "monk". For successful performance, observers had to bind the letters presented simultaneously (forming a word).

RESULTS: Temporal frequency thresholds were remarkably poor for each subject, ranging from 5 Hz (100 ms/word) to as low as 2 Hz (250 ms/word). Binding letters into strings which were not words yielded even slower thresholds.

CONCLUSIONS: The low temporal resolution of binding letters into words indicates that decades of training is not sufficient for high-resolution access to stimulus information. Instead, conscious access to high temporal frequencies may be limited to those cases where a visual mechanism turns rapidly changing information (e.g. stimulation from rapidly drifting gratings) into a constant percept (e.g. motion direction or depth).

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http://www.psych.utoronto.ca/~richard
perceiving temporal events.

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TA188
Attentive tracking can modulate the illusory misalignment of a flash
Won Mok Shim (wshim@wjh.harvard.edu), Patrick Cavanagh; Harvard University, USA—Purpose: The perceived position of a static flash can be shifted by nearby motion (flash-shift: Whitney & Cavanagh, 2000) but the role of attention in the flash-shift effect has not been explored. To investigate whether attention drawn to a moving, tracked stimulus can modulate the position information of static objects, the perceived misalignment of a flash was measured while the offset between the attentively tracked stimulus and the flash was varied. Methods: Subjects were instructed to attentively track a pair of stimulus bars (dark bars) of the rotating radial grating (a twelve-cycle sinusoidal luminance grating), indicated by a pointer. The pointer rotated with the target pair for 667ms and subjects continued to track the indicated bars with attention after the pointer disappeared. A further 833ms later, two horizontal lines were briefly flashed adjacent to the grating at the 3 and 9 o’clock positions. The perceived misalignment of two flashes was measured as a function of the angular position of the tracked bars at the moment of the flashes. At the moment of the flash, the radial grating was always at the same orientation (light bars aligned with vertical and horizontal) and the location of the tracked bar was an integer number of cycles of the grating away from the flash (2- to +2). Results: When the test flashes were presented before the tracked bars had reached their location, the two flashes showed a misalignment in the direction of the motion of the grating. However, when the flashes were presented after the tracked bars had passed their location, the illusory displacement was considerably reduced or reversed. Conclusion: Even though the moving stimulus was physically identical for each of the offsets between the tracked bar and the test, the perceived position of the tests depended on the locus of attention. This result shows that attention to a moving stimulus can influence the perceived position of a nearby, briefly presented stationary object.

TA189
Motion-biasing, not asynchronous feature binding, explains the feature-flash drag effect
David M Eagleman (dmeagleman@wjh.harvard.edu), Terrence J Sejnowski; The Salk Institute, CA, USA—Cai and Schlag [VSS 2001] demonstrated that a flashed feature of a moving object—say, a translating bar that flashes blue for one frame—is mislocalized to a later point in the trajectory. If the bar changes height as it moves, then the blueeness appears to fill the height of a bar further along the trajectory. They suggested the illusion results from asynchronous feature binding (AFB), i.e., the flashed color change is “delayed and assigned to a later occurring bar” [Cai & Cavanagh, VSS 2002]. Our evidence speaks against an AFB explanation, suggesting instead that motion signals drag the position judgments of the feature-flashed bar (causing ‘feature-flash drag’). To distinguish between the AFB and motion-biasing models, we presented the illusion with fewer apparent-motion stations: the bar completes its trajectory in the same amount of time, but with fewer appearances. Here, the blue bar appears shifted to a location where no bar was presented. This speaks against AFB, which predicts the assignment of blue to a later appearance of the bar. Cai & Cavanagh suggested that positions of the moving object may be interpolated before AFB; however, our alternative hypothesis of motion-biasing may account for more data (ref. Whitney, 2002). Next, 5s counted the number of white bars that appeared after the blue bar. In the AFB model, blueeness assigned to a later bar should cause 5s to undercount. However, 5s counted veridically, supporting the motion-biasing model. Lastly, the blue bar is seen at intermediate heights that never actually occurred (also shown by Cai & Cavanagh). We suggest that motion signals may be applied differentially to the individual edges of an object (here, the top and bottom edges of a growing bar move orthogonally to the bar’s translation). Instead of asynchronous perception, this illusion may demonstrate the generality of motion biasing and offer a unified explanation for flash-lag and flash-drag effects.

http://www.cnl.salk.edu/~eagleman/flashdrag

TA190
Distorting time with motion
Derek H Arnold (derek.arnold@ucl.ac.uk), Colin W.G. Clifford, Alan Johnston; 1University College London, UK., 2School of Psychology, The University of Sydney, Australia—It is possible that the time course of perceptual experience is not be determined by the time course of neural activity, but by an interpretive process that corrects for the inherent temporal ambiguities of sensory processing. We examined this possibility by manipulating a low-level stimulus attribute designed to influence sensory processing in a characteristic fashion. When successively presented opponent directions of motion were contrasted, the second interval of motion needed to be longer than the first to be perceived as being of the same duration. This asymmetry was reversed when the angular difference between the successive directions was reduced to 90°. This suggests that the inherent dynamics of sensory processing can perturb our sense of timing. Therefore, our results suggest that any interpretive analysis that is causally involved in the production of perceptual experience may be subject to the temporal limitations of the sensory processing on which it is based.

Object Recognition

Wednesday, May 14, 2003
10:45 am – 12:30 pm
North Hall

Moderator: Isabel Gauthier

10:45 Kourtzi, Tolias, Altman, Augath, Logothetis, TA191
11:00 Zago, Bar, TA192
11:15 O’Toole, Haxby, Abdi, TA193
11:30 Wang, Yen, Wang, TA194
11:45 Zhu, von der Malsburg, TA195
12:00 Torralba, Oliva, Freeman, TA196
12:15 James, Gauthier, TA197

TA191
Integration of local features into global shapes: monkey and human fMRI studies
Zoe Kourtzi (zoe.kourtzi@tuebingen.mpg.de), Andreas S Tolias, Christian F Altman, Marc Augath, Nikos K Logothetis; Max Planck Institute, Tuebingen, Germany—The perception of global visual shapes entails the integration of local image features into global configurations. Traditionally, the visual system is thought to be hierarchically organized in early visual areas (V1, V2, V3, V4) that are involved in the analysis of simple local features and higher visual areas (regions in the inferotemporal cortex) that are implicated in the processing of complex global shapes. We investigated the integration of local image features into global shapes across visual areas in the monkey and the human brain using fMRI. An adaptation paradigm was used, in which stimulus selectivity was deduced by changes in the course of adaptation of a pattern of randomly oriented elements. Accordingly, we observed stronger activity after adaptation when orientation changes in the adapting stimulus resulted in a collinear shape than a different random pattern. This selectivity to collinear shapes was observed not only in higher visual areas, but also in early visual areas where selectivity depended on the receptive field size. These findings suggest that unified
shape perception in both monkeys and humans involves multiple visual areas that may integrate local elements to global shapes at different spatial scales.

Acknowledgment: Mac Planck Society

TA192
THE RISE AND FALL OF VISUAL PRIMING
Laure Zago (zago@nrr.mgh.harvard.edu), Moshe Bar; NMR Center at MGH, Harvard Medical School, Charlestown, MA, USA—Seeing a picture of an object primes its cortical representation and consequently facilitates its recognition in later encounters. Such priming has been linked to the physiological finding that repeated stimuli elicit relatively reduced activation. By showing that the behavioral development of priming under various conditions correlates with the dynamic of fMRI signal change, we provide a critical support for this link.

Twelve subjects participated in this study. Objects appeared first for one of six possible durations (40, 150, 250, 350, 500 or 1900ms), followed by a mask and a blank interval (total 2000ms). All stimuli were presented once again in subsequent blocks for a fixed duration of 500ms each. Subjects were required to decide whether each of the individual objects was natural or man-made. Repetition priming (measured by difference in reaction time between recognizing repeated and novel objects) and repetition suppression (measured by the corresponding reduction in fMRI signal) peaked by 150-250ms from stimulus onset.

An intuitive prediction would be that an increased presentation duration in the first encounter will result in an increased, or at least an equal amount of priming. However, our findings indicate that presenting the stimulus for a longer duration did not contribute further to these effects, but rather resulted in less priming and less repetition suppression. In other words, objects that were initially presented for 350–1900ms showed significantly less priming and less signal reduction compared with objects that were initially presented for 150-250ms. We will discuss the implications of these findings on our understanding of long-term object representations and the possible effect of top-down processes on efficient coding of visual information.

Acknowledgment: Supported by the James S. McDonnell Foundation-21st Century Science Research Award #21002039 (to MB)

TA193
Classification-based approaches to the analysis of functional neuroimaging data on face and object perception
Alice J O’Toole1 (otoole@utdallas.edu), James V Haxby2, Hervé Abdi3, 1The University of Texas at Dallas, USA, 2Princeton University, USA—The analysis of functional neuroimaging data relies primarily on inferential statistics such as analysis of variance to detect differences in brain voxel activations as a function of experimental condition. These analyses, however, do not answer an important question: “How reliably do patterns of brain activation indicate the task in which the brain is engaged or the stimulus being processed by the subject?” Recent work shows the utility of refocusing the analysis on patterns of activation (Carlson et al., 2001). We applied classification analyses to fMRI data from Haxby et al., (2001) to measure the discriminability of brain activation patterns resulting from viewing different kinds of objects (e.g., faces, houses). Principal component analysis was used to derive a basis set from a subset of the brain scans, using ventral temporal voxels that differed significantly for objects in the inferential analyses. Individual scans were coded via their projections in the derived space. The utility of individual principal components (PCs) for separating object classes was assessed by discriminant analysis of the individual scan projections. All analyses used generalized classification tests in which odd/even runs of scans served alternatively as training/test scans. We computed d’s for discriminating face versus object scans from 7 categories. We found that single PCs discriminated between faces and the object categories, with d’s for the best PCs ranging from .91 to 1.64. An interesting aspect of this finding is that orthogonal patterns of activation discriminated face versus object categories with high accuracy. Thus, more than one kind of pattern can discriminate between categories. An advantage of this analysis is that the patterns of activity most useful for separating the object categories can be mapped back onto structural scans and interpreted as brain images.

Acknowledgment: This project was supported in part by a grant from ONR to A.OT.

TA194
Reading word “airplane” is seeing object “airplane” in the right cerebral hemisphere: The effect of object contour diagnosticity on within-modal and cross-modal priming
Linyu L. Wang1 (lenowellwang.tw@yahoo.com.tw), Nai-Shing Yen1, Man-Ying Wang2, 1Department of Psychology, National Chengchi University, Taiwan, 2Department of Psychology, Soochow University, Taiwan—Within-modal priming (e.g., naming picture “bus” primes naming picture “bus”, P-P priming) is always found to be substantially larger than cross-modal priming (e.g., reading word “bus” primes naming picture “bus”, W-P priming). In the present study, we manipulated “global diagnosticity” of object contour to examined whether P-P priming is always larger than W-P priming. We found P-P priming is equivalent to W-P priming on “globally diagnostic” (GD) objects, but the P-P priming is still larger than W-P priming on “globally non-diagnostic” (GN) objects. This phenomenon appeared on both picture-naming (Experiment 1) and perceptual-identification (Experiment 2) tasks. Better explicit (conscious) memory performance (recognition memory) in P-P condition than in W-P condition showed that equivalent priming across P-P and W-P conditions on GD objects was dissociated from the influence of conscious recognition memory. Experiment 3 found equivalent P-P priming and W-P priming appeared only when GD objects in the test phase were presented to the right cerebral hemisphere (in the left visual field). These results suggest that reading names of globally diagnostic objects can access the representation or essential features of globally diagnostic objects, and right cerebral hemisphere might be responsible for the processing.


TA195
Object recognition by Dynamic Link Matching in biologically realistic time
Junmei Zhu1 (junmeizhu@organic.usc.edu), Christoph von der Malsburg1,2, 1Computer Science Department, University of Southern California, USA, 2Institut für Neuroinformatik, Ruhr-University Bochum, Germany—Object recognition invariant to translation or scale is effortless for humans, but computationally very difficult. Many algorithms have been developed, most of which do not work well in real environments, lacking the ability to handle situations not programmed explicitly. In contrast to this algorithmic schema, a better way to understanding brain and vision is to start from basic self-organization principles, and let the system create optimal algorithms itself, through adaptations to its environment. This organic computing schema has been demonstrated in a very successful face recognition system by Dynamic Link Matching (DLM), a recognition method based on self-organization of a 1:1 mapping between corresponding points in an image and a model. Dynamic links are rapidly switching synapses whose dynamics are controlled by cooperation from neighboring synapses. However, DLM is too slow as it needs thousands of iterations. Here we extend DLM by allowing system dynamics, specifically cooperative strengths, to change as a function of local transformations between image and model, estimated from the system state. The adapted system converges much faster to a stable state because of more specific and longer range cooperation. This change is mediated by control units, groups of synapses consistent with each other in terms of transformation parameters. They represent synaptic arrangements that, once acquired, can apply to any object. We also showed they can be learned from experience. A face recognition system based on this extension of DLM is...
shown to be much faster and can deal with scale and in-plane rotation in addition to shift without much extra cost. The recognized model is picked already after 3 iterations as the one with the best similarity points linked in the mapping. Recognition rate on 110 rotated faces against 110 frontal ones is 93%, as compared to 66.4% in the original DLM on the same database (Wiskott & Malsburg 1996).

Acknowledgment: We gratefully acknowledge support by ARO-WASSP under contract DAAD19-00-1-0356

TA196
Object recognition by scene alignment Antonio Torralba (torralba@ai.mit.edu), Aude Oliva, William T. Freeman; 1Massachusetts Institute of Technology, Artificial Intelligence Laboratory, USA, 2Department of Psychology, Cognitive Science Program, Michigan State – Object representations (geometric models, component based descriptions, view based representations, etc.) pay little or no attention to contextual features. Traditional approaches in object detection and recognition in computer vision consider an image as a collection of patches or regions that have to be classified. These techniques can be very fragile and slow, requiring exhaustive scanning of the image (in location and scale) and each object is recognized independently. Contextual information is known to have a big influence in object recognition by humans. The identification of scene views will provide strong priors for object identities, locations and points of views. Even in unfamiliar environments, the categorization of a scene (a street, an indoor, etc.) will constrain the presence and location of objects in the image. We show that scene features (obtained by pooling low-level features across the whole image) can be use to prime the presence/absence of objects in the scene and to predict their location, scale and appearance before exploring the image. We show how global image features can predict with 80% accuracy the presence/absence of animals and people in scenes without applying object detection mechanisms. In this scheme, visual context information is used early in the visual processing chain, in order to provide an efficient short cut for object detection and recognition.

TA197
fMRI studies of multi-modal semantic knowledge using artificial concepts Thomas W James (tom.james@vanderbilt.edu), Isabel Gauthier; Psychology Department, Vanderbilt University, USA – Recent findings suggest that semantic memories may be stored in multiple modalities, as opposed to being stored using an amodal code. Furthermore, these findings suggest that semantics from different modalities may be stored in modality-specific processing regions of the cortex. We tested these ideas using novel objects and artificial concepts. Objects were divided into sets of four and were all highly visually similar, biological looking, and three-dimensional. Artificial concepts were triads of semantic features (presented as words) from the auditory (AUD) modality (e.g. howls, squeals, etc.), the tactile (TAC) modality (e.g. hard, cold, etc.), or a combination (SEM) of modalities (e.g. noisy, soft, friendly, etc.). Objects and artificial concepts were associated during two one-hour training sessions prior to scanning. During scanning, participants performed a simultaneous match task, a task that could be performed using only the information in the visual images, and without explicit reference to the trained concepts. As expected, objects in the AUD condition produced more activation along the superior temporal gyrus than objects in a NON-trained condition. TAC objects produced less activation in parietal and occipital cortex than NON objects. One speculation is that the TAC concepts actually interfered with visual processing, because they invoked associated visual features that were incongruent with the visual stimulus. SEM objects produced more activation in the inferior frontal and fusiform gyrus compared to a name-only condition and the NON condition. In conclusion, associating artificial concepts with novel objects produced activation in similar regions to those found with familiar objects, despite the fact that associations were developed over a short time period, and the test task was implicit. These regions respond in a modality-specific manner and they are found near modality-specific perceptual processing regions.

Acknowledgment: Supported by NSF and JSMF grants to IG and CIHR fellowship to TWJ

Motion 2

Wednesday, May 14, 2003
10:45 am – 12:30 pm
South Hall
Moderator: Lynne Kiorpes

TA198
Single neuron sensitivity for a fine motion discrimination task Gopathy Purushothaman, Bradley, TA198
10:45

Liu, Newsome, TA199
11:00

Krekelberg, Dobkins, Albright, TA200
11:15

Bair, Movshon, TA201
11:30

Ruppertsberg, Waerger, Bertamini, TA202
11:45

Dobkins, Fine, Hsueh, Vitten, TA203
12:00

Kiorpes, Movshon, TA204
12:15

Single neuron sensitivity for a fine motion discrimination task Gopathy Purushothaman (gopathy@uchicago.edu), David C Bradley; Department of Psychology, University of Chicago, Chicago, IL U.S.A – AIM: The primate visual system is capable of discriminating minute differences (1-2 deg) in motion directions. Neural mechanisms underlying this acute psychophysical ability are unknown. The aim of this study was to determine whether single neurons can mediate such perceptual decisions. METHODS: A rhesus monkey was trained to fixate a central dot while a reference RDK with upward-moving dots was presented. After a brief interval, a similar RDK moving in a direction 0.25-3 deg offset to one side of the reference was presented. The monkey indicated the side of the offset. Thresholds were estimated at 80% levels on the psychometric function. Responses of single MT neurons of various preferred directions were recorded for reference and test stimuli whose location, size and speed matched those of the RFs. Thresholds were estimated at 80% levels on the neurometric functions.

RESULTS: Most neurons (37/59) had a threshold 10-100 times the psychophysical threshold. The “best” neural threshold obtained (2/59) was 4 times the behavioral threshold. The mean threshold of 59 neurons was 35.7 deg and the mean psychophysical threshold (n=11) 1.8 deg.

CONCLUSIONS: Previous studies reported motion detection thresholds of single MT neurons to be similar to psychophysical thresholds for discriminating opposite directions [Newsome et al, 1989] indicating that broad pooling may result from anatomically coarse read-out mechanisms [Shadlen et al, 1996]. This study, using a fine discrimination task, showed motion discrimination thresholds of single MT neurons are significantly higher than psychophysical discrimination thresholds and established a functional necessity for broad pooling.

Acknowledgment: Supported by NIH grant R01-EY13138

TA199
Correlation between MT activity and behavioral judgment of visual speed in macaque monkeys Jing Liu (jingliu@stanford.edu), William T Newsome; HHMI and Dept. Neurobiology, Stanford University, Stanford,CA, USA – The middle temporal area (MT) has been implicated in the visual perception of the speed of moving objects. MT of macaque monkeys contains neurons tuned for the speed of moving stimuli, and monkeys with MT lesions exhibit impaired speed perception. The human
homolog of MT exhibits elevated activity when human subjects perform speed-related tasks, as revealed in imaging studies. In this study, we investigated whether fluctuations in MT activity correlate with a monkey's judgments of speed on a trial-to-trial basis.

We trained two monkeys to perform a fine speed discrimination task. During each trial, the monkey fixated on a central spot while viewing peripherally moving random dots in two apertures symmetric around the fixation point. Dots within each aperture moved at the same direction and speed, but the two groups of dots differed slightly in their speeds. At the end of each trial, the monkey had to make a saccade to the aperture containing the faster dots. We positioned one aperture within the MT receptive field and recorded multi-unit responses as the monkey performed the task. Using methods based in signal detection theory, we computed a 'choice probability' for each site. The distribution of choice probabilities shows that the trial-to-trial fluctuations of neural activity in MT are correlated with perceptual judgments of speed. In other words, by monitoring the activity of MT neurons, one can predict with greater than chance probability the monkey's speed judgment on individual trials. This finding strongly implies that MT contributes to the monkey's perceptual decisions on speed. A comparison of neurometric and psychometric thresholds revealed, however, that MT multi-units are generally less sensitive to small speed differences than are the monkey psychophysically. Pooling may be necessary to account for psychophysical sensitivity. We have been unable to bias speed judgments using electrical microstimulation, presumably due to a lack of speed columns in MT.

**TA200**

**Fourier motion energy analysis in macaque MT**

Bart Krekelberg\(^1\)

(bart@salk.edu), Karen Dobkins\(^2\), Thomas D Albright\(^1\); \(^1\)Vision Center Lab, The Salk Institute, USA, \(^2\)Dept. Psychology, University of California San Diego, USA.

There is convincing evidence that neurons in the medial temporal area of the macaque are involved in, even responsible for, the analysis and perception of motion. The underlying mechanisms, however, remain unclear. In psychophysical and computational studies, the reverse-phi phenomenon has been used as an argument in favour of Fourier energy models: when a rightward stepping bar reverses its contrast sign on every step, it is perceived to move to the left. This is interpreted as an argument in favour of energy models, because the contrast-reversal introduces Fourier components that move in the reverse direction. We applied this logic to individual MT cells to determine to what extent they can be considered Fourier energy detectors. We recorded from 81 MT cells in three monkeys that fixated a central dot while a phi or reverse-phi sine-wave grating was positioned in the cell's receptive field. Consistent with a Fourier energy model, the majority of cells reversed their preferred direction for the reverse-phi stimulus. We then recorded from a monkey that was rewarded for reporting the phi direction of motion for phi motion, and rewarded randomly on interleaved trials with reverse-phi motion. Both types of trials used quarter duty-cycle, square wave gratings. The monkey's behaviour differences in reverse-phi trials were predominantly in the reverse-phi direction, suggesting that his perceptual experience was similar to that of human subjects. ROC analysis of the neural responses recorded from 50 MT cells in this monkey showed that an ideal observer using these cells would report a reversed direction of motion for reverse-phi stimuli. The trial-by-trial covariation of neural responses and decisions implied that about one-third of the cells were significantly involved in the animal's directional decision process. Taken together, these findings give strong support to the claim that MT cells are well modelled as Fourier motion energy detectors.

**TA201**

**A neural substrate for illusory motion induced by static orientation: responses of complex direction selective neurons in macaque V1**

Wyeth Bair (wyeth@cns.nyu.edu), John Anthony Movshon; Howard Hughes Med. Inst., Center for Neural Science, New York Univ., New York, NY USA. After prolonged viewing of a static, oriented grating (the inducer), illusory motion ensues when gaze is transferred to a blank field: moving particles appear to stream orthogonal to the orientation of the inducer. Explanations of the classical motion aftereffect (MAE, in which motion adaptation induces opposite directed motion) cannot directly apply to a static inducer. Other accounts based on competition between orthogonal orientation channels or based on motion from eye movements are heavily debated. We propose that the illusory motion arises from responses of complex cells to a negative afterimage of the inducer. We recorded extracelllular single unit responses in V1 in anesthetized, paralyzed macaques. We presented static sinusoidal gratings at the optimal orientation, spatial frequency, and size on a mean gray field. Upon removal of a stimulus that lasted 20-40s, most complex cells began to fire at an elevated rate. This after-discharge (AD) decayed over periods varying from ~10ms to several sec. Our critical finding is that direction selective (DS), not just non-DS, complex cells in V1 show AD. Thus, following the removal of a static oriented stimulus, complex DS cells in V1 tuned to motion in both directions orthogonal to the inducer generate a strong output. To account for the AD, we used a phase-independent, oriented complex cell model and assumed that a negative afterimage of the inducer emerged peripherally in the visual system. When an inducer of preferred orientation is removed, its afterimage drives the model complex cell because it has the same orientation as the inducer. The model predicts that the AD is orientation tuned, and preliminary neuronal data support this. We are using our model to explore how DS cells can produce such strong responses to static stimuli. The explanation of illusory motion offered by our model differs from previous accounts because it requires neither eye movements nor competition between orthogonal orientations.

**Acknowledgment:** This work was supported by National Institutes of Health Grant EY02017.

**TA202**

**S-cone input into global motion processing**

Alexa I Ruppertsberg\(^1\)

(a.ruppertsberg@keele.ac.uk), Sophie M Vuerger\(^1\), Marco Bertamini\(^2\); \(^1\)MacKay Institute of Communication and Neuroscience, Keele University, United Kingdom, \(^2\)Department of Psychology, University of Liverpool, United Kingdom. Last year we reported that chromatic global motion extraction in the observer's isoluminant plane appears to be mediated by a red and a green mechanism and that S-cone input in our task was negligible for the majority of observers. We found this by determining the motion discrimination thresholds (81%) as a function of the chromatic contrast in the isoluminant cone-opponent colour-space (S-(M-L) space; isoluminance adjusted for individual observers). We used random dot kinematograms with 300 coloured gaussian blobs (0.22 , 1 /s, 5.1 x 4 , 200cm viewing distance). Observers had to distinguish between an interval with random motion and an interval with 40% of the blobs moving either left or right (2IFC). Experiment 1: To support our results for genuine chromatic input into the motion system we added luminance noise to our stimuli and reran the motion discrimination threshold experiment for various directions in the cone-opponent colour-space and find the same result as without added luminance noise. Experiment 2: We established motion discrimination thresholds for a range of spatial and temporal parameters (stimulus size and velocity: 0.22 + 0.86 , 1 /s + 5 /s) and found that S-cones do contribute to global motion extraction. These experiments were carried out with added luminance noise. S-cone contribution depends not only on the stimulus size (0.86 ) but also on the displacement of the stimuli (1.165 ).

Conclusion: There is a genuine chromatic input to global motion processing. The spatial and temporal parameters for which global motion can be extracted are very similar for luminance and red-green RDK's. Whereas, S-cone input to global motion processing is only effective for relatively large displacements (> 1 ) and large stimulus sizes (ca. 1 ).

This research is supported by the WellcomeTrust.
TALKS

TA203
Infants integrate local motion  Karen R Dobkins (kdobkins@ucsd.edu),
Ione Fine, Annie C Hsueh, Carolin Vitten; Psychology Department, UC San
Diego, USA — PURPOSE: It is not yet clear whether infants integrate
component motions into coherent pattern motion. Though infants track
moving plaids in the pattern direction (Manny & Fern, 1990), this may be
due to tracking the “nodes” of plaid intersections rather than to true
integration of the components. Here, we tested infant motion integration
using component gratings that were spatially separated, and thus did not
contain trackable intersections. METHODS: The control stimulus was a
field of evenly spaced moving grating patches (2 x4 , 0.8 cpd, 80% contrast,
6 /sec). Every patch moved in one of four directions (72 , -72 , 108 or 252 ).
The integration stimulus consisted of grating patches, but two directions
(72 /-72 or 108 /252 ) were presented in an alternating checkerboard
pattern. When integrated, pattern motion for these paired component
motions was 0 (right) or 180 (left) at 20 /sec. Using a directional (left vs.
right) eye movement technique, we compared infants’ ability to track
horizontal pattern motion in the integration stimulus to their ability to
track the horizontal component of oblique motion in the control stimulus.
Integration was computed as the difference in percent correct for
integration and control conditions. For integration to occur requires the
summation area of integrative motion mechanisms to be relatively large
compared to the distribution of the grating patches. RESULTS: Data from
2-, 3-, 4- & 5-month-olds revealed significant integration at all but the
oldest age. Integration decreased consistently and significantly with age
(17%, 19%, 12% & 2%, p<0.03). Adults did not show significant integration.
CONCLUSIONS: By 2 months of age infants integrate local motion signals
into coherent global motion. Given that motion integration is subserved by
area MT, this suggests that human MT is functional by 2 months of age.
The decrease in integration with age implies a reduction in the size of
motion summation areas over the course of development.
Acknowledgment: Supported by NIH Grant EY12153 (KRD)

TA204
Differential development of form and motion perception in
monkeys Lynne Kiorpes1 (lynnec@cns.nyu.edu), J. Anthony Movshon2,1;
1Center for Neural Science, New York University, New York, NY, USA,
2HHMI — Visual acuity and contrast sensitivity develop to adult levels
over the first 6-9 months in macaque monkeys. This developmental period
for basic spatial vision was thought to represent the period over which V1
receptive field structure and local connectivity mature. However, recent
data from our lab show that postnatal neuronal development in V1 is
minimal in comparison to behavioral development. Thus we suggest that
the important limitations on visual performance in infants lie in
extrastriate cortex. Relatively little is known about cortical development
beyond V1. To study extrastriate development we used two tasks that
reflect processing in either the form or motion pathways.
We compared the development of form and motion perception in
individual monkey subjects (Macaca nemestrina). Motion discrimination
was tested by detection of coherent motion in random dot kinematograms.
Form discrimination was tested by detection of coherent organization in
Glass patterns. In each case the monkey’s task was to choose one of a pair
of circular targets that had coherent motion or structure; the comparison
stimulus had random motion or lacked structure. For the form test we
used concentric, or radial, and linear Glass patterns. Contrast sensitivity
functions were measured for comparison. Animals were tested at ages
ranging from 8 weeks to 4 years.
The results show that motion discrimination is demonstrable by 8 weeks,
but develops over an extended time course up to about 3 years of age.
Infants younger than 5-6 months were unable to perform the form
discrimination task, and became adept at much older ages. These
tasks require integration over space and time and develop over extended
time periods compared to contrast sensitivity. We conclude that form
perception develops late in comparison to basic spatial vision and motion
perception. Our results suggest a difference in maturation of dorsal and
ventral stream extrastriate areas.
Acknowledgment: Supported by NIH grants EY05864 and 02017, and
HHMI
Posters Abstracts

**Friday Poster Session:** 3:00 pm – 8:30 pm (Authors present 5:00 – 8:00 pm)

**Saturday Poster Session:** 8:30 am – 8:30 pm (Authors present 5:00 – 7:00 pm)

**Sunday Poster Session:** 8:30 am – 8:30 pm (Authors present 1:30 – 3:30 pm)

**Monday Poster Session:** 8:30 am – 8:30 pm (Authors present 2:30 – 4:30 pm)

**Tuesday Poster Session:** 8:30 am – 8:30 pm (Authors present 2:30 – 4:30 pm)

Posters should be displayed for the entire day, and authors may be present at any time. First authors *should* be present during “Authors present” times. Posters will be posted beginning at 3:00 pm Friday and 8:30 am other days.

For an index by day and topic, see “Daily Poster Topic Index” on page 249.
FR1
Texture regions are more easily detected than texture edges
Francois Xavier Sezikke (fxsezik@vax2.concordia.ca), Rick Gurnsey; Department of Psychology, Concordia University, Montreal, Canada—Purpose: Texture discrimination is widely believed to rely on mechanisms that detect discontinuities within neural images (Landy & Bergen, 1991, Vision Research). An alternative view is that texture discrimination is "region-based" meaning that sensitivity to a texture difference is not significantly affected by the proximity to the two textures involved (e.g., Gurnsey & Laundry, 1992, Canadian Journal of Psychology). To examine this question we compared the relative discriminability of circular and annular texture regions embedded in a larger background textures.
Method: Foreground and background textures comprised filtered noise. The filters have 1.25 octave bandwidths and centre frequencies that ranged from 3.65 cpd to 4.74 cpd in seven equal logarithmic steps. In one condition the foreground frequency was fixed at 3.65 cpd and the frequency of the background texture was varied. In a second case the frequency of the background texture was fixed at 3.65 cpd and the frequency of the foreground texture was varied. The disparate texture was contained within either a circular region or an annular region. The area of disparate texture within the circular region was 35% greater than in the annular region, whereas the annular region had 50% more boundary locations than the circular region. Nine subjects performed a 4AFC in which they were to indicate the location of the disparate region.
Results: Threshold was calculated as the frequency difference that elicited 72% correct responses. Thresholds were significantly lower for circular texture regions than for annular texture regions F(1, 8), p < 0.001. In neither case was there an asymmetry and there was no interaction of region type with foreground/background.
Conclusions: These results suggest an important role region-based processes in texture discrimination. Comparisons of texture properties appear to be performed over relatively large distances and are not restricted to the vicinity of the texture discontinuity.
Acknowledgment: Supported by NSERC and FCAR grants to Rick Gurnsey

FR2
The first conclusive evidence for the existence of energy-based texture mechanisms Nicolas Prins (nicolaas.prins@mcmill.ca), Frederick AA Kingdom; McGill Vision Research Unit, Dept. of Ophthalmology, Montreal, Canada—Two classes of models have been proposed to account for the processing of texture modulations. In one class of model abstract representations such as feature or texton maps are assumed to underlie detection. In the second class of model texture modulations are processed by an energy mechanism which compares the spectral energy within narrow orientation and spatial frequency bands between different texture regions. Our textures contained concurrent modulations of orientation and spatial frequency. Through adaptation we determined the orientation and spatial frequency tuning of the luminance filters involved in their detection. Results indicate that such concurrent modulations in texture are processed jointly by mechanisms that employ luminance filters tuned to orientations and spatial frequencies at which the different texture regions differ most in their spectral energy. These orientations and spatial frequencies do not correspond to those predicted by feature or texton processing models.
Acknowledgment: Supported by NSERC (RGPIN 0121713-01)

FR3
Spatial phase related nonlinearity in alignment of contours Sabin Dang1 (sabindang.com), Bosco S. Tian1, Susana T.L. Chung2; 1University of Southern California, Los Angeles, CA, USA, 2University of Houston, Houston, TX, USA—Neurons involved in early visual processing are often tuned to narrow bands of spatial frequencies. In contrast, important image features such as edges are often broadband, comprising precisely positioned narrow-band components. Merely perturbing the relative positions (i.e. phase) of these components will destroy the image feature. If broadband features are ecologically critical for form perception, then there must exist nonlinear mechanisms that combine the outputs of front-end narrow-band neurons for the detection and discrimination of these features. This study examines the presence of these non-linear mechanisms. We asked observers to detect the misalignment of 2 identical, vertically separated patterns, each windowed by a circular Gaussian, at near-fovea and 5 deg eccentricity. Each pattern in the in-phase condition was a vertical bar with sharp edges. Patterns in the out-of-phase condition were phase-scrambled versions of the in-phase stimuli. An ideal-observer’s alignment threshold for these patterns was the same since their auto-correlation functions were identical. At near-fovea, the two patterns were separated by 1 deg and the in-phase bar width and the space constant of the Gaussian window were 0.1 deg. Stimuli at 5 deg eccentricity were scaled (10x) versions of the foveal stimuli. Averaged alignment threshold for the in-phase condition was 0.03 deg at near-fovea and 0.11 deg at 5 deg eccentricity. Phase-scrambling had little effect on the foveal threshold, but elevated the peripheral threshold by a factor of 2.3. Results were similar when a single edge was used instead of a bar. Our results suggest that contour alignment relies in part on nonlinear broadband mechanisms for
sharp edges. We speculate that in the fovea, a dense array of different nonlinear broadband mechanisms may form a complete basis set, allowing an effectively linear representation of the input; whereas in the periphery, sparse placement of these mechanisms "unlocks" their nonlinearity.

**Acknowledgment:** Supported by: USC Zumberge Grant & USC Undergraduate Research Grant to Tjan; NIH grant EY12810 to Chung.

FR4

A psychophysical test of the saliency map in V1

Li Zhaoping

School of Psychology, Cardiff University, UK – It has been observed (Snowden J. Exp. Psychol. 1998) that although random variations in colour of the stimulus bars does not disrupt visual search for a target bar defined by its unique orientation among distractor bars of a different orientation, it does impair texture segmentation between textures each defined by a uniform orientation of texture bars. These observations can be accounted for by the proposal that V1 produces a saliency map, as demonstrated by a V1 model (Zhaoping, Soc. Neurosci. abstract, 2002). The ease of the task is determined by the saliency of the target or the texture border, which in turn is determined by the evoked V1 responses subject to contextual influences from the contextual bars. Random colour variations affect performances by altering the contextual influences via intra-cortical interactions. The model predicts that the colour interference on the texture segmentation defined by orientation should become more pronounced as the stimulus bars become thicker and shorter. To test this prediction, subjects reported the orientation, either vertical or horizontal, of an elongated target texture region defined by an area of 2x8 bars that differed in orientation by 90 degrees from the background texture bars. The texture bars were either all fat or all thin. The two cases were equated such that the fat bars were twice as fat as the thin bars which were in turn twice as long. The reaction times of the subjects were measured, and as expected, they were longer with than without the random colour variations of the texture bars. This reaction time increment was used as a measure of the colour interference. The results showed that the fat texture bars resulted in at least a 65% increase in colour interference relative to the case with the thin bars. These results are consistent with the model prediction and thus support the proposal of a saliency map from V1.

**Acknowledgment:** Zhaoping is supported by the Gatsby Foundation.

FR5

Interaction of first-order and isodipole statistics in a texture segregation task

Jonathan D Victor, Mary M Conte, Charles F Chubb, Well Medical College of Cornell University, USA, University of California at Irvine, USA – Image statistics are often classified as first-order (e.g., luminance), second-order (e.g., contrast, autocorrelation, power spectrum) and high-order (e.g., fourth-order isodipole). Many studies of visual texture processing have considered texture discrimination based on one kind of image statistic, but few have examined how these statistics interact.

To examine the interaction of isodipole statistics and luminance statistics, we construct a novel two-dimensional space of binary textures. One axis in this space, gamma, specifies the bias in luminance statistics (gamma=1 for white, 0 for all white, 0 for a 50:50 mix, -1 for all black). The second axis, alpha, specifies the bias in local fourth-order statistics (alpha=1 for the "even" texture, -1 for the "odd" texture). Long-range statistics and statistics of other orders are determined by maximizing entropy. This uniquely defines the textures in terms of alpha and gamma (within a defined range), and thus generates a two-parameter perceptual space.

We examined the ability of subjects (N=2) to segregate textures with specified structure (alpha and/or gamma nonzero) from a fully random texture (alpha=0, gamma=0) in a 4-AFC paradigm. For subject CC, similar Weibull functions (shape parameter 2) provided good fits to the data along the luminance and fourth-order axes in this space. Sensitivity along the luminance axis was approximately four times the sensitivity along the fourth-order axis. For subject MC, sensitivities to the two statistics were in similar ratio, but Weibull functions along the fourth-order (alpha) axis were substantially steeper (shape parameter 4) than along the luminance (gamma) axis (shape parameter of 2).

Along oblique directions, performance of both subjects was significantly less than predicted by probability summation. For subject CC but not MC, performance was also significantly less than predicted by a Euclidean geometry within this texture space.

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FR6

The temporal impulse response function during smooth pursuit

Harold E. Bedell (HBedell@Optometry.uh.edu), Malakhalsh Ramamurthy, Saumil S. Patel, Lan-Phuong Vu-Yu, College of Optometry, University of Houston, TX, USA, College of Optometry, University of Houston, TX, USA, College of Engineering & CNES, University of Houston, TX, USA – PURPOSE. Human observers report that the extent of perceived motion smear is less during smooth pursuit than when comparable motion of the retinal image occurs during steady fixation. We asked if this reduction of perceived motion smear is attributable to an increase in the speed of the temporal impulse response during pursuit eye movements, as reported previously to occur during saccades (Burr & Morrone, 1996).

METHODS. Increment thresholds were determined for pairs of successively presented flashes (5.9 ms each) of a long horizontal line, presented on a 65 cd/m^2 background field, 1 deg above or below a continuously visible cross. The stimulus-onset asynchrony (SOA) between the first and second flash varied randomly among blocks of trials from 5.9 to 234 ms. The observer either fixated on the stationary cross (fixation condition) or tracked the cross as a mirror galvanometer moved the entire display at 8 deg/s (pursuit condition). Monitoring of horizontal eye position indicated that small saccades occurred during target presentations on fewer than 10% of the trials in the pursuit condition. Temporal impulse response functions were modeled as impulse responses of a second order linear system and were estimated using an optimization procedure. When summed at the various SOAs, each estimated impulse response function best fit the aggregate increment threshold data of 6 normal observers.

RESULTS. The measured 2-pulse increment thresholds varied similarly with SOA in the fixation and pursuit conditions. However, the estimated temporal impulse response function indicated a natural temporal frequency ca. 10% higher and a damping ratio ca. 20% larger during the pursuit than the fixation condition.

CONCLUSIONS. Although the fitted temporal impulse response function indicates a faster temporal response during pursuit than fixation, we conclude that the difference in response speed is too small to account for previously reported differences in perceived motion smear.

**Acknowledgment:**Supported by NIH grants R01 EY05068, R01 MH49892, T35 EY07088 and F30 EY07351, and Texas ARP award 003652-0185-2001.
in this way will yield new insights into the mechanisms of visual right and leaning-left trials was found. We believe that combining illusions conditions described above, but investigations continue to eliminate a participants whose data yielded a significant difference between the estimates should compare with estimates for a static Poggendorff illusion if the flashed line was to the left or the right of an imaginary line extending lower end touching the upper horizontal line. The horizontal offset display, another diagonal line, parallel to the first, was flashed, with its the display at 12 deg./sec. When the moving line was near the centre of the lines were vertically offset by 3 deg. A diagonal line at 45 deg. to the interaction of these streams by combining the illusions. Two horizontal and dynamic flash-lag illusions would arguably be principally processed by the ventral and dorsal streams, respectively, so we sought to investigate the magnitude of the flash lag effect in narrowband stimuli does not depend on the velocity, but rather a more complicated relationship between the spatial and temporal frequency content of the stimulus. Acknowledgment: This work was supported by NIH Training Grant in Vision Science, T32 EY07043, and is part of the SUPTDA. http://schorlab.berkeley.edu/cantu/flashlag

FR8
Combining the Poggendorff and flash-lag illusions Mark Chappell (m.chappell1@mailbox.gu.edu.au), David Hardwick, Trevor J Hine; School of Applied Psychology, Griffith University, Australia—The static Poggendorff and dynamic flash-lag illusions would arguably be principally processed by the ventral and dorsal streams, respectively, so we sought to investigate the interaction of these streams by combining the illusions. Two horizontal lines were vertically offset by 3 deg. A diagonal line at 45 deg. to the horizontal, whose upper end touched the lower horizontal line, traversed the display at 12 deg./sec. When the moving line was near the centre of the display, another diagonal line, parallel to the first, was flashed, with its lower end touching the upper horizontal line. The horizontal offset between these diagonal lines was varied. The participant’s task was to say if the flashed line was to the left or the right of an imaginary line extending from the moving diagonal line and logistic regression was then used to find the point of subjective alignment for the two diagonal lines. We hypothesized that when the diagonal line was leaning to the right and moving to the right the two illusions would cancel each other, whereas when this right-leaning line was moving to the left the illusions should add, so that the displayed offset between the two lines for subjective alignment would be smaller in the former case than in the latter. If the illusions were literally additive, it should be possible to solve simultaneous equations to estimate the size of each of them, and these estimates should compare with estimates for a static Poggendorff illusion and regular flash-lag illusion. Pilot experiments yielded 5 out of 8 participants whose data yielded a significant difference between the conditions described above, but investigations continue to eliminate a range of confounding variables. A surprising asymmetry between leaning-right and leaning-left trials was found. We believe that combining illusions in this way will yield new insights into the mechanisms of visual perception.

FR9
Postural control without optic flow Jonathan W Kelly (kelly@psych.berkeley.edu), Andrew C Beall, Jack M Loomis; University of California, Santa Barbara, USA—Discrete visual displacement of a room has been shown to cause body sway in adults and cause children to stagger (Lee & Aronson, 1974; Lee & Lishman, 1975). Sinusoidal displacement has been shown to cause body sway at the frequency of the room motion (Dijkstra, et al, 1994). Presumably this effect is due to an attempt to stabilize posture with respect to the external environment. Our experiments tested the idea that visually controlled postural stabilization may occur in the absence of optic flow. To investigate this, we measured postural response to a moving room presented in virtual reality. Subjects viewed either a lumino-ance-defined dioptric environment containing smooth optic flow or a rapidly scintillating random dot cinematogram (SRDC) environment (Julesz, 1971), devoid of any optic flow relating to the task. The SRDC environments consisted of a sequence of random-dot stereograms with single-frame lifetimes, which to each eye appeared as a scintillating dot display of uniform density. Thus, the SRDC stimulus contained no optic flow related to the motion of the room. In both conditions, subjects stood 30 cm. from the wall of a room that oscillated longitudinally at 0.2 Hz. with an amplitude of 10 cm. An optical tracking system measured body sway during exposure to both a moving and stationary (control) room. Spectral analysis of the body motion data revealed significant body sway at the frequency of the visual stimulus (0.2 Hz) for both dioptric and SRDC conditions. During dioptric exposure, room motion produced body sway amplitude that was 5.6 times greater than the control condition. Similarly, SRDC exposure resulted in sway amplitude that was 2.4 times greater than the control. These data suggest that optic flow is not necessary for visual control of posture. Rather, perceived motion regardless of how it is evoked drives postural control. Acknowledgment: Supported by AFOSR grant F49620-02-1-0145

FR10
A visual factor in rear-end collisions? Theodore E Cohn1 (tecohn@spectacle.berkeley.edu), Tieuvi Nguyen2, Jay E Barton1,1; Visual Detection Lab, UC Berkeley, USA, 2Biomedical Engineering, CUNY, New York, USA—In the US, over 20% of collisions between automobiles are rear-end collisions. But for transit buses, whose exposure and pattern of movement may be quite different, the number is significantly higher, being over 35%. If buses are more susceptible to this type of collision than automobiles, one wonders why. In this report we describe both a property of human vision that may relate to the answer plus a theory as to the link. Some formulations of the visual task inherent in avoiding such collisions suggest that an observer may utilize the angular width of an object ahead, divided by its time rate of change, to calculate a time to collision (TTC). Consider the initial act of perceiving closure with a vehicle ahead. If the quotient of angular width to its time derivative is what is used to initiate braking, then it must be done accurately. We have discovered that the time to react (RT) to a step increase in angular width is seen more slowly the larger the object. The stimulus contained only the 2D cue to closure and depth of field was unchanged at 1.5 m. Objects were light gray squares set in a dark gray surround. The size change started at a random time after a ready signal and was effected gradually, averaging close to a pixel per MSEC in 13.3 MSEC steps. Six normal observers were employed. Average reaction time (2 s.e.) were 284.5 (1.65) MSEC for 3.7 DEG, 294.2 (1.69) MSEC for 5.3 DEG, and 296.5 (1.80) MSEC for 7.6 DEG. The effect is small, about 10% of the estimated perceptual delay, but it is significant. Suppose that the computation of the time derivative of width, dw/dt, is thus distorted by an elevated dt. This lowers dw/dt and thus raises TTC. This finding accords with a conjecture by Leibowitz to explain collisions where trains strike vehicles. He suggested that larger objects appear to move more slowly, damaging the accuracy of the required TTC computation. His conjecture may also apply to collisions between automobiles. Acknowledgment: California PATH TO-4221.

FR11
The effects of contrast and size on orientation discrimination Isabelle Mareschal (isabelle@ccn.mit.edu), Robert M Shapley, Center for Neural Science, New York University, USA—Motivated by the recent physiological finding that a neuron’s receptive field can increase in size by a factor of 2-4 fold at low contrast (Senciak et al 1999; Kapadia et al. 1999), we sought to examine whether a psychophysical task might reflect the contrast dependent changes in the size/structure of a receptive field. We postulate that since spatial summation is not contrast invariant, a task which relies on the spatial structure of a receptive field, such as orientation discrimination, should also be affected by changes in contrast. Previously, orientation discrimination thresholds have been reported to be roughly
independent of the contrast of a stimulus for most of the visible range of contrasts. In this experiment, subjects were presented with two patches of gratings and were required to indicate whether the second was shifted clockwise or counter-clockwise relative to the first. Contrast and size of the gratings were varied independently and measurements were made in the fovea and near periphery. We found large improvements in orientation discrimination with contrast that were parametric in stimulus area. Furthermore, the apparent constancy of orientation discrimination for large area stimuli is likely a result of a floor effect on the threshold. Therefore we conclude that there is not strong evidence for contrast invariant orientation discrimination.

**FR12**

**Orientation discrimination across the visual field: size scaling estimates at near threshold levels of contrast**

Sharon L. Sally (ssally@cc2.concordia.ca), Rick Gurnsey; Department of Psychology, Concordia University, Canada—Purpose: Sally and Gurnsey (2001, ARVO) measured orientation discrimination thresholds for high contrast stimuli as a function of stimulus size and eccentricity. We ensured that orientation thresholds for stimuli of different sizes were not affected by changes in perceptual contrast. At all eccentricities, orientation thresholds decreased as stimulus size increased. However, thresholds obtained at all sizes and eccentricities could be collapsed onto a single function of stimulus size by dividing the sizes of peripherally presented stimuli by $F = 1 + E/E2$ where $E2 = 1.29$. Sally and Gurnsey (2002, VSS) presented data suggesting that $E2$ associated with the orientation discrimination task might be larger for low contrast stimuli. The purpose of the present research was to replicate the procedure of Sally and Gurnsey (2001) but with perceived contrast for all stimuli matched to a low contrast standard.

**METHODS:** Stimuli were narrow-band line patterns presented at a range of sizes (0.19 to 12) and eccentricities (0 to 15) in the temporal periphery. A 3 reference line presented at fixation (0) was set to two JNDS above detection threshold. Subjects matched the perceived contrast of all other stimuli to this reference line. Orientation discrimination thresholds were then obtained at these matching contrasts for all stimulus sizes and eccentricities.

**RESULTS.** At all eccentricities, orientation thresholds decreased as stimulus size increased. All data could be fit to a single function of stimulus size by dividing the sizes of peripherally presented stimuli by $F = 1 + E/E2$ where $E2 = 3.36$.

**CONCLUSIONS.** Orientation discrimination thresholds obtained at low perceptual contrasts elicit an $E2$ that is 2.6 times greater than that elicited at high perceptual contrast. This may reflect a change in the structure of orientation selective mechanisms as a function of stimulus contrast (Mareschal, Henrie, & Shapley, 2002, Vision Research).

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**FR13**

**Global or local shape discrimination of radial frequency patterns?**

Kathy T Mullien (kathy.mullen@mcgill.ca), William H.A Beaudot; McGill Vision Research, Dept of Ophthalmology, McGill University, Montreal, Canada—Purpose: Color vision performs below luminance vision on global shape discrimination measured with radial frequency patterns (Mullen & Beaudot, Vision Research, 2002). This effect might reflect a genuine deficit of color on global shape processing, or it might originate from the fact that color vision is poorer at encoding local orientation. In a series of experiments we test and compare the role of local orientation cues in the shape discrimination of radial frequency (RF) patterns for chromatic and achromatic vision.

**Methods.** Stimuli are contours described by the 4th derivative of a gaussian and form radial patterns (global task) or parts of the pattern (local task). We designed the following tasks in order to separate the role of local-orientation and global cues in the shape discrimination task: 1) we compare performance for the discrimination of local parts (corners or sides) of a RF pattern versus circular arcs of the same radius; 2) we compare the performance for the detection of line modulation versus radial frequency modulation for otherwise identical contours; 3) we compare the effect on shape discrimination of varying the spatial frequencies of the contour of the radial frequency pattern. Data were fitted with a model that uses changes in local curvature to discriminate shape.

**Results.** We find very little performance difference between the local-orientation based tasks and the global shape discrimination task, regardless of whether stimuli were chromatic or achromatic.

**Conclusions.** We conclude that performance on the shape discrimination of radial frequency patterns is limited by local orientation cues in our experiments. While RF patterns presumably exploit a global shape processing mechanism, this affords little or no performance advantages in the task.

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**FR14**

**Age-related changes in orientation discrimination: Calculation efficiency or equivalent input noise?**

Lisa R Betts (bettslr@mcmaster.ca), Patrick J Bennett, Allison B Sekuler; McMaster University, Canada—Many aspects of vision deteriorate as a function of age. However, it is not well understood what factors limit vision in older observers. Previous studies, from our lab and others, have addressed this issue in the context of age-related changes in contrast sensitivity. Those studies demonstrated that decreased sensitivity is due to a reduction in calculation efficiency with age, rather than to changes in equivalent input noise. The present study examined whether similar factors underlie age-related changes in another spatial attribute, namely orientation. Seventeen old and 17 young observers performed a 2-IFC task using 3 cpd Gabor patterns that differed in orientation by 12 degrees. The gratings were embedded in high and low levels of white, Gaussian external noise, and orientation discrimination thresholds were obtained by varying grating contrast. An ANOVA on the log-transformed discrimination thresholds revealed a significant main effect of external noise (thresholds were significantly higher in high external noise) and a Group x Noise interaction. The interaction reflected the fact that discrimination thresholds were significantly higher for old observers than for young observers in the low noise condition, but not in the high noise condition. These results suggest that age-related changes in orientation discrimination are due to age differences in equivalent input noise rather than to differences in calculation efficiency. Thus these results suggest that different mechanisms may underlie the effects of aging on gratings detection and orientation discrimination. We currently are conducting experiments to identify the causes of the age-related increase equivalent input noise that affects orientation discrimination.

**Acknowledgment:** CIHR, NSERC, CRC Foundation

**FR15**

**Factors affecting stimulus detection in the cortically blind**

Ceri T Trevethan (C.Trevethan@abdn.ac.uk), Anish Saha; Vision Research Laboratories, Dept. of Psychology, Univ. of Aberdeen, Scotland—Background: Some cortically blind patients have the ability to discriminate visual stimuli presented within their field defect. This residual visual capacity may or may not accompany any acknowledged awareness of the visual event, termed blindsight type I and II respectively. We have previously reported the presence of blindsight in 8 out of 10 cortically blind patients studied. Purpose: To determine the spatio-temporal properties of residual visual capacities in order to characterise the psychophysical channels mediating blindsight performance. Methods: In a 2AFC experiment we have systematically determined the detection of spatially and temporally modulated Gabor patches presented within the blindfield of 10 cortically blind patients. The spatial and temporal frequency ranges investigated were (0.5-7.0) c/deg and (static - 33) Hz respectively. The effect of stimulus size was also determined by systematically varying the standard deviation of the spatial Gaussian (sz) envelope (range 0.5 – 3 degrees). Results: The...
spatial channels mediating blindsight in all 8 cases were optimally sensitive to low spatial frequencies (0.5–2 c/deg) with no significant responses above 4 c/deg. The temporal channel in 4 out of 5 cases examined had a bandpass response characteristic with optimal response between 5–20 Hz. The stimulus size resulting in above threshold (75%) detection was also variable between 6 cases studied (sz between 0.8–2.6 deg.). The two negative cases of blindsight performed at chance level under all stimulus conditions tested. Conclusions: The combination of sensitivities to the low spatial and high temporal frequencies together with large spatial summation indicate that mechanisms mediating blindsight are largely driven by magnocellular pathways. The above study demonstrates the importance of stimulus parameters in eliciting blindsight performance. This in part may be responsible for the small number of cases described previously in the literature.

Acknowledgment: Supported by a project grant from Chief Scientist’s Office, Scottish Executive (CZB/4/30).

FR16 Boosting multifocal VEP responses from the central visual field with pattern onset stimulation Michael B Hoffmann1 (hoffmannm@aug.ukl.uni-freiburg.de), Sirko Straube2, Michael Bach3; 1Visual Processing Lab, Ophthalmic Department, University of Freiburg, Germany, 2Institute of Biology III, University of Freiburg, Germany, 3Electrophysiology Lab, Ophthalmic Department, University of Freiburg, Germany – Purpose: Multifocal VEPs [1] allow to measure functional correlates of the cortical representation of the visual field in a spatially resolved manner. They might therefore provide a powerful tool for both an objective visual field perimetry and for the assessment of visual pathway abnormalities. However, cortical convolution and its variability cause signal loss at variable visual field locations and therefore introduce spurious scotomata [2]. Methods: We here compared pattern-reversal and pattern-onset stimulation in their efficacy to activate the visual cortex and recorded mVEPs to 60 locations comprising a visual field of 44 degree from 6 subjects using VERIS 4.8 (EDI). Results: We report three main findings: (1) Pattern-onset compared to pattern-reversal stimulation enhances the amplitude by 30% for stimulation of the central visual field (<10 radius), but evokes 30% less response in the periphery (>15 ). (2) While pattern-onset and pattern-reversal responses markedly differ in their eccentricity dependence, they have a similar topographical distribution. (3) Combining both stimuli reduces the number of false positives in objective visual field perimetry. Conclusion: We conclude that pattern-onset and pattern-reversal activate identical visual areas but target different neuronal mechanisms within these areas. Furthermore, pattern-onset stimulation greatly enhances the sensitivity of the mVEP to assess the cortical representation of the central 10 of the visual field.

FR17 Motion induced blindness is affected by head-centered and object-centered mechanisms Yoram Bonneh (bonneh@iasrsns.net.il), Alexander Cooperman; Department of Neurobiology, Brain Research, The Weizmann Institute of Science, Rehovot, ISRAEL – In Motion-induced-blindness (MIB; Bonneh et. al., Nature 2001), a salient static pattern may disappear and reappear spontaneously in the presence of a global moving pattern. We have previously showed that this phenomenon is unlikely to reflect retinal suppression, sensory masking or adaptation, but that the mechanisms involved in MIB are largely unknown. Recent evidence suggests that parietal mechanisms representing space in different reference frames may be involved in the control of awareness, and possibly in MIB. Here we ask in what frame of reference does the disappearance during MIB occur. To answer this question we measured the magnitude of disappearance at different spatial locations in three different conditions: (1) retinotopic mapping in which a single target dot was presented at different locations relative to fixation, (2) a head-centered condition in which the direction of the head was displaced by 20 deg. to the right or left keeping direct fixation and (3) object-centered condition in which a target dot in fixed retinal location was surrounded by an elliptic contour with different relative displacement along its main axis. Results show the effect of all three manipulations. Anisometropic disappearance was found for most observers with more disappearance in the upper and upper-left visual fields. The disappearance map changed for different retinal locations at the same direction of the head. The two negative cases of blindsight performed at chance level under all stimulus conditions tested. Conclusions: The combination of sensitivities to the low spatial and high temporal frequencies together with large spatial summation indicate that mechanisms mediating blindsight are largely driven by magnocellular pathways. The above study demonstrates the importance of stimulus parameters in eliciting blindsight performance. This in part may be responsible for the small number of cases described previously in the literature.

Acknowledgment: Supported by a project grant from Chief Scientist’s Office, Scottish Executive (CZB/4/30).

FR18 Phosphene mapping strategies for cortical visual prosthesis recipients Gislín Dagñlie (gislindagnelie@lifumi.edu), Vivian T Yin, David Hess, Liancheng Yang; Lions Vision Ctr, Johns Hopkins Univ, Baltimore, MD, USA – Purpose. To develop strategies allowing phosphens from implanted cortical electrodes to be mapped in visual space. Accurate, individualized phosphene maps are essential to derive the inverse maps needed to present recognizable images to visual prosthesis recipients. Methods. Flashing dots were presented to normally-sighted observers in 32-128 positions randomly chosen in the central 18 of one visual hemifield. Gaze maintenance on a steady fixation point was monitored, and test dots blanked if the gaze deviated by more than 0.5 °. Three different mapping techniques were investigated, using the same set of dots in each test: 1. Touchscreen method, in which the subject traced the index finger from the direction of gaze to the direction of the flashing dot; 2. Eye movement method, in which the flashing dot and fixation point disappeared, and the subject then moved his/her gaze to the remembered location of the flashing dot; 3. Triadic distance comparison method, in which the subject indicated which pairs among three sequentially presented dots were closest and farthest, and a multidimensional scaling technique was used to reconstruct relative dot locations. All tests were performed three times, thus far by 4 subjects. Results. Touchscreen and eye movement tests had a similar topographical distribution, but their reproducibility was poor (up to 25% variability). Triadic comparison test performance was better on clusters of more closely spaced phosphens than on distant clusters. A distortion metric was constructed by comparing distance estimation errors for all possible phosphene pairs across tests. Three subjects had distortions scores under 15% for all tests; combining maps across tests reduced the errors below 10%, enabling adequate image recognition to naive viewers. Conclusion. These procedures, especially in combination, permit construction of distortion maps with sufficient fidelity to enable image presentation to future prosthesis wearers.

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slant were maximized (binocular viewing), observers were less able to locate the correct station point, because they were now able to compensate for obliqueness of view. In a second experiment, observers adjusted the aspect ratio of a simulated ellipsoid viewed obliquely on a CRT until they perceived it as a sphere. They were better able to perform the task when cues to the CRT’s surface were minimized which again reflects increased sensitivity to distortions in the retinal image when cues to surface slant are minimized. In conclusion, we found that slant cues from the surface of a picture or CRT influence the perception of simulated scenes.

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FR20
A labile representation of spatial information in the visual cortex
Alan Johnston (a.johnston@ucl.ac.uk), Szonya Durant, Jason L Dale; Department of Psychology, University College London, UK — Classical ideas of labile representation place an essential constraint on the form of the representation of spatial information can be modified in place to mimic a representations in the brain are physically shifted within a cortical map. However, it is unlikely that apparently moving or flashed lines associated with movement appears to recent years by phenomena in which the spatial location of moving, space perception based on local sign (Lotze, 1884) have been challenged in the median plane and those same retinal orientation variation, but without changing stimulus line eccentricity relative to the median plane along with the normally accompanying retinal eccentricity are produced by changing horizontal gaze direction. Although a horizontal shift of a small circular target, horizontal eccentricity of the inducing line was in darkness induces large changes in the setting to VPEL of the elevation of aspect ratio of a simulated ellipsoid viewed obliquely on a CRT until they were maximized (binocular viewing), observers were less able to compensate for obliqueness of view. In a second experiment, observers adjusted the aspect ratio of a simulated ellipsoid viewed obliquely on a CRT until they perceived it as a sphere. They were better able to perform the task when cues to the CRT’s surface were minimized which again reflects increased sensitivity to distortions in the retinal image when cues to surface slant are minimized. In conclusion, we found that slant cues from the surface of a picture or CRT influence the perception of simulated scenes.

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FR22
Orthogonal S-R compatibility and stimulus saliency
Akio Nishimura (akio@i.u-tokyo.ac.jp), Kazuhiko Yokosawa; University of Tokyo, Japan — According to the salient-features coding hypothesis, the S-R translation is fast when the salient stimulus and response alternatives correspond in an experimental task (Weeks & Proctor, 1990). When a stimulus set is spatially orthogonal to a response set (e.g., vertical stimulus and horizontal response configurations), an up-right/down-left mapping has an advantage over the reverse mapping. This is termed an orthogonal S-R compatibility (SRC), and interpreted that “above” and “right” are the salient features in horizontal and vertical axes, respectively. However, in the previous studies about the orthogonal SRC, all the stimulus sets were displayed above the response keys. It means that, in above-below spatial representation, the relative “aboveness” of the stimulus set might determine the saliency. In our experiment, two response keys were set on the right and the left of a fixation point (green LED), respectively. The fixation was at the midpoint and intersection of both stimulus and response sets. Each trial began with the display of the fixation LED for 1s that was followed by the stimulus (red LED) appeared above or below it 100ms later. Each participant engaged in both up-right/down-left and up-left/down-right mapping conditions. If the relative position of each S-R pair determines the saliency, there would be no mapping preference in this configuration. However, as a result, mean RT was significantly shorter with the up-right/down-left mapping than with the reverse mapping. This shows that the saliency of “above” in orthogonal SRC is not due to the stimulus pair’s “aboveness” but to the fact that “above” is the spatially salient feature in a vertical axis. In the following experiment, we investigate the relationship between salient features and spatial axes.

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FR23
An effect of mood on perceiving spatial layout
Cedar R Riener (criener@virginia.edu), Jeanine K Stefanucci, Dennis Proffitt, Gerald Clore; University of Virginia, USA — Previous research by Proffitt et al. (1999, 2003) showed that the perception of spatial layout (geographical slant, egocentric distance) is influenced by altering the observer’s bodily state. For example, hills appear steeper and distances appear farther to participants who are fatigued, of old age, or wearing a heavy backpack. Research investigating possible links between emotion and cognition has suggested that emotional state can influence seemingly unrelated aspects of cognition (Gasper and Clore, 2002). The current study sought to combine these two research programs by asking whether emotion (possibly an aspect of bodily state) can influence the perception of spatial layout. Mood was induced by having participants listen to happy music (major key, upbeat) or sad music (minor key). While listening to the music, participants made three judgments of the slant of the hill: verbal estimate, visual matching, and a visually guided action measure (a haptic palmboard). Sad participants verbally judged the hill as being steeper than those in the happy condition, and the visual matching measure showed a non-significant trend in the same direction. As was found in previous work, the visually guided action measure was unaffected across conditions. Results support the hypothesis that the bodily state associated with a sad mood resembles that of a fatigued or encumbered participant. A similar follow-up study was conducted on the effect of mood on the perception of egocentric distance.

FR24
Human Search Performance is a Threshold Function of Cortical Image Separation
Diglio A Simoni (diglio@cnycrg.org), Brad C Motter; Veterans Affairs Medical Center, Syracuse, NY, USA — We have previously reported that detection performance of monkey subjects during active visual search is constrained by object density. Here we report similar results for human subjects. Methods. Three subjects searched for a trial-by-trial cued T or L target in arrays of rotated (60 deg increments) T’s & L’s. Array set sizes of 6, 12, 24, or 48 items were randomly placed within a 35.5
x 26.5 deg display area. Each stimulus segment was 1.0 x 0.25 deg. Stimuli were either all green or all red, varied by trial. The task was to find and fixate the target for 600 ms. Target detection was defined as having occurred when the next saccade captured the target by landing within 1.1 deg of the target center. Eye position measurement was made using an SMI Eyelink system. Detection probability was measured as a function of the V1 cortical image separation of the target and its nearest neighbor. Separations were measured on a 3D model of the curved V1 surface constructed using current estimates of a human cortical magnification factor. Results. In humans, as well as in monkeys, active search proceeded via sequential fixations of stimuli (75% of fixations within 2 deg of nearest stimulus). Target detection probability can be described as a threshold function of the mm separation of the V1 cortical image representations of the target and its nearest distractor. To achieve comparable performance, humans require about twice (2X) the cortical separation as monkeys. The similarity of this result to the known doubling of the size of the ocular dominance column widths in humans versus monkeys, suggests that the scale of spatial interactions between objects is linked to the scale of hypercolumns in V1.

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FR25
Symmetry relations influence target-distractor comparison in visual search Alexa B. Roggeveen, Alan Kingstone, James T. Enns; University of British Columbia, Canada – Resemblance theory predicts that visual search efficiency is a function of similarity along two dimensions: increased similarity between targets and nontargets decreases efficiency, while increased similarity among nontargets increases efficiency (Duncan & Humphreys, 1989). However, the theory does not specify the basis on which similarity is defined.

Tests of visual discrimination involving isolated objects have shown that symmetry relations have a direct influence on perceived similarity, with shapes that are related by symmetry over the vertical axis seen as more similar than those related by symmetry over the horizontal axis (Bornstein et al, 1978; Richards, 1978).

This study asked whether the effects of inter-object symmetry are the same for both dimensions of search efficiency in resemblance theory. Target-nontarget relations were examined by having participants search for an F among F’s rotated around either a horizontal or vertical axis; nontarget-nontarget relations were examined using search for an F among distorted F’s, which were symmetrical to one another over either a horizontal or vertical axis. These displays were also rotated by 90 degrees to control for any effects of shape familiarity.

The results showed that symmetry had a strong influence on search only when it involved target-nontarget relations. Symmetry among non-targets had no effect, even when a cortical scaling factor was introduced to equate the visibility of nontargets (Sally & Gurnsey, 2001).

These results imply that the two dimensions of resemblance theory do not apply uniformly to shape similarity. Further experiments are planned to determine whether this is because similarity differs for (a) target selection versus distractor exclusion, (b) explicit target comparison versus implicit distractor comparison, or (c) because shape attributes are processed differently from those that tend to group together, such as motion and color attributes.

FR26
An exact picture of your target guides visual search better than any other representation Naomi Kenner1 (nky@search.bwh.harvard.edu), Jeremy M Wolfe1,2, 1Brigham and Women’s Hospital; United States, 2Harvard Medical School; United States – Even in the simplest of visual searches, observers are faster if they know what they are looking for. Thus, search for a red item among green is faster if Os know they are looking for red, even though a unique red singleton would be easy to find in the uninformed case. How long does it take for top-down information about target identity to become effective in guiding the deployment of attention?

Are all forms of top-down information equivalent? In order to answer these questions, Os searched amongst photorealistic objects for a target that had been cued 50-800 msec prior to presentation of the search array. There were 8 conditions, each run separately. In 3 Blocked conditions, targets were constant across a block of trials. In different conditions, all targets could be EXACTLY the same (e.g. always a specific dog), of the same TYPE (always a dog), or of the same CATEGORY (always an animal). In 5 Mixed conditions, targets varied from trial to trial. 3 of these conditions used Picture cues. If, for example, the target was a dog, the cue could match EXACTLY (the same dog), by TYPE (the same or another dog), or by CATEGORY (any animal, except dog). The other 2 Mixed conditions had Word cues that matched the target by TYPE (“dog”) or CATEGORY (“animal”). 13 Os were tested. Exact cues were fully effective. If an Exact cue preceded the search array with SOA > 200 msec, the RT was the same as the Blocked condition RT. TYPE cues were never fully effective, remaining 100 msec slower than Blocked RTs after an 800 msec SOA. Picture and Word TYPE cues showed the same asymptotic performance, though words required longer SOAs to reach asymptote.

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FR27
The Influence of meaning and search strategy on the efficiency of visual search Daniel Smilêk1 (domiêk@psych.ubc.ca), Mike J Dixon2, Philip M Merikle2; 1University of British Columbia, Canada, 2University of Waterloo, Canada – We evaluated whether the meaning of objects and the search strategy adopted by observers influences search efficiency. In two experiments, observers were trained to associate verbal labels with simple shapes. By training observers it was possible to vary the semantic similarity between targets and distractors in the visual search displays while eliminating the influence of target-distractor visual similarity through counterbalancing. In one condition the targets and distractor shapes were associated with the same verbal label and therefore observers searched for targets embedded among semantically similar distractors. In another condition the target and distractor shapes were associated with different verbal labels and therefore observers searched for targets embedded among semantically dissimilar distractors. In addition, search strategy was varied across experiments by instructing observers to adopt either an active or a passive search strategy. The efficiency of search was assessed in terms of the slopes of the search functions. The results showed that when observers searched passively, search was more efficient in the semantically dissimilar condition than in the semantically similar condition. In contrast, when observers searched actively, there was no difference in search efficiencies between the semantically similar and semantically dissimilar conditions. These findings indicate that the meaning of objects influences search efficiency and that this influence of meaning depends on the search strategy adopted by observers.

FR28
Context effects on border assignment in the target stimulus in visual search Mary A. Peterson (MAPeters@u.arizona.edu), Robert Rauschenberger; University of Arizona, USA – Using a modified version of Rauschenberger & Yantis’ (2001) search task, Rauschenberger, Peterson, Mosca, & Bruno (VS’02) presented evidence for a dynamically evolving influence of the non-target stimuli on the representation of the target stimulus (spatiotemporal context effect). Here, we extend this finding, building a case for the generality of spatiotemporal context effects in visual search. In displays that were masked after either 100 or 250 ms, subjects searched for an enclosed geometric novel outline target whose vertical edges sketched a ‘standing woman’ on the ground side. This target was presented among one of two types of non-targets (in fully mixed blocks): One type of non-target had the same vertical edges as the target; but they
were each mirror reflected so that the 'standing woman' was sketched on the figure side of the edge rather than the ground side (experimental condition). The other type of non-target was a scrambled version of the 'standing woman' non-targets (control condition). The control condition serves as a baseline against which the experimental condition may be compared, as it is less subject to context effects. Because spatiotemporal context effects require time to evolve, we predicted that the non-targets would exert a greater influence on the perception of the target in the 250 ms SOA condition than in the 100 ms SOA condition (as compared to the control condition). Results were consistent with this prediction. In the experimental condition, the search slopes were significantly larger in the 250 ms SOA condition than in the 100 ms SOA condition, whereas in the control condition, the slopes in these two SOA conditions were not statistically different. Moreover, the 100 ms condition showed the typical pattern of more efficient search among familiar non-targets than among unfamiliar non-targets. This pattern disappeared in the 250 ms condition, however. We attribute this disappearance to context effects.

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FR29
Memory deployment in visual search: insights from pupillometry Gillian Porter (gillian.porter@bris.ac.uk), Tom Troschiano, Iain Gilchrist; University of Bristol, UK — The extent of dilation of pupil of the eye is a reliable measure of cognitive load. We have previously shown that with appropriate luminance controls, pupillary dilation during visual tasks offers insight into the extent of higher level processing occurring during task performance (Porter, Troschiano, and Gilchrist, Perception 31 suppl, 170-171; 2002). In particular, differences were found in the dilatory pattern between difficult visual search and counting tasks despite matched reaction times and identical stimuli. Counting elicited immediate marked pupil dilation, sustained until response, whereas dilation during search increased gradually until response and was reduced in overall magnitude. To investigate whether these patterns correspond to memory load, pupil size was measured during performance of search tasks in which the memory component was manipulated. By changing a traditional "target absent or target present?" search task to "one target present or two targets present?", spatial memory was increased, as the need to remember one target's location, once found, was introduced. Accordingly, pupillary dilation was slightly greater in the "one or two?" task than in the target absent/present task, but only when nearing response. When target identity varied by trial, greater dilation was seen early in the search process than when target identity remained constant. This corresponded to the increased effort in encoding the target. These results suggest that pupil dilation is sensitive to both spatial and recognition memory load, and that memory for both target identity and location is differentially involved in different visual search tasks.

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FR31
Short- and long-term memory contributions to the online visual representation of natural scenes Andrew Hollingworth (andrew-hollingworth@uiowa.edu); The University of Iowa, USA — Visual representation of complex scenes requires the retention and integration of information from separate eye fixations on local objects. In the present study, a "follow the dot" method was used to investigate the memory systems supporting accumulation of visual information from objects in scenes. Participants fixated a series of objects in 3-D rendered environments, following an abruptly appearing dot-cue from object to object. During this sequence, a change detection test was introduced: A single target object was masked briefly, and the mask was removed to reveal either the original object or a different object from the same basic-level category. A verbal working memory load minimized verbal encoding. The delay between the examination of the target object and the test was manipulated: The target object was examined either 0, 1, 2, 4, or 10 objects prior to the initiation of the test. In a final condition, the test was delayed until all scenes had been viewed (a delay of 376 objects, on average). Detection sensitivity was highest in the 0-back condition (testing the currently attended object), with A' = .91. Detection sensitivity declined to A' = .87 for the 1-back and A' = .84 for the 2-back condition, but was unreduced from this level in the 4-back (A' = .81) and 10-back conditions (A' = .83). Thus, the recency effect was limited to the 2 most recent objects, with no evidence of further forgetting when the retention of 4 or 10 objects was required. Performance remained well above chance (A' = .75) on the test delayed until the end of the session. These data allow the following conclusions: 1) Online scene representation is supported by VSTM retention of approximately 2 objects; 2) Online scene representation is also supported by visual LTM, and visual LTM capacity is not exhausted by the retention of many hundreds of objects; 3) Memory for an object attended immediately before a change is only slightly more reliable than memory for previously attended objects.

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FR32
Representation of occluded objects in natural scenes: Are all forms of occlusion equal? Helene Intraub (intraub@udel.edu), Michelle Aker, Melissa Fiorito, Victoria Simoshina; University of Delaware, USA - Viewers remember having seen beyond the edges of a picture (boundary extension). Recent research indicates that this unconscious extrapolation is limited to pictures of scenes - suggesting a possible role in the integration of successive views. What implications might this have for the representation of occluded objects in scenes? Occlusion by a viewpoint may elicit extrapolation, whereas occlusion by another object in the scene may not. Alternatively, Kanizsa's 'occlusion illusion' raises the possibility that extrapolation of an object may occur whenever occlusion is present.

Two versions of 12 multi-object scenes (digital photographs) were created...
FR33
Rapid scene processing: Can a salient central object influence background perception? Jodi Davenport (jodid@mit.edu); Massachusetts Institute of Technology, USA — How do we succeed in recognizing scenes in as little as 100 ms? What features of a picture contribute to this rapid processing? Previous research has looked at the effects of scene context on object identification. The results from this work remain inconclusive: in some cases scene context facilitated object perception but in others it did not. Most prior studies used black and white line drawings as stimuli, and we investigated not only how scene context may affect object identification, but also how a single salient object may affect background identification. Our stimuli consisted of color photographs manipulated in Photoshop. Scene backgrounds and single objects were selected independently. Eight uninformed raters named each object and background to ensure reliable naming. Two types of object/background pairings were created by pasting an object into each scene. Scenes were either consistent; the object was typical for that type of scene, or inconsistent; the object was unusual for that type of scene. Each object and background was seen only once. Whether a given background appeared with a consistent or inconsistent object was counterbalanced between subjects. Items appeared for 107 ms followed by a mask, and the task was to name either the background or the central object. A control group named objects on a neutral background and the task was to name either consistent; the object was typical for that type of scene, or inconsistent; the object was unusual for that type of scene. Items appeared for 107 ms followed by a visual noise mask (½ sec, 1sec, or 10 sec), and then it reappeared. Using a mouse, the viewer positioned the target object within the digital photograph (multiple graphics layers allowed viewers to move the objects behind other objects or behind the view-boundaries). Viewers remembered seeing more of the target object than before when it had been occluded by the view-boundary, but not when occluded by another object in the scene. Might this be attributed to the lack of visual information outside the view? In another experiment the view-boundary was composed of occluding objects. Thus the local information at the point of occlusion was controlled. Again, extrapolation occurred only at the view-boundary. Not all occluding borders are equal — extrapolation beyond a view-boundary may serve an adaptive purpose in understanding and integrating successive views.

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FR34
Parallel extraction of statistical descriptors in visual displays Sang C Chong (scchong@princeton.edu), Anne Treisman; Princeton University, NJ, USA — When attention is distributed over an array of similar items, the general statistics of the array may become perceptually available. In an earlier dual task study, we found that tasks requiring global attention were easier to combine with extracting the mean size of the circles than tasks requiring focused attention. One explanation may be that extracting the statistic descriptors requires parallel access to all the information in the array. To test this hypothesis, we presented 8 circles either successively in different display locations or simultaneously and then asked participants to identify the mean size of the 8 circles. The simultaneous displays were presented for two different durations, one matching the duration of the whole sequence of successive presentation, and the other matching the duration of a single circle in the successive presentation. The threshold for successive presentation did not differ significantly from either of the two simultaneous presentation thresholds. The long simultaneous presentation gave a slightly lower threshold than the short one. The three conditions may have given similar results simply because the four different sizes appeared equally often in each display, allowing participants to attend to just one of each. To rule out this possibility, in Experiment 2 we used only two sizes and varied their relative frequency in different displays. Thresholds were now lower with the long simultaneous presentation than with the successive one, but no difference was found between the short simultaneous and the successive presentation. This result is surprising because the total presentation time decreased by a factor of 8 with the simultaneous display and yet the thresholds for averaging sizes did not rise. We infer that the mean size can be extracted through rapid parallel processing with simultaneous displays, as well as through the accumulation across time of serially presented items.

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FR35
The visual information underlying the categorization of natural scenes Maxine V McCotter1 (maxine@psych.gla.ac.uk), Frederic Goselin2, Paul Snowden1, Philippe G Schyns1; 1University of Glasgow, Scotland, UK, 2University of Montreal, Quebec, Canada, 3University of Surrey, England, UK — Whether a scene is to be classified at the superordinate level as man-made or natural, the basic level as a particular outdoor scene (e.g., mountain), or as a specific example of an outdoor scene at the subordinate level (e.g., the Himalayas) will modify the visual information required. To approach these issues, we focussed on the superordinate categories, Oman-made1 and Onatural1, and implemented an ideal observer simulation using 3200 images of scenes (from Oliva & Torralba, 2001) to derive a benchmark of the information available for these categorizations (A). Stimuli were the scenes with phase noise introduced at randomly selected spatial frequencies and orientations in Fourier Space. The density of the noise was adjusted to maintain classification performance at 75% correct. The same method was applied to human observers, for the same 75% accuracy level to derive D, the information Diagnostic of these categorizations. We then computed the relative efficiencies (E = D/A) of the scene classifications. Stimuli reconstructed from the diagnostic Fourier coefficients reveal the information (both in terms of bandwidths and orientations) that characterized the human biases.

FR36
Temporal variations in visual completion: A reflection of spatial limits? Sharon E. Guttman1 (sharon.guttman@vanderbilt.edu), Allison B. Sekuler2, Philip J. Kellman1; 1Department of Psychology, University of California, Los Angeles, USA, 2Department of Psychology, McMaster University, Canada — The completion of partly occluded objects appears instantaneous and effortless. However, research indicates that completion takes measurable time, and that time-to-completion depends on a number of stimulus variables. The current study asks how the time course of visual completion depends on the amount of occlusion, and examines the mechanisms underlying temporal variations. Experiment 1 used a primed-matching paradigm to determine completion times for circles and squares occluded by different amounts: 20% and 32.5% contour occlusion. Experiments 2 and 3 used a dot localization paradigm to probe completed contour representations for a qualitative shift as the amount of occlusion exceeds some spatial limit. Our results provide the first demonstration that, if given sufficient processing time, highly occluded objects — including some with visible contours exceeding the limits of spatial relatability — achieve functional equivalence to their complete counterparts. This finding suggests that the visual system can complete highly occluded objects, although time-to-completion rises with amount of occlusion. Furthermore, the dot localization results indicate that the precision and shape of the interpolated contour representations vary smoothly with amount of occlusion, even though the visible edges in the more highly occluded shapes were non-relatable (because the interpolated edge needed to bend through more than 90 degrees). Thus, increases in completion times do not appear to result from a breakdown of low-level interpolation processes beyond some spatial limit: The same contour completion mechanism operates on objects occluded by different spatial extents. Implications for models of boundary interpolation will be discussed.

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FR37
Temporal aspects of global form perception  Marco J.H. Puts (m.puts@nici.kun.nl), Charles M.M. de Weert; Nijmegen Institute for Cognition and Information, University of Nijmegen, The Netherlands – Puts and de Weert (1998, Does colour influence subitization? Acta Psychologica, 97(1), 71-78) found that determining the number of presented elements was unaffected by color when the dots are in well-known, global configurations (e.g., three dots in triangular configuration, four dots in rectangular configuration and five dots in pentagonal configuration), while the counting is harder when all dots are placed in the same global configuration. They argue that determining the number can be done in two different ways. First of all by counting, secondly by using the shape information. The counting mechanism is not color blind, whereas the mechanism that is based on shape recognition is much faster and color blind. In the experiment to be reported here we investigated the temporal aspects of these two different mechanisms. In one condition, three, four or five dots were placed in well-known global configurations, called the form condition. In another condition, three, four or five dots were placed in a configuration where all dots were placed on a line, called the line condition. The patterns were alternated with a mask at different frequencies (7.5, 10, 15 and 30 Hz.), limiting the available time for detecting the target. Subjects had to perform a detection task, where they had to press a button when four dots were presented. We found out that in the form condition, the detectability showed a different behavior than in the line condition at different frequencies. There was no difference at 7.5 Hz. The difference in detectability was highest at 10 Hz. At this frequency, the configurations in the form condition were much more detectable than the configurations in the line condition, due to the highest contribution of the global form detection mechanism. At frequencies higher than 10 Hz., the difference in decreased with increasing frequency. On the basis of this experiment we may conclude that we have to do with two different ways of counting the dots.

FR38
Robustness of bilateral symmetry to temporal offset  Gert van der Vloed (g.vandervloed@nici.kun.nl), Arpad Csatho, Peter A van der Helm; University of Nijmegen, Netherlands – Previous research indicates that symmetry is especially 'good' when it is defined by a single object while it is weakened when symmetrical information is distributed over multiple objects (Baylis and Driver 1994,2001). Our current research investigates the robustness of symmetry to temporal offset. Temporal offset can serve as a cue for figure/ground segmentation (Leonards, Singer & Fahle 1996). By means of two experiments we investigate whether temporal segmentation into multiple objects impairs symmetry perception.

In our first experiment subjects had to discriminate patterns that were perfectly symmetrical from patterns that were partially symmetrical (i.e. stimuli that were composed of a symmetrical part and an asymmetrical part). In the second experiment subjects had to discriminate stimuli that were completely asymmetrical from partially symmetrical stimuli. Temporal offset of the two stimulus parts ranged from 0 to 100 milliseconds.

The results show that the identification of completely symmetrical stimuli is not affected by temporal offset while the identification of completely asymmetrical stimuli is. This suggests that symmetry is robust to temporal offset.

For the partially symmetrical stimuli the results were as follows. When the symmetrical part is presented last, performance decreases when subjects had to discriminate these patterns from perfectly symmetrical patterns (Exp. 1), while they showed improved performance when discriminating these patterns from completely asymmetrical patterns (Exp. 2). When the symmetrical part was presented first there were no effects of temporal offset. We argue that these results can be explained by an order-dependent salience effect of symmetry.

FR39
Neural correlates of texture boundary detection and surface segregation are present in human V1  H. Steven Scholte1 (sscholte@fmg.uva.nl), Jacob Jol1, Henk Spekreijse2, Victor AF Lamme2, 1Department of Psychology, University of Amsterdam, The Netherlands, 2Academic Medical Center, University of Amsterdam, The Netherlands – Texture segregation, an example of scene segmentation, can be divided into two different processes: texture boundary detection and subsequent surface segregation (Lamme et al., 1999). Neural correlates of texture boundary detection have been found in monkey V1 (Rossi et al., 2001); whether surface segregation can be measured in monkey V1 (Lamme, 1995, Rossi et al., 2001), or whether texture boundary detection and surface segregation can also be measured in human V1 is more controversial (Kastner et al). Here we present EEG and IMRI data that has been measured during three different conditions in human subjects. Within these conditions, we varied surface segregation independent of textures boundaries. In this way, we were able to show that a) neural correlates of texture boundary detection are present in human V1, b) neural correlates of surface segregation are present in human V1, c) texture boundary detection, as measured with EEG, starts at approximately 60 msec, and d) surface segregation starts at approximately 100 msec.


FR40
Effect of region information on perception of partially occluded figures  Michael R. Schesesse (mschesesse@iusb.edu), Thomas Perez; Indiana University, South Bend, USA – Purpose: Prior theories of the perception of partially occluded figures have stressed the role of contour information. Meanwhile, the role of region information has been less understood. We investigated the extent and nature of the contribution of region to the perception of partially occluded figures. Method: Each stimulus contained a black figure against white ground. Each figure was composed of 4 rectangles, so that contours of a figure had either horizontal or vertical orientation. In Experiment 1, white diamond distractors were used as occluding elements, while in Experiment 2, white square distractors were used as occluders. In both experiments, 2 factors were manipulated: presence of region information (present vs. absent) and occluder size (small vs. large). Thus, each experiment had 4 conditions. Stimuli in the 'region absent' conditions were created from those in the corresponding 'region present' conditions by displaying only edges (contours). On each trial, a subject's task was to respond whether the occluded figure was displayed in its upright or upside-down orientation. Results: In both experiments, performance in the 'region present' conditions was superior to that in the corresponding 'region absent' conditions. This was true whether occluders were large or small, although the effect of region was greater when small occluders were used.

Conclusions: These results suggest that contours alone cannot account for perception of partially occluded figures. Also, because white diamond occluders were used in Experiment 1, it might be argued that these occluders gave rise to illusory diamonds appearing 'in front' of the figure. Thus, depth information would have been available in the 'region present' conditions of Experiment 1. However, the results of Experiment 2 show that depth cues cannot wholly explain the effect of region - white square occluders did not give rise to illusory squares appearing 'in front' of the figure in 'region present' conditions.

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FR41
Figure-ground segregation and spatial phase tuning of extra-receptive field of V1 neurons in awake monkey
Weifeng Xu (wfxu@ion.ac.cn), Zhiming Shen, Chaoyi Li; Institute of Neuroscience, Shanghai Institutes of Biological Sciences, Chinese Academy of Sciences, Shanghai, China — Segregating a figure from a background is one of the most fundamental tasks that have to be performed by the visual system. In the primary visual cortex (V1), the majority of cells respond preferentially to line segments with a specific orientation. This selectivity enables V1 neurons to isolate an object from its background on the basis of differences in segment orientation. Psychophysically “pop-out” figures can also be constructed with an iso-orientation configuration, in which the line segments confined to the figure differ in terminations or spatial phase from the line segments confined to the background. In the iso-orientation paradigm, the only cue that can be used to separate figure from background is the difference in relative spatial phase of the constituent lines between figure and background. In the present study, we measured the spatial phase tuning of the ERF (side- and end-regions) for neurons in the primary visual cortex of awake monkey (macaca mulata). We evaluated the tuning by varying the relative spatial phase between a grating confined to the excitatory RF and a grating confined to the inhibitory end- or side regions. Our results showed that the response of the V1 cells depends on the relative spatial phase of gratings between the CRF and ERF. To investigate which neural mechanisms underlie this capacity and why only some proportion of V1 cells respond to such subjective contours, we determined the relationship between spatial-phase sensitivity and strength of surround inhibition at cells respond to such subjective contours, we determined the relationship between spatial-phase sensitivity and strength of surround inhibition at V1 simple cells in layer 4 can simulate these data. The model also clarifies how this constraint may arise during development, and is consistent with lateral masking experiments in which two flanking Gabor patches with the same contrast polarity as the target increase the target's detection threshold. In the model, when contrast relationships within an X-junction do not favor transparency, all surface boundaries occur at the same depth plane and no surface appears transparent, because none can fill-in surface brightness or color behind the other. The model also explains how the Metelli (1974) Rules can cause transparent percepts, how bistable transparency can arise, and how transparency reversal can be facilitated by an attention shift.

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FR42
A new way of assessing the strength of a figure-ground cue
Johan Hulleman (j.hulleman@bham.ac.uk), Luan Gedamke, Glyn W Humphreys; University of Birmingham, United Kingdom — Methods to assess the strength of figure-ground cues generally fall into two categories: (1) Subjective reports about which part of a display is seen as figure. (2) Reaction time measures to stimuli that probe a part of a display. Both methods have drawbacks. Subjective reporting manipulates the process under investigation. Studies with probes can superimpose a new figure on the figure-ground display, possibly changing the representation, or fail to control what subjects do during the presentation of figure-ground displays (when probes follow the display).

In our approach we try to increase control over the behaviour of subjects using a visual short term matching task (Driver & Baylis, 1996), while refraining from explicit figure-ground instructions. We biased figure-ground assignment by presenting the first half of an ambiguous figure-ground display before adding the second half. The first half will initially become figure, since it is presented on a large background. If the first half contains a strong figure cue, it should be resistant against the distraction caused by the onset of the second half, 100 msec later. If, however, the second half contains a strong figure cue it self, this may cancel the initial figure assignment to the first half. Figure assignment was probed afterwards and subjects decided which of two mirror images was part of the figure-ground display.

In our experiment, we used the lower-region cue (Vecera, Vogel & Woodman, 2002). We report an interaction between region presented first, and whether this region is subsequently probed. For upper regions presented first and probed, reaction times are slower than for lower regions presented first and probed. This illustrates the viability of our approach: a strong figure cue will overcome the disadvantage of being presented second, whilst also holding on to the advantage of being presented first.

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FR43
Laminar cortical dynamics of 3-D surface stratification, transparency, and neon spreading
Stephen Grossberg (Steve@bu.edu), Arash Yazdanbakhsh; Dept. of Cognitive and Neural Systems, Boston University, Boston, MA, USA — How does the laminar circuitry in areas V1 and V2 generate 3-D percepts of stratification, transparency, and neon color spreading in response to 2-D pictures and 3-D scenes? Such percepts are sensitive to whether contiguous regions in an image have the same contrast polarity (Adelson, 2000; Anderson, 1997; Watanabe and Cavanagh, 1992, 1995), yet long-range perceptual grouping pools over opposite contrast polarities. In binocular displays that create neon color spreading, like-ocularity of contiguous regions is critical for spreading (Takeichi et al., 1992). Half-visible points in a stereogram can induce near-depth transparency if the contrast relationship favors transparency in the half-visible areas (Nakayama, 1996). The whole contrast relationship must be in the monocural configuration, since splitting it between stereogram images cancels the effect. A recent model of cortical development, grouping, attention, learning, and 3-D planar surface perception by V1 and V2 is extended to show how adding like-polarity competition between V1 simple cells in layer 4 can simulate these data. The model also clarifies how this constraint may arise during development, and is consistent with lateral masking experiments in which two flanking Gabor patches with the same contrast polarity as the target increase the target's detection threshold. In the model, when contrast relationships within an X-junction do not favor transparency, all surface boundaries occur at the same depth plane and no surface appears transparent, because none can fill-in surface brightness or color behind the other. The model also explains how the Metelli (1974) Rules can cause transparent percepts, how bistable transparency can arise, and how transparency reversal can be facilitated by an attention shift.

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Object recognition impedes stereo discrimination

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Purpose: We examined the extent to which recognition of a structured object influenced stereo discrimination.

Method: Our stimuli were static frames of a point-human figure (13 points) in stereo. Of the 13 points that were otherwise green, two were red depicting one forearm (elbow and wrist), and two blue depicting the other. Subjects discriminated, in a staircase procedure and without feedback, whether the 3D distance between the red points was longer than between the blue ones. The 2D distances of the two pairs, in contrast, were always kept the same in each trial. The static human figure was presented upside-down so no naïve subject recognized it. After Session 1, the upright human figure in stereo was presented in a movie so that all subjects recognized it. The next session repeated Session 1 except that the human figure was now upright.

In the first control condition, the human figure movie was not shown after Session 1, while everything else remained unchanged.

In the second control, the 3D distance between the shoulder and wrist was used instead. This distance remained the same on average as that between the elbow and wrist in the experimental condition.

Results: In the experimental condition, although subjects’ threshold decreased from Session 1 to 2, this decrease was smaller than in the first control (p<0.05). No subject in the first control recognized the human figure. In the second control, in contrast, the threshold increased (p<0.025).

Discussion: Stereo distance discrimination was impeded when two pairs of points, which were otherwise meaningless, were recognized as a human figure's two forearms that were presumed equal in length. Discrimination was also impeded when the recognized context distracted an otherwise direct comparison (an elbow in between shoulder and wrist).

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Combining Multiple Cues for Contour Detection: Lessons from (and to) the Visual Cortex

Chunhong Zhou (chunhonz@lnc.usc.edu), Bartlett W Mel; Department of Biomedical Engineering, University of Southern California—Object recognition depends heavily on shape information, and object shape is often primarily determined by contour structure. As such, reliable detection of shape-defining contours in complex scenes—that is, seeing the line drawing—is a visual computation of enormous scientific and practical importance. We have developed a neuromorphic architecture for shape-contour extraction, inspired by several features of visual cortex and informed by concepts from optimal probabilistic inference. The system combines 4 sources of information to estimate the probability of any given contour hypothesis. Two boosting influences arise from (1) long-range high-resolution contour structure in which learned prototypes are combined with a MAX-like operation, and (2) local coarse-scale input, which modulates the contour hypothesis through a multiplicative factor. Two suppressive influences include (1) a measure of local edge density which acts through divisive normalization, and (2) spatial mutual exclusion effects, including cross-phase inhibition, which act via subtractive normalization. The network is highly effective at detecting well-organized contours in complex natural scenes. In this presentation, we discuss aspects of our approach that could help to explain several poorly understood features of visual cortical organization, including the existence of two distinct lateral inhibitory networks, multiple forms of synaptic temporal dynamics, and specific forms of nonlinear processing within the dendrites of visual cortical neurons.

Acknowledgment: This work is supported by ONR, NSF and ARO.
FR50
What factors determine the stabilization of a bi-stable stimulus? Xiangchuan Chen (chenx244@tc.umn.edu), Shiong He; University of Minnesota, Minneapolis, MN — It was recently reported that the perceptual alternation in viewing bi-stable stimuli could be slowed down, and even brought to a standstill, if the stimuli are presented intermittently. What are the factors that are important for the preservation of one percept over sequential presentations? The factors that affect this stabilizing effect will help us to understand the mechanism of the perceptual alternation for these bi-stable images.

We adopted a bi-stable rotating cylinder as the stimulus. It is a parallel projection of 200 random dots painted on the surface of a rotating cylinder. On computer screen, these 200 dots move left and right with their speed following a sinusoidal function. In our experiment, the stimulus was presented with a 1-second on-time and 2-second off-time paradigm. The key manipulation is that in alternating presentations, we physically changed certain properties of the stimulus, including the spatial location, the color of the dots, the size of the cylinder, or the moving speed of the dots.

In all six observers tested, changing the color, the moving speed of the dots, or the size of the cylinder had no or minimal effect on the stabilization of perceived rotating direction. The only factor that affected the stabilizing effect was the location change. Changing the location of the stimulus often resulted in a change in perceived direction. Interestingly, it seemed that the perception of the rotating direction was stabilized in a given location but independent between locations. Furthermore, switching between two locations projecting to the two hemispheres was more likely to break the stabilizing effect than switching between locations that project to the same hemisphere.

The results suggest that the stabilizing effect is affected by retinotopically specific mechanisms, but is insensitive to the features that define the object.

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FR51
Generalization of perceptual learning across the visual field Bernard Gee (bgee@cw.rochester.edu), William Merigan; University of Rochester, Ophthalmology and Center for Visual Sciences, USA — Purpose: To determine how training-induced improvement in the matching of 2D shapes generalizes to non-trained regions of the visual field. Methods: Prolonged training on the delayed matching of 2D shape stimuli in one quadrant of the visual field results in marked improvement in matching, as indicated by a 3-fold reduction in the minimum stimulus onset asynchrony (SOA) between shape stimuli and a masking stimulus. After five days of training, performance was tested in visual field quadrants across the vertical and horizontal meridian, to determine if the improvement transferred to these locations. Results: We found only partial transfer of the improvement in performance across the horizontal meridian of the visual field, and even less transfer across the vertical meridian. Conclusions: These results suggest that a portion of the perceptual learning of shape matching involves visual mechanisms that extend across the horizontal and vertical meridia of the visual field, such as those found in inferotemporal and prefrontal cortex. However, an additional component of the learning appears to involve quadrant specific visual neurons, such as those in earlier nuclei of the visual pathways.

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patches. They varied in orientation from 10 deg to 80 deg (in 10 deg steps) and were presented in the periphery at each of two SFs (0.86 & 6.9 cpd). Spatial phase was randomly varied for each stimulus. Next observers were trained to categorise stimuli into one of two categories that were defined by dividing the orientation continuum in half. During training, stimuli were presented at just one of the SFs. Categorisation training was then repeated on day 2. Finally on day 3 observers’ orientation discrimination was re-measured for stimuli presented at both SFs.

We found that observers’ orientation discrimination between stimuli that cross the category boundary was significantly improved following training. This is consistent with a learned CP effect for orientation categories. Furthermore, the learned CP effect was specific to the trained SF. Our findings are consistent with the possibility that a perceptual learning process operating on early SF tuned stages of visual analysis results in the observed CP effects.

FR54

Hemispheric specificity of perceptual learning effects under hard conditions Marina Pavlovskaya1 (marinap@netvision.net.il), Shaul Hochstein2; 1Revuestein Rehabilitation Hospital, Faculty of Medicine, Tel-Aviv University, Israel, 2Hebrew University, Jerusalem, Israel — Previously, we found hemispheric differences when testing feature search with arrays wholly in one hemifield (Pavlovskaya et al., Spatial Vision, 2001), rather than testing with central arrays and lateral target elements. In parallel, Ahissar & Hochstein (Nature, 1997) found that perceptual learning transfer across position or orientation depends on the spatial conditions of the task: Learning effects transfer for easy tasks (large target-distractor difference; limited target-position uncertainty; long test-mask stimulus onset asynchrony) and are considerably specific with harder conditions. These differences are presumably related to cerebral modification site: hard tasks are seen as requiring low-level (specific) representations while easy tasks are performed using high cortical level mechanisms alone. We now ask if inter-hemispheric transfer also depends on task difficulty. Hard task learning might not transfer since low-level neurons have local receptive fields. Easy tasks, on the other hand, might transfer more than across hemispheres. Subjects performed color and orientation feature search, each with arrays in one hemifield. Separate sessions had easy or hard conditions. Following training, we switched the sides of the orientation and color tasks. We find nearly complete transfer for easy conditions, and considerably less with difficult conditions. Our results support the notion that feature search with easy conditions is performed at high cortical levels where representation mechanisms include much of the visual field on both sides of the vertical meridian.

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FR55

Acquiring long term visual representations in visual form agnosia Orna Rosenthal (ornar@andrew.cmu.edu), Marlene Behrmann; Carnegie Mellon University, CNBC, Pittsburgh, PA, USA — Patients with visual form agnosia are severely impaired at perceptual organization of visual information and consequently, at shape perception and object recognition, despite intact retinal and low level vision. At the same time many of these patients have the intact ability to imagine shapes and objects, implying spared long-term representation of visual information. What remains unclear in these patients is whether they can acquire new long-term visual representations.

We studied the ability of a visual form agnostic patient to learn new visual classes, abstracted from simple exemplars (stripes pairs), which were distributed across one dimension (stripe width). Initially, this patient was unable to classify stripes wider than 2 degrees, suggesting a deficit in processing stimuli that require neurons with large receptive fields. However, following long training the patient succeeded to learn the classification pattern, suggesting that he acquired and maintained representations of the new visual classes. The possible loci of plasticity/processing modification will be discussed.

FR56

Perceptual learning reveals separate neural events for speed and direction Tiffany N Saffell (saffell@denison.edu), Nestor Matthews; Department of Psychology, Denison University, Granville, OH, USA — Purpose: In principle, our ability to see subtle speed differences could be mediated by neural events that are the same as, or different from, the neural events mediating our ability to see subtle direction differences. Here, we sought to distinguish psychophysically between these possibilities by using a perceptual learning paradigm.

Method: Twenty-two Denison University undergraduates participated in the study. For each participant, we measured speed-discrimination thresholds and direction-discrimination thresholds before, during, and after extensive training. Half of the participants trained extensively on speed discrimination, while the other half trained extensively on direction discrimination. The speed judgments and direction judgments, for each participant, were made under identical stimulus conditions. The stimuli on each trial were two random-dot cinematograms (RDCs) that always differed from each other in speed and direction of motion. To ensure a fair comparison in learning rates, the initial levels of discriminability (d’ = 0.52) were equated across participants and tasks.

Results: The results indicated that the learning curves for direction discrimination were significantly steeper than those for speed discrimination (F(1,20) = 9.581, p = 0.006). Additionally, the significant practice-based improvements on each motion task did not transfer to the other motion task.

Conclusions: The task-specific learning rates and the lack of transfer suggest that the neural events mediating speed discrimination are at least partially independent from those mediating direction discrimination, and vice versa, even under identical stimulus conditions.


FR57

Bayesian model for reaching and grasping peripheral and occluded targets Erik J Schlicht (eriks@ege.psych.umn.edu), Paul R Schrater; University of Minnesota, USA — To make a successful reach, the visual system must take into account the accuracy of its knowledge of the location and size of an object. The spatial certainty of a target's location with respect to the hand is limited by the eccentricity of viewing (Hess & Hayes, 1994), and by the ability to convert a target in retinal coordinates to arm-centered coordinates in the presence of noisy transformations. In previous work (Schlicht, et al., VSS 2001), we found that for visible targets, max. grip aperture was at a minimum near the target location and increased linearly away from the target. More surprisingly, max. grip apertures for reaches to occluded targets show dependence on eye position, even though there is no visual information specifying target location. This dependence takes the form of a U-shaped grip aperture function centered around forward-view eye-position, irrespective of the target location. We developed a Bayesian model that can account for these changes in grip aperture. We assume that max grip aperture is a measure of spatial uncertainty in the observer’s estimate of the target location (Paulignon, 1991). Spatial uncertainty is modeled as increasing with target eccentricity, and with the amount of noise in the eye-to-arm coordinate transformations. We postulate that eye-position noise increases with deviations from the forward-view direction and that target locations are computed in eye-centered coordinates. By making both of these assumptions, we are able to account for both of the visual and eye-position effects observed in our previous findings. This modeling effort suggests that both the quality of visual information and the noise in sensori-motor transformations are taken into account when planning reaching movements. In addition, we suggest that target locations are converted and stored in eye-centered coordinates, even when the information about target location is not visual.
FR59
No evidence for visuomotor priming in a visually-guided action task Jonathan S. Cant1 (jcant@uwo.ca), David A. Westwood2, Kenneth F. Vohrer3, Melelyn A. Goodale1. 1University of Western Ontario, Canada, 2Dalhousie University, Canada – Craighero et al (Neuroreport 8, 1996, 347-349) demonstrated that grasping can be primed by previously viewing a bar in the same orientation as the goal object. However, because participants could not see the object they were grasping, it is not clear that the effects on reaction time should be construed as evidence for visuomotor priming (as the authors contend), or are simply due to the priming of a memory-driven movement (i.e., grasping of an unseen target). Therefore, in Experiment 1, we directly compared priming of memory-guided and visually-guided grasping using a paradigm similar to Craighero et al. We found that only memory-guided grasping showed evidence of priming. In Experiment 2, we used a more conventional priming paradigm to compare the effects of priming on both grasping and naming of a novel probe object. Prime and probe objects varied in orientation (same/different) and/or shape (same/different). Participants were faster to name the probe when its shape was the same as the prime. We were confident, therefore, that our paradigm could reproduce standard repetition priming effects on naming. Nevertheless, reaction time for grasping was unaffected by the orientation or the shape of the prime. In Experiment 3, participants reached to grasp a probe object after first viewing or grasping a prime. Reaction time for grasping again remained unaffected in both tasks. Taken together, these results suggest that the initial programming of visually-guided grasping is determined more by what is on the retina than by what is in memory.

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Clinical, Tübingen, Germany—Recent studies have shown that global information about shapes is processed in both early ventral (i.e. V1, V2, Vp, V4) and higher occipitotemporal visual areas (i.e. Lateral Occipital Complex-LOC). However, the temporal properties of shape processing across visual areas in the human brain are not known. We addressed this question in a combined fMRI and MEG study that made use of the complimentary spatial and temporal resolution of the two techniques. We used an event-related adaptation paradigm in which lower neural responses are observed for two identical than two different consecutively-presented stimuli. The stimuli were closed contours that consisted of collinear Gabor elements. We manipulated the interstimulus interval (ISI: 100 vs. 400 msec) between the two consecutively-presented stimuli. The fMRI results showed adaptation for both the short and the long ISI in the LOC but only for the short ISI in early visual areas. The MEG data showed similar patterns of response amplitude to the fMRI data and differences in latencies for the different ISIs across visual areas. These findings suggest sustained shape processing in higher visual areas compared to more transient visual analysis in early visual areas. Further studies test the analysis of local vs. global shape features across areas with different temporal processing properties.

Acknowledgment:

Max Planck Society

FR63

One channel per object? Denis G Pelli (denis.pelli@nyu.edu), Marialuisa Martelli, Najib J Majaj, Tracey D Berger; Psychology and Neural Science, New York University, USA—We grew up thinking that all our channels are always available, waiting to be used, like the strings in a piano. Majaj et al. (2002 & this VSS) show that observers identifying letters or reading use only one spatial frequency channel, determined by the stroke frequency of the letters. We show that this is also true for faces and line drawings of common objects. There are indications that our visual system assigns an independent neural assembly to each perceived object/event in order to estimate speed or orientation, or track position (Verghese & Stone, 1995; Berger et al., submitted; Pylyshyn, 1989). Are all these mechanisms—channels, estimators, and trackers—just different aspects of the same neural assembly, synthesized, bottom-up, by the visual system, to represent each perceived object/event?


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FR64

Learning and recall of object and pattern discriminations during bilateral reversible deactivation of the superior colliculus

Stephen G Lomber1 (lomber@utdallas.edu), Amanda B Kopacz2; 1Behavioral and bilateral reversible deactivation of the superior colliculus and the other three animals served as controls. Bilateral deactivation of the superficial layers of the superior colliculus impaired the learning of both the simple and complex patterns, with the complex pattern learning being profoundly retarded. Bilateral collicular deactivation had a minor effect on the learning of black three-dimensional object pairs. Deactivation of the superior colliculus did not have any effect on the ability to recall any of the form discriminations. Therefore, we conclude that bilateral cooling of superior colliculus disrupts the tecto-extrageniculate pathway to extrastriate visual cortex and impairs the learning of two-dimensional patterns. These observations have significant bearing on our understanding of contributions that non-geniculate pathways to extrastriate cortex make to visual processing in cat, monkey and human cortices.

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FR65

A stereo advantage in generalizing over rotations in depth on a same-different successive matching task

David J. Bennett (David_Bennett@Brown.edu); Brown University, USA—PURPOSE. To determine whether there is a stereo advantage in generalizing over rotations in depth on a same-different successive matching task, as a way of testing 2D template-matching models of form-matching performance. METHODS. The stimuli were (simulated) shaded, randomly shaped, closed tubes. On some trials (“Same trials, different rotation”) the second presentation consisted of the form shown first, rotated in depth around a horizontal or ‘side-to-side’ axis. In Experiment 1, performance when viewing was in (simulated) stereo was compared to performance when one eye was covered, using (total) rotations of 38 degrees (19 degrees ‘up’ and 19 degrees ‘down’). On Same trials with differing rotations there was a stereo advantage of 70.6 percent to 57.3 percent; t(17) = 5.154, p < .001. In Experiment 2, rotations of 38 degrees (total) were also used, and the nonstereo condition consisted of showing (essentially) the same image to each eye. On Same trials with differing rotations there was a stereo advantage of 64.34 percent to 56.81 percent; t(25) = 2.718, p = .006. Experiment 3 was the same as Experiment 2, except that rotations of 30 degrees (total) were used. On Same trials with differing rotations, there was a stereo advantage of 68.43 percent to 57.85 percent; t(25) = 3.991, p < .001. In each experiment, performance under nonstereo viewing (Same trials, different rotation) was significantly greater than 50 percent (p < .025, p < .005, respectively). Signal detection analyses will also be presented.

CONCLUSIONS. At least with a difficult task, and stimuli that encourage global encoding, there is a stereo advantage in generalizing over changes of rotation in depth. The results count against 2D template-matching models of subject performance.

FR66

Superior change detection at shape concavities

Elias H Cohen (elias@ruccs.rutgers.edu), Elan Barenholz, Manish Singh, Jacob Feldman; Rutgers University, USA—Shape representation was studied using a change detection task. Observers viewed two individual shapes in succession, either identical or one a slightly altered version of the other, and reported whether they detected a change. We found a dramatic advantage for changes involving shape concavities compared to those involving convexities of equal magnitude. In Experiment 1, observers were more accurate when a concavity along the contour was introduced, or removed, compared to a convexity. Experiment 2 showed the same detection asymmetry for changes involving a simple modification of an existing concave or convex vertex. In both experiments, a large difference in sensitivity for contour type (reported in d’) was observed across both directions of change (addition or deletion of shape area) as well as across all change magnitudes studied. This result sheds light on the underlying representation of visual shape, and in particular the central role played by part boundaries. Moreover, this finding shows how change detection methodology can serve as a useful tool in studying the specific form of visual representations.

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FR67  
Superordinate interference in basic level object recognition: The effects of object typically  
Jun-ichi Nagai  
Kazuhiko Yokosawa, University of Tokyo, Japan - It has been claimed that object recognition at the basic level is prior to other levels (Rosch et al., 1976). However, recent results suggest that superordinate categorical information can interfere with basic level recognition, independent of perceptual properties of objects (Yokosawa et al., ARVO 1996; Nagai & Yokosawa, ARVO 2001). In this study, we further examined the influence of superordinate category, especially whether the within-category typology would affect basic level object recognition. The typicality was manipulated according to the results of a questionnaire rating experiment. We employed an object detection paradigm: Following a basic level word cue (1000 ms; e.g., "dog"), a two-frame sequence of color photographic objects was presented rapidly (200 ms for each frame, with 100-ms ISIs). By means of the three-way choice, participants were required to judge correctly whether 1) the target object appeared in the first frame, 2) it appeared in the second frame, or 3) it did not appear, as fast as possible. When the target objects appeared in the first frame, the judging time was not influenced by whether the second objects belonged to the same superordinate category (e.g., DOG - CAT). However, when the target objects appeared in the second frame and the first objects belonged to the same superordinate category (e.g., CAT - DOG), the judging time became slower than when the two objects had no relation. We refer to this delay effect as 'superordinate interference,' which indicates that superordinate categorical information is processed automatically and interfere with basic level object recognition. More importantly, the superordinate interference was observed when the objects were typical, whereas it was not observed when the objects were atypical (e.g., HIPPOPOTAMUS - CAMEL). We discuss the relations between these results and the family resemblance structure of category (Rosch & Mervis, 1975).

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FR68  
Center-surround antagonism affects visual motion coherence  
Joseph S Lappin (joe.lappin@vanderbilt.edu), Duje Tadin, Anup Panduranga; Vanderbilt Vision Research Center, Vanderbilt University, US – Purpose: Motion responses of many cells in the macaque area MT exhibit center-surround antagonism. Recently, we discovered a surprising psychophysical correlate of this physiological effect: Duration thresholds for discriminating directions of brief moving Gabors increase substantially when spatial area and contrast exceed critical values (e.g., Tadin & Lappin, VSS 02). The present study extended this finding to partially correlated random-dot kinematograms (RDks). We asked two questions: (1) Does increasing the size of a moving pattern reduce its visual signal/noise ratio? (2) Is the signal/noise of a central pattern enhanced by an oppositely increasing the size of a moving pattern reduce its visual signal/noise ratio?

Methods: RDks appeared in Gaussian spatial and temporal windows. A Quest procedure adjusted the percentage of pixels maintaining the same value (black or white) between adjacent frames (120 Hz), with the remaining pixels independently regenerated. One experiment measured correlation thresholds for discriminating directions of brief (2s = 16-64 ms) patterns of varied spatial area (15-300 arcmin diameter). Another experiment evaluated correlation thresholds for discriminating correlated from uncorrelated central patterns surrounded seamlessly by RDks moving the same or opposite direction.

Results: With increasing size, spatial summation initially produced lower correlation thresholds at small sizes, but further size increases produced spatial suppression. The largest patterns had the highest thresholds. Correlation thresholds were also higher when the surrounding pattern moved the same direction than when it moved the opposite direction.

Conclusion: Signal/noise ratios of visual motion signals are context-sensitive, apparently involving early spatial differentiation.

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FR69  
Perception of coherent pattern in motion  
Shin’ya Nishida  
(Nishida@bri.ntt.co.jp); NTT Communication Science Laboratories, Atsugi, Kanagawa, Japan – The first stage of visual motion processing is a bank of direction and spatial-frequency selective sensors. If the analysis of moving pattern is completely independent between different frequency bands, it should not be possible to properly integrate pattern information across spatial frequencies that are signalling different directions of motion. An analysis of the multi-slit view however indicates that even when motion detection fails for certain frequencies, we can see a spatially coherent pattern in motion. In the multi-slit view, horizontally moving letters presented through an array of vertical slits can be effortlessly read in spite of only a fraction of the image being actually presented at any instant of time. This phenomenon can be ascribed to the brain’s spatiotemporal interpolation by direction-selective integration of spatial pattern information (Nishida, VSS’02). In order to determine the degree to which pattern information is recovered by the interpolation, I conducted a psychophysical reverse-correlation experiment. The result suggested that observers could see image components whose horizontal frequencies were slightly higher than the Nyquist frequency of the slit sampling, although these components, when presented alone, should appear to move in the reverse direction (motion aliasing). Although this finding could indicate the perception of the fragmented (and left-right reversed) pattern information in the aliasing components, it was found that the addition of the over-Nyquist components significantly improved the discrimination of normal letters from mirror writings. In addition, this improvement occurred only when these components were presented together with sub-Nyquist low-frequency components, which resulted in coherent pattern motion in the correct direction. These findings suggest that the moving pattern analysis involves a cooperative interaction between different spatial frequency bands that helps us see coherent dynamic visual scene.

http://www.bri.ntt.co.jp/people/nishida/Presentation/VSS2003

FR70  
Motion coherence thresholds can be elevated by flicker adaptation or red background  
Ryan A Hoag (hoag@interchange.ubc.ca), Craig S Chapman, Deborah E Giaschi; University of British Columbia, Canada – Purpose: Previous studies have shown that motion coherence thresholds are elevated in several disorders including dyslexia (Cornelissen et al. 1995), glaucoma (Silverman et al. 1990), Alzheimer’s disease (Gilmore et al. 1994) and Parkinson’s disease (Trick et al. 1994). This threshold elevation is consistent with a deficit in the functioning of the magnocellular (M) pathway. We compared two psychophysical methods of temporarily disrupting normal M-pathway functioning as indexed by elevated motion coherence thresholds. Methods: 30 normal adults participated in this study. We measured motion coherence thresholds for limited lifetime dots moving left or right at a speed of 0.935 deg/s. Dot density was 1 dot/deg2. Coherence thresholds were determined in 4 conditions: after 2 minutes of adaptation to (i) a uniform field flickering at 9 Hz (experimental 1) (ii) a uniform gray field (control 1) and with dots presented on (iii) a uniform red background (experimental 2) and (iv) a gray background (control 2). Results: Motion coherence thresholds were significantly elevated in both experimental conditions (experimental 1 M = 0.2271, control 1 M = 0.1981, experimental 2 M = 0.2198, control 2 M = 0.1873). In addition, the threshold elevation was significantly greater after flicker adaptation than in the presence of a uniform red background. Conclusions: Either flicker adaptation or a red background can be used to disrupt direction selective global motion perception. Physiological studies have shown that magnocellular layers of the LGN are inhibited by a red background (Wiesel & Hubel, 1966) and are essential for flicker perception in monkeys (Mergian, Byrne & Maunsell, 1991). Therefore our results suggest that interference with processing at this level in the M pathway disrupts global motion perception. These techniques are currently being used to study the relationship between M-pathway functioning and reading in people with dyslexia.
Acknowledgment: Supported by a grant from the March of Dimes Birth Defects Foundation

FR71
Catastrophic Switching of Perceived Motion Direction  Linda Browns1 (lbowns@psychology.nottingham.ac.uk), David Alais2; 1University of Nottingham, UK, 2Istituto di Neurofisiologia del CNR, Italy – Aim: The motion literature contains two hypothetical rules for combining 1D moving Fourier components into pattern motion, the Intersection of Constraints (IOC) and the Vector Average (VA). Last year we presented data showing that stimuli perceived in the (IOC) direction shifted to the VA direction following adaptation in the IOC direction by a moving plaid or grating. This year we report experiments conducted at short durations (160 ms). Methods: Two type II plaid patterns were examined. Preadaptation, one was perceived in IOC direction, the other in VA direction. Perceived pattern direction was remeasured after 16s of grating adaptation in either IOC or VA direction. Adaptation duration, spatial and temporal frequency of the adaptor were also investigated. Results: Adaptation led to dramatic direction shifts: (i) Patterns moving in IOC direction (preadapt) switched to VA direction following IOC adaptation; (ii) Patterns moving in VA direction (preadapt) switched to IOC direction following VA adaptation. Adaptation time-course showed as little as 1s was enough to produce catastrophic switching between IOC and VA directions. Strikingly, direction switching is not tuned to adaptor spatial or temporal frequency (over a 6-octave range) or spatial frequency (over 4 octaves). Conclusions: The IOC and VA solutions are both encoded by the motion system. Either direction can be perceived in the same test pattern: simply adapting the dominant direction solution will reveal the other. The mechanism(s) underlying the two solutions appear not to be spatially or temporally tuned.

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FR72
Spatial integration of curved surfaces in structure from motion  Massimiliano Di Luca1 (Massimiliano.Di_Luca@brown.edu), Faivilo Dominì1, Corrado Caudek2; 1Brown University - USA, 2Università di Trieste - Italy – Structure-from-motion studies have shown that the perceived slant of a local planar patch is (1) an increasing function of deformation and (2) a decreasing function of the average velocity of the first-order optic flow (Dominì Caudek 1999, Todd and Perotti, 1999). Recent findings, however, indicate that local judgments are subject to a process of spatial integration when local patches are embedded in a global optic flow (Di Luca, Dominì and Caudek, 2002).

To generalize the previous work, in this study we asked human observers to judge the perceived orientation of local patches of a rotating random-dot spherical surface. These patches could either be seen in isolation or as part of the whole surface. In two experimental conditions the axis of rotation was either in front or behind the simulated surface so to allow the same surface patch to project in each condition the same deformation but different average velocities. The results can be summarized as follows: (1) When the patches were judged in isolation perceived orientations were consistent with those in previous studies on local slant perception. (2) When the whole surface was visible, the local judgments were consistent with the perception of a quasi-spherical surface, suggesting a process of spatial integration. (3) These judgments were not consistent, however, with the veridical percept of the spherical surface and they also indicated that different structures were perceived when the position of the axis of rotation was changed. Surprisingly, we also found that when the same random-dot sphere rotates about different axes of rotation it is perceived as having two qualitatively different shapes (see demo on www.cog.brown.edu/~max/pub/sphere_integration/index.htm).

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FR73
Direction repulsion – a local or global phenomenon?  Christopher P Benton1 (chris.benton@bristol.ac.uk), William Curran2; 1University of Bristol, UK, 2Queen’s University Belfast, UK – It is widely believed that motion processing can be split into two stages, a local directionally selective stage followed by a global velocity sensitive stage. Here we investigate the phenomenon of motion repulsion and ask at which of these stages in the motion processing hierarchy repulsion occurs. Our stimulus consisted of two translating, superimposed planes of Laplacian of Gaussian dots whose directions of motion differed by 60 degs. Using an adaptive method of constant procedure, we measured the strength of the direction repulsion of a target (speed 2.5 deg/sec) as a function of distractor speed (0.625-15.0 deg/sec) and found an inverted-U function peaking at about 5 deg/sec. To distinguish between local and global theories of motion repulsion we investigated the target repulsions induced by distractors containing pairs of velocities (2.5 & 10 deg/sec, 1.25 & 12.5 deg/sec, 0.625 & 15 deg/sec). Each constituent dot was assigned one of the two speeds (with equal probability) for the duration of the stimulus. We define a local repulsion model as one in which the repulsion of the target is a weighted sum of local repulsion measures. Our inverted-U tuning function gives the local repulsion for each distractor speed. The model cannot produce a magnitude of motion repulsion that is greater than that given by the more efficacious of the distractor velocities. For both subjects, the magnitude of repulsion was consistently (and significantly) greater than the maximum repulsion predicted by the local model. In fact, the magnitude of repulsion would be better predicted by the mean of the distractor set (our global prediction). This pattern of results occurs in spite of the fact that the distractors themselves appear to contain two transparent motions. Our findings argue strongly against the local model of direction repulsion. We propose that motion repulsion occurs after global motion extraction.

FR74
Linking levels in motion pattern formation through dynamical coupling: evidence from psychophysics and simulations  David F Nicholls3 (haveanicedave@hotmail.com), Howard S Hock4, Arnemie Pluiger2, Gregor Schöner5; 1Department of Psychology, Florida Atlantic University, USA, 2Department of Psychology, University of Amsterdam, The Netherlands, 3Institute for Neuroinformatics, University of the Rühr, Germany – Motion pattern formation is studied for the motion quartet, a bistable apparent motion stimulus for which either a horizontal or vertical motion pattern is perceived. Because there is more detector activation for shorter motion paths (Gilroy & Hock, 2000), the horizontal pattern is favored when the aspect ratio of the quartet (vertical/horizontal distance) is relatively large, and the vertical pattern is favored when the aspect ratio is relatively small. The dynamical basis of pattern formation is indicated by the occurrence of hysteresis when the aspect ratio is gradually increased and gradually decreased (Hock, Kelso & Schöner, 1993). In the current study, changes in motion detector activation were introduced during the course of hysteresis "runs" by perturbing the luminance contrast of the motion quartet. This perturbation affects the dynamics of local motion detectors; for the same reduction in contrast, motion sometimes is perceived and other times nonmotion is perceived (Hock, Kogan & Espinona, 1997). It was found that perturbations of luminance contrast affect the pattern-level hysteresis obtained by varying the aspect ratio of the motion quartet, and further, that the reduction in hysteresis due to a downward perturbation depends on the local-level dynamics (i.e., whether or not there is a switch from motion to nonmotion as a result of the perturbation). This evidence for the coupling of local- and pattern-level dynamics is simulated with non-linear dynamical equations representing the activation of directionally selective motion detectors in Area V1 (where inhibitory interactions are with detectors activated by motion-independent stimulus information) and Area MT (where inhibitory interactions are with motion detectors having different directional selectivity).
FR75
Parametric decomposition of complex motion by humans Jose F Barraza1 (jfb@bmsr.usc.edu), Norberto M Grzywacz 2; 1Department of Expansion and spiral motions. With the hypothesis that the brain parametrically decomposes complex motions to estimate elementary motion parameters, such as angular velocity and rate of expansion. Although these estimates are correct, the sensitivity for discrimination is maximal for pure motions, decreasing with the increase of the mask component. Conclusions: Our results are consistent with the hypothesis that the brain parametrically decomposes complex motions to estimate elementary motion parameters, such as angular velocity and rate of expansion. However, pure rotations and pure expansions are rare in natural motions. Nevertheless, one can almost always decompose visual motions of small surface patches in terms of few elementary components including rotation and expansion. Hence, we wondered whether the brain can decompose complex motions to estimate elementary motion parameters, such as angular velocity and rate of expansion. Although these estimates are correct, the sensitivity for discrimination is maximal for pure motions, decreasing with the increase of the mask component. Conclusions: Our results are consistent with the hypothesis that the brain parametrically decomposes complex optic flows into few elementary components. We interpret these results with a population-code model based on cells selective to rotation, expansion and spiral motions.

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FR76
The neural correlates of global flow motion by fMRI in the conditions in which motion opponency and attention were controlled Shinichi Koyama1,2, (skoyama@bu.edu), Yuka Sasaki2, Roger B Tootell2, Takeo Watanabe2; 1Boston University, Boston, USA, 2MGH-NMR Center, Boston, USA – Watanabe et al (2001, VSS) showed that in MT+ and V3A of humans fMRI signals were higher when the subjects were viewing a global motion flow in a so-called Sekuler display (in which dots moved spatiotemporally locally within a certain range of directions, Williams & Sekuler, 1984) than random motion. In contrast, in V1 no significant difference was found between the two types of displays. The results suggested that that global flow motion might be generated in V3A and MT+ and local motion in V1. However, it was not clear whether the activation in MT+ and V3A was due to the global motion signal or due to a smaller amount of suppression between opponent motion directions in the Sekuler display than in the random motion display. To control the motion opponency (Heeger et al., 1999), here we used a transparent Sekuler display (TSD) in which half dots moved randomly within a 45 degree range and the other half within the opposite 45 degree range (e.g., 0 deg-45deg and 180deg-225deg), so that two global motion flows in opposite directions were clearly perceived to move transparently. TSD gives greater opponent-motion suppression than the random motion display. Siemens 3T scanner was used along with flattened occipital format. The subjects were instructed to maintain fixation at a central spot while the TSD and the random motion display were presented alternately every 16 seconds. Despite the greater opponent suppression, the same results as in the previous study were obtained. That is, TSD induced significantly higher activity in MT+ and V3A than the random motion display, whereas no significant difference was found in V1 activity between the two conditions. We conducted another experiment in which a speed increment detection task was performed during the exposure to the two displays to control attention (Huk et al., 2001). The same tendency was obtained. We conclude that global flow motion is indeed processed in V3A and MT+ and local motion in lower stages including V1.

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FR77
The effect of dot lifetime, dot size, & percent area covered by dots on motion coherence thresholds: Implications for diagnosing reading difficulties Nancy S Wada (nswada@vax2.concordia.ca), Michael W von Grunau, Guy L Lacroix, Roberto G de Almeida, Rick Gurney, Normam S Segalowitz; Concordia University, Montreal, Quebec, Canada – Purpose: Prior research has established that individuals with reading difficulties tend to perform more poorly than controls on tasks requiring them to identify the overall direction of motion within a random dot kinematogram (RDK). However, it is unclear whether the size of the difference in performance between individuals with reading difficulties and their ‘normal’ counterparts is a function of reading ability or the stimulus parameters used. In this investigation, we examine the degree to which the lifetime of dots, the size of dots, and the percent area covered by dots affect the ability to identify the direction of motion in normal individuals. Methods: Observers (N=7) were asked to indicate whether the global direction of the dots contained within a 3 degree square region was leftward or rightward. The dots within the RDK varied in terms of lifetime (16.7 or 33.3ms), size (1 or 2 pixels in diameter), and percent area covered (1 or 21%). Results: Changes in the parameters of the RDK affected subjects’ ability to identify the direction of motion. When the lifetime of the dots was short and the percent area covered was high, observers had more difficulty in judging the overall direction of movement for larger than for smaller dots. In addition, when the lifetime of the dots was short and the dot size was large, observers had more difficulty in identifying the motion direction for higher than for lower percent area covered. In contrast, these effects disappeared when the lifetime of the dots was lengthened; the overall pattern of results suggests that increasing the lifetime of the dots increased the difficulty of the task. Conclusion: Motion coherence thresholds are dependent on the parameters used during testing. One implication of this investigation is that the specific combination of parameters used may facilitate or hinder the detection of differences between those with reading difficulties and controls.

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FR78
Oblique effect in human MT+ follows pattern rather than component motion Denis Schlippeck (ds@mcs.qupa.edu), Stephen A Engel; UCLA Department of Psychology, USA – Behavioral experiments reveal that motion in cardinal (vertical or horizontal) directions is represented more strongly in the visual system than motion in oblique directions. For example, discrimination of direction of motion is better for cardinal than oblique stimuli. The goal of this study was to determine whether human MT+ shows the neural bias predicted by these behavioral findings. We first localized human MT+ and area V1 in four subjects using standard methods. We then compared cortical responses to two types of stimuli. In the first, two component gratings were oblique (spatial freq 0.8cpd, temporal frequencies 2-6Hz, contrast 0.4, orientations 45º and 135º) and formed a plaid pattern that moved at 90º. In the second stimulus, the components were cardinal (0º and 90º) and formed a plaid that moved at 45º. Patterns were presented in two Gaussian windowed patches (sigma=2º) at 5º eccentricity, to the left and right of fixation. To control for effects of attention, subjects performed speed discriminations on the stimuli in a two-interval forced choice paradigm. Change in fMRI signal (3T BOLD, EPI) in human MT+ was reliably greater for patterns moving in cardinal than oblique directions. V1 activity showed opposite effects: change in fMRI signal was reliably greater for patterns moving in oblique directions (containing cardinal components). Our results indicate that MT+ responds best to principal pattern motion even though the components are oblique. These findings suggest that human MT+ contains large populations of pattern-selective cells, whose distribution is biased towards cardinal directions. Such a bias in the neural circuitry could explain the perceptual oblique effects for moving stimuli.
FR79
Direction discrimination performance measured using a Fourier domain signal-to-noise paradigm George W Mather (georgem@biols.susx.ac.uk), Andrew K Daniell; University of Sussex, UK – Local motion sensors are selectively sensitive to the spatiotemporal Fourier energy generated by retinal image movement. We have developed a Fourier-domain signal-to-noise paradigm to investigate how the outputs of motion sensors are combined during integration. In the space domain, stimuli were two-frame 1-D random-line kinematograms. In the Fourier domain, frequency components were divided into noise components and signal components. Noise components shifted in phase by a random amount in either direction. Signal components either (i) shifted in phase in the same direction by a constant phase angle; or (ii) shifted in phase in the same direction by a constant velocity. Signal direction varied randomly from trial to trial, and the observer was required to report the direction of motion seen in each trial. We measured the minimum ratio between signal and noise components required for reliable direction discrimination. Data showed a performance advantage for the constant-phase stimulus over the constant-velocity stimulus. This result, and data from subsequent experiments, is discussed in the context of current motion integration models.

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FR80
Bias past the vector-sum direction in Type 2 plaids Alan B Cobo-Lewis (alanc@maine.edu), Richard S Hetley; University of Maine, USA – Purpose: It is commonly reported that the perceived direction of moving Type 2 plaids is biased away from the veridical intersection-of-constraints (IOC) direction and toward the vector-sum direction. A recent analysis of a Bayesian model of motion extraction predicts that when one of a plaid’s component gratings gives a more reliable motion signal than the other component grating, perceived direction should be biased toward the grating with the more reliable motion signal. In Type 2 plaids, a sufficiently large bias toward the lower-speed grating could yield perceived direction beyond the vector-sum direction. By presenting Type 2 plaids whose components are of unequal spatial frequency (SF), we can manipulate the reliabilities of the gratings’ respective motion signals and thus test the prediction. Methods: Naïve subjects viewed Type 2 plaids whose component gratings drifted in directions separated by 15° and whose speeds differed by a factor of sqrt(1.5). We manipulated the ratio of the gratings’ SFs while holding constant the geometric mean of their SFs. Subjects pointed an arrow in the direction of perceived drift. Results: When the gratings were of equal SF, perceived direction was close to the vector-sum direction. When the faster grating had higher SF, perceived direction was between IOC and vector-sum directions. When the slower grating had sufficiently higher SF, perceived direction was beyond the vector-sum direction, as predicted. Conclusions: A Bayesian computational model of motion extraction suggests that the vector-sum rule is a special case of an endpoint prediction whose general case is a weighted vector sum, with weights given by reliability of a grating’s motion signal. Because a computational analysis indicates that the reliability varies with SF, the model predicts bias toward the higher-SF grating, which sometimes entails bias beyond the vector-sum direction. This prediction was confirmed.

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FR81
Contrast, coherence and directional tuning Christina M Anderson (canderson@psy.ucsd.edu), Ione Fine, Karen R Dobkins; UC San Diego, California, USA – Purpose: Previous psychophysical and neurophysiological studies report broad directional tuning of motion mechanisms, with bandwidths (width at half height) ranging from 70 -120 (e.g., Ball & Sekuler, 1980; Albright, 1984). In motion area MT, this tuning is also largely invariant with coherence (Britten & Newsome, 1998). We measured directional tuning psychophysically by having subjects detect global motion across a wide range of motion coherence and contrast levels. Methods: A 2-FC procedure was used; the ‘noise’ interval contained randomly moving dots and the ‘signal’ interval contained noise plus two superimposed fields of coherently moving dots. We tested 7 angular differences between the directions of the two dot fields (delta=0, 22.5, 45, 67.5, 90, 135, and 180). We obtained two types of thresholds for 3 subjects: (1) coherence thresholds, where the proportion of dots moving coherently in the ‘signal’ interval was varied. Coherence thresholds were obtained for several fixed contrasts (rms, 3.2 – 30.2%), and (2) contrast thresholds, where the contrast of the dots was varied. Contrast thresholds were obtained for several fixed coherence levels (20 – 100%). Thresholds for a given contrast and coherence did not depend on whether coherence was fixed and contrast varied, or vice versa. Directional tuning bandwidths were calculated by fitting Gaussian functions to threshold ratios (threshold for delta=0 / thresholds for the other deltas) plotted as a function of delta. Results and Conclusions: We found that directional tuning had a bandwidth of 60-70 that was nearly invariant across a wide range of luminance contrasts and coherence levels, including contrasts and coherences for which MT responses saturate. However, we found broader tuning, of ~110-120 , at the intersection of very low contrasts (< 4%) and high coherences (> 45%).

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http://psy.ucsd.edu/~ifine/

FR82
Polarity-contingent motion aftereffects at the stage of local motion processing Erik Blaser1 (erik.blaser@umb.edu), Thomas V Papathomas2, Zoltan Vidnyanszky2; 1Human Vision Laboratory; University of Massachusetts, Boston; USA, 2Laboratory of Vision Research; Rutgers University; USA, 3Vision Research Laboratory, Neurobiology Research Group; Hungarian Academy of Sciences; Hungary – It has been shown that there is strong inhibition between opposite motion directions at the global motion stage, while at the local motion stage opposite directions are processed independently. We predict that adaptation to opposite motion vectors – even in the case of locally-paired opposite motion which is perceived as motionless fliccker – will lead to a local, direction-specific motion adaptation. Procedure: Observers viewed two fields of superimposed, limited-lifetime (6 frames) drifting dots. One field (of black dots) drifted rightward, the other (white dots) leftward. In one condition, black and white dots were strewn independently, so transparent motion was seen; in another condition, each black dot was locally paired with a white dot, so the display appeared as directionless flicker. These stimuli were used as adaptors in a motion aftereffect (MAE) paradigm, using a top-up procedure. Test stimuli consisted of one field of static, infinite-lifetime dots (either black or white) and another field of dots (of opposite polarity to static field) drifting upward. Any polarity-contingent MAE (PCMAE) would introduce a tilt in the motion vector of the upward drifting field; this tilt was taken as a measure of the direction and magnitude of the PCMAE. (At last year’s VSS we reported that the addition of a relative motion cue to the presence of two surfaces is necessary for expression of the PCMAE when both polarities are in the test.) Results: In both non-paired and locally-paired conditions, both naive and expert observers showed significant PCMAE’s of comparable magnitude. Conclusion: Adaptation to opposite motion leads to polarity-contingent motion aftereffects at the local motion processing stage even in those cases when, due to the short range integration of locally paired motion vectors, global motion is cancelled and only local signals remain. Such local PCMAE’s can be a useful new tool for the study of the mechanisms of local motion processing.

Acknowledgment: grant from NEI-NIH
FR83 Extending the ‘dorsal stream vulnerability hypothesis’: Spatial reorientation and motion and form coherence in children and adults with Williams syndrome Janette Atkinson1, (j.atkinson@ucl.ac.uk), Oliver Bradrick2, Shirley Anker3, Marko Nardini1, Ursula Bellugi1, Frederic E. Rose2, Yvonne Searcy2, Nasim Bavar2; 1Visual Development Unit, Psychology Dept, University College London, UK, 2Dept Experimental Psychology, Oxford University, UK, 3Laboratory of Cognitive Neuroscience, Salk Institute, San Diego, CA, USA – INTRODUCTION. From results of our previous studies on motion and form coherence thresholds, and on a modification of the Goodale post box task, we have put forward a general hypothesis of ’dorsal stream vulnerability’, where certain brain circuits, within the parietal and frontal lobes together with the cerebellum, develop differently to normal in Williams Syndrome (WS) children. Using comparative measures of motion and form coherence, we have extended this hypothesis to children with autism and focal lesions leading to hemiplegia and elucidated the brain networks using fMRI in normal adults.

METHODS. We have tested both high functioning adults and young children with WS. We report results on two tasks: (a) an adaptation of the ‘altered views’ task of spatial reorientation - a virtual reality game to assess hippocampal function (adapted from O’Keefe, Burgess and King); (b) Form and motion coherence thresholds in WS adults.

RESULTS. In the altered views task, two inter-related difficulties have been identified for WS individuals: i) understanding the visual transformation from 2D to 3D; ii) the ability to switch between spatial representations at different positions in space (although spatial memory from a constant viewpoint may be normal). On coherence tasks we find that form coherence thresholds did not differ significantly between our groups of WS adults and normal controls, but motion coherence thresholds were significantly higher for the WS group.

DISCUSSION. The results suggest that poor dorsal stream functioning in WS continues into adulthood, and that it is coupled to a difficulty in transforming environmental spatial information which may require hippocampal processing or visuospatial information. We discuss the broader ‘dorsal stream hypothesis’ in relation to other neurodevelopmental disorders such as perinatal brain injury.

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FR84 Motion processing in Williams syndrome: Evidence against a general dorsal stream deficit Jason E. Reiss1 (jreiss@udel.edu), James E. Hoffman1, Barbara Landau2; 1University of Delaware, USA, 2Johns Hopkins University, USA – Williams syndrome (WS) is a rare genetic disorder characterized by profound spatial deficits and relatively spared language skills. One attempt to understand the nature of the WS spatial deficit draws on the distinction between ventral and dorsal visual pathways. Findings of intact WS face recognition and object identification suggest preserved ventral stream functioning while other reports are consistent with a dorsal visual processing deficit in WS. For example, Atkinson et al. (1997) reported that WS subjects were impaired in motion coherence tasks, a putative dorsal stream function. In contrast, Jordan et al. (2002) reported that WS individuals were at least as good as mental-age-matched controls (MA) in their ability to discriminate biological motion. Preserved biological motion perception might reflect a general sparing of form-from-motion systems or could be due to the high level of interest in social stimuli associated with WS. We tested this by examining performance of WS individuals on three motion tasks: motion coherence, 2D form-from-motion, and biological motion. Tasks were equated for the size, speed, and contrast of the moving elements. Results indicated that WS individuals performed at normal levels for both motion coherence and biological motion tasks but had slightly elevated thresholds for the 2D form-from-motion task. These findings argue against characterizing WS as including a general motion processing deficit and are considered in the context of the role of dorsal and ventral processing in WS.

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FR85 Deficits in the processing of local and global motion in very low birthweight children Terri L. MacKay1 (ummackay1@cc.umanitoba.ca), Lorna J Jakobson1, Dave Ellemberg2, Terri L Lewis1, Daphne Mauer1, Oscar Casiro3; 1Department of Psychology, University of Manitoba, Winnipeg, MB, Canada, 2McGill Vision Research Unit, McGill University, Montreal, PQ, Canada, 3Department of Psychology, McMaster University, Hamilton, ON, Canada – INTRODUCTION. From results of our previous studies on motion and form coherence thresholds, and on a modification of the Goodale post box task, we have put forward a general hypothesis of ‘dorsal stream vulnerability’, where certain brain circuits, within the parietal and frontal lobes together with the cerebellum, develop differently to normal in Williams Syndrome (WS) children. Using comparative measures of motion and form coherence, we have extended this hypothesis to children with autism and focal lesions leading to hemiplegia and elucidated the brain networks using fMRI in normal adults.

METHODS. We have tested both high functioning adults and young children with WS. We report results on two tasks: (a) an adaptation of the ‘altered views’ task of spatial reorientation - a virtual reality game to assess hippocampal function (adapted from O’Keefe, Burgess and King); (b) Form and motion coherence thresholds in WS adults.

RESULTS. In the altered views task, two inter-related difficulties have been identified for WS individuals: i) understanding the visual transformation from 2D to 3D; ii) the ability to switch between spatial representations at different positions in space (although spatial memory from a constant viewpoint may be normal). On coherence tasks we find that form coherence thresholds did not differ significantly between our groups of WS adults and normal controls, but motion coherence thresholds were significantly higher for the WS group.

DISCUSSION. The results suggest that poor dorsal stream functioning in WS continues into adulthood, and that it is coupled to a difficulty in transforming environmental spatial information which may require hippocampal processing or visuospatial information. We discuss the broader ‘dorsal stream hypothesis’ in relation to other neurodevelopmental disorders such as perinatal brain injury.

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FR86 Motion perception with 5-HT2 receptor-blocking medications Chentel Christman1 (Chentel.Christman@ndsu.nodak.edu), Stephen Setterberg2, Mark Nawrot, 1Department of Psychology, North Dakota State University, Fargo, ND, USA, 2Prairie at St. John’s, Fargo, ND, USA – It has been suggested that medications blocking 5- HT2 receptors may produce a selective motion perception deficit called akinetopsia. Horton and Trobe (1999) reported two cases of transient akinetopsia resulting from high doses of serotonin ( nefazodone ). However, it is difficult to distinguish akinetopsia from more common visual side effects including palinopsia, a prolonged image of an object after it has moved or the observer looks away, and polyopia, multiple images of a moving object, based solely on patient report. Moreover, it is known that another similar 5- HT2 blocker, trazodone, lowers flicker fusion frequency ( Riedel et al, 1999 ) although its effect on motion perception has not been investigated. In the current study, flicker fusion frequency (FFF) and motion perception were assessed in outpatients taking prescribed therapeutic doses of serotonin and trazodone. FFF was assessed with LED’s using method of limits with increasing computational complexity. These findings serve to increase our understanding of the impact of premature birth on the development of motion-processing subsystems in humans.

Acknowledgment: This research was supported by an NSERC grant to LSJ.
Medicated outpatient group had significantly lower FFF than the normal control group. However, on the motion perception tasks, performance within the outpatient group was highly variable, but overall, the outpatient and normal groups were not significantly different. It appears that typical therapeutic doses of these 5-HT2 blocker medications affect FFF, but not motion perception. As suggested by Horton and Trobe (1999), motion perception deficits might only be found at much higher, perhaps even toxic levels, of these medications.

Acknowledgment: NIH EY12541

FR87

Lightness constancy through transparency
Manish Singh (mansih@bruc.s.rutgers.edu); Rutgers University, New Brunswick Campus—How does the visual system assign lightness to surface patches seen through partially-transmissive surfaces? We employed asymmetric lightness matching using stereoscopic transparency displays with textured backgrounds. Observers adjusted the luminance of a comparison patch seen through a transparent surface, in order to match the lightness of a standard patch seen in plain view. Plots of matched-to-standard luminance were linear, and the pattern of slopes—obtained via matches through different transparent surfaces—was consistent with Metelli’s alpha. Moreover, the matches revealed a high degree of constancy (80 – 96%). A control experiment confirmed that these matches were indeed transparency based, and could not be explained by simultaneous contrast or anchoring.

The consistency with Metelli’s alpha is surprising given that when observers directly match the transmittance of transparent surfaces, their matches deviate strongly and systematically from Metelli’s alpha, and are consistent instead with the ratio of contrasts (Singh & Anderson, 2002). Formal analysis reveals, however, that there is a deeper mutual consistency between the two sets of results. In particular, we demonstrate that the success of Metelli’s model in predicting lightness transparency, as well as its failure to predict perceived transmittance, can both be understood in terms of contrast-based mechanisms.

Researchers have often expressed surprise (and/or skepticism) concerning why a rather simplistic physical model (i.e., the episcotister setup) should yield perceptually valid equations. Our analysis provides a principled reason—based on known properties of visual mechanisms rather than a reason—based on known properties of visual mechanisms rather than a physical model—for the perceptual validity of Metelli’s equations in capturing lightness through transparency. The analysis also suggests a solution to the related problem of lightness constancy through veiling luminance (Gilchrist & Jacobsen, 1983).

Acknowledgment: Funded by NSF BCS-0216944.

FR88

Low-level mechanisms for processing of junctions
Xoana G Troncoso (x.troncoso@neuralcorrelate.com), Stephen L Macknik, Susana Martinez-Conde; Institute of Ophthalmology, University College London, United Kingdom—Neurons in the early visual system are often considered “edge detectors”. However, there is some psychophysical evidence that supports an alternative view, in which the junctions of edges are often more salient than edges themselves. Last year we presented preliminary results (Martinez-Conde et al., VSS’02) showing that single units in the LGN and area V1 of the awake monkey respond more strongly to junctions than to edges. These results suggested that junction processing may not be a subsequent stage to edge processing, but that junctions may in fact be a more optimal stimulus than edges for early (i.e. center-surround) receptive fields. We have now recorded from 110 neurons in the LGN and area V1, confirming our preliminary conclusions. We have now also developed theoretical computational models of junction processing in the retina/LGN and area V1, which make quantifiable and principled predictions of how early neurons of the visual system should respond to junctions versus edges. By measuring the response from these models to visual scenes (both illusory and non-illusory) that contain edges and junctions we have discovered that early visual receptive fields (i.e. those from center-surround cells, simple cells, and complex cells) are shaped so as to theoretically respond more strongly to junctions than to edges. This is the first time that the salience of junctions has been quantified against the salience of edges, either physiologically or computationally. Both approaches match our qualitative perception of visual illusions in which junctions are more salient than edges. Moreover, our data are compatible with the idea of junctions being processed very early in the visual system (i.e. starting in the retina, with antagonistic center-surround receptive fields), without the implication of high-level mechanisms, such as feedback loops or intracortical circuits.

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FR89

Perception of the direction of illumination in shaded images of convex polyhedra
Byung-Geon Khuang (b.g.khuang@phys.uu.nl), Jan J Koenderink, Astrid M Kappers; Utrecht University / Helmholtz Institute, The Netherlands—Shading of 3-D objects refers to variations in luminance or color as a function of the angle of the illumination direction with respect to the surface. Shading gives rise to a compelling sense of shape, illumination conditions and surface properties. However, it is not yet certain how this is achieved. We used an illuminant direction matching procedure to examine how well human observers can estimate the direction of illumination in images of rotating 3-D geometrical shapes in different light fields. Stimuli were renderings of a dodecahedron and a sphere projected orthographically and juxtaposed on a CRT screen. Two lighting modes (collimated and hemispherical diffuse lighting), twenty-six illuminant directions (differing in azimuth and elevation) and perfectly diffuse reflectance with albedo 0.5 were used to render the faces of the two stimuli. Since the two shapes were convex and situated in empty space, neither interreflection nor cast shadow was produced. At the start of each trial, the two stimuli were presented with different directions of illumination. Observers adjusted the direction of illumination on the sphere to match the direction of illumination on the dodecahedron. Results revealed no systematic difference in matched directions between the two lighting conditions, neither in azimuth nor in elevation. This suggests that in the absence of cast shadow, observers may use the location of the brightest point as a cue to the direction of illumination. Although the appearance of image shading can be appreciably changed under different lighting conditions, for the case of Lambertian reflectance, the peak in the luminance distribution remains fixed.

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FR90

Using colour to disambiguate contrast and assimilation in White’s Effect
Colin W G Clifford1 (colinc@psych.usyd.edu.au), Branka Spehar2; 1School of Psychology, The University of Sydney, 2School of Psychology, The University of New South Wales—Identical grey patches placed on the black and white bars of a square wave grating appear to differ markedly in lightness: White’s Effect. The difference in apparent lightness is in a direction opposite to simultaneous contrast, such that the grey patches on the white bars are more extensively bounded by black borders than by white ones yet appear darker than the grey patches on the black bars. The apparent lightness can be described phenomenologically either as exhibiting contrast with the bars upon which the patches are lying or as assimilation with the neighbouring bars. Here, we disambiguate the effects of contrast and assimilation in White’s Effect by using bars that differ along orthogonal colour and luminance axes in DKL colour space. To measure the effect of stimulus background on a given patch, subjects adjust the appearance of a comparison patch presented on a variegated background such that it matches as closely as possible the appearance of the target patch. At low spatial frequencies, we find that White’s Effect is due predominantly to contrast with the bar upon which the patch is lying.
At high spatial frequencies, the effect is strengthened by assimilation of a similar magnitude with the neighbouring bars. For individual observers, the magnitude of contrast and assimilation measured using colour-luminance stimuli provide a quantitative prediction of the strength of the traditional achromatic White's Effect.

Acknowledgment: Supported by Australian Research Council Discovery Project DP0545612

FR91

Object lightness constancy: effects of object pose and shape
Caterina Ripamonti1 (ripamonti@psych.upenn.edu), Marina Bloj1, Robin E Hauck2, Kiran Mitha1, David H Brainard2; 1Department of Psychology, University of Pennsylvania, Philadelphia, PA, 2Department of Optometry, University of Bradford, England – Purpose. Most studies of lightness constancy have considered how light source intensity affects perceived object lightness. Here we report experiments designed to help unravel how perceived lightness depends on object pose and shape. Methods. Subjects viewed gray test objects placed in an illuminated experimental chamber. The chamber illumination was provided from above by a single theater stage lamp. Each test object was uniformly painted. Across the set of test objects, both object reflectance and shape varied. The chamber also contained a palette of 36 grayscale samples. On each trial of the experiment, subjects viewed a test object and indicated which palette sample had the same paint. The arrangement of the samples on the palette was varied from trial to trial. Objective instructions (match the physical paint rather than the appearance) were used. Results and Conclusions. When object reflectance is held fixed, constancy may be assessed by examining the stability of subject’s matches across variations of pose and shape. This stability may be compared to the variation expected if subjects showed no constancy and based their matches directly on some simple property of the retinal image (e.g. mean luminance of the test object). We used this idea to develop a constancy index (CI) that takes on a value of 1 for perfect constancy and 0 for no constancy. A) We studied the effect of the pose (45 rotation) of a flat smooth object. On average, subjects showed substantial constancy with respect to the change of pose (mean CI 0.54, 21 naive subjects). There were, however, enormous individual differences. Some observers showed complete constancy, while others showed none at all. Different observers may have employed different conscious strategies to perform the objective task. B) Varying the shape of the flat surfaces by introducing relief texture had no effect on subjects’ matches. Relief texture does not provide useful cues about the reflectance of matte objects.

FR92

Adapting to a new visual environment: A field study of face perception
Daniel Kaping (kaping@unr.nevada.edu), Yoko Mizokami, Michael A Webster; University of Nevada, Reno USA – Laboratory studies with controlled stimuli have shown that adaptation to natural variations in faces can strongly bias natural categorical judgments of faces (e.g. of gender, ethnicity, or expression). We tested for signs of these adaptive adjustments outside the lab, to examine how adaptation might influence face perception in “real” natural environments. To assess this, we probed judgments of ethnic category (Caucasian vs. Japanese) in observers who were exposed to different face populations. Participants were newly arrived (< 1 week) exchange students from Japan and Caucasian students in Reno, NV. Stimuli were morphs between Japanese and Caucasian face images from the Matsumoto and Ekman neutral-expression set. Observers made forced-choice judgments of ethnicity, with the morph level varied in a staircase to determine their category boundary. Japanese and Caucasian students chose boundaries closer to their own categories, suggesting that observers are more sensitive to how stimuli differ from their individual category. To test whether these boundaries might adjust in a changed environment, we tested a second group of Japanese students who had been resident in the US from 18 to 72 months. The mean boundary for this group was intermediate to and significantly different from both the Caucasian and newly-arrived students. Individual boundaries were also positively correlated with their self-reports of time in the US and negatively correlated with their report of the percent of time they spent with their own ethnic group. These shifts are consistent with an adaptive change in face coding that renormalizes face perception according to the average set of faces observers are exposed to.

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FR93

The multiple-faces effect: occurrence and frequency using digitized achromatic photos
Maria Lucia B. Sinha1, Nathan A Santos2; 1Laboratório de Percepção Visual, Universidade Federal de Pernambuco, Brazil, 2Universidade Federal da Paraíba, Brazil – The multiple-faces effect (Perception, 2000, 29(11): 1393-1394) was first investigated at the blind spot using familiar faces. We analysed the effect into four categories: (1) disappearance/darkening/whitening of: eyes, nose, mouth, face, nasal face, temporal face, hair; (2) variation in size of theses face parts; (3) movement perception/change in facial expression of: eyes, mouth, face, eyebrow; (4) perception of different characteristics or of other faces: 3D, face upside down, the subjects own face, younger, older, see tooth, moustache/beard, hair changes, see profile, see other faces. Categories 1 and 2 include most of the initial impressions, but only reports falling into categories three and/or four show the multiple-faces effect. We present additional detailed results on this effect, analysing data from 15 subjects (each using both mother and father faces in all instances). Analysis across both subjects and categories 3&4 yielded 100% occurrence for mother and father faces. In sub-category 3, changes in facial expression were 80% and 47% for mother and father faces, respectively. Subjects reported seeing their own face in 33% (mother) vs 13% (father) of the cases. In sub-category 4, other faces were more frequently observed with the mother’s face (40%) than the father’s (27%) face. We discuss these results in terms of peripheral processing of form considering a possible tuning for faces that could result from the frequency of viewing the same face during early visual development.

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FR94

Face attractiveness aftereffects: filling the mind to the world
Gillian I Rhodes1 (gil@psy.uwa.edu.au), Linda Jeffery2, Tamara L Watson2, Colin W Clifford2, Ken Nakayama3; 1Department of Psychology, University of Western Australia, Australia, 2Department of Psychology, University of Sydney, Australia, 3Department of Psychology, Harvard University – Average faces are attractive, but what is average depends on experience. We investigated the role of perceptual adaptation in tuning our preferences to fit the faces we experience. We examined the effect of brief exposure to consistent facial distortions on what looks normal (average) and what looks attractive. Adaptation to a particular distortion resulted in a shift in what looks normal and what looks average in the direction of that distortion. These normality and attractiveness aftereffects occurred when the test faces were rotated 90° relative to the adapting faces (from 45° left to 45° right, or vice versa), suggesting that the adaptation affects high-level neurons whose coding is not strictly retinotopic. Our results suggest that perceptual adaptation can rapidly renormalize face-space to reflect consistent changes in the characteristics of faces that we experience and that our preferences are calibrated to match those characteristics. They also suggest that average faces are attractive because of their central location in a distribution of faces (i.e., their prototypicality), rather than any intrinsic appeal of particular characteristics, because faces with those characteristics become less attractive when they become less prototypical. The functional consequences of this recalibration are far from trivial, giving the powerful effects of perceived attractiveness on person perception, mate choice, social interactions and social outcomes for individuals.

FR95

Contrast, sex, and facial attractiveness
Richard Russell (ruessell@mit.edu); Massachusetts Institute of Technology, USA – Purpose: The relative darkness of the eyes and mouth compared to the surrounding skin has been suggested to be a unique aspect of faces as a class. The goal of these
experiments was to determine whether the size of this luminance contrast plays a role in facial attractiveness. Besides providing insights regarding the determinants of facial aesthetics, this study also has implications for understanding how cosmetics enhance attractiveness. Method: Grayscale images of male and female faces were manipulated such that the contrast between the average luminance of the eyes and mouth and that of the rest of the face was increased, decreased, or left unchanged. Subjects rated the attractiveness of all three versions of each face on a Likert scale. Results: Images of male faces were judged more attractive with this kind of contrast reduced than with it increased. Images of female faces were judged more attractive with this contrast increased than with it decreased. Discussion: The manipulations had opposite effects on male and female faces. This suggests a possible explanation of the results based on the notion that changes that accentuate differences between male and female faces tend to enhance perceived attractiveness. Preliminary investigations with a collection of male and female faces suggest that female faces have greater luminance contrast between the eyes and mouths and the rest of the face than do male faces. Stimuli wherein this sex difference is accentuated may prove to be more attractive than the originals. Much of cosmetics serve to darken the eyes and lips of females, and their effectiveness may lie in accentuating this sex difference in contrast.

FR97
Recognition of emotion in facial expressions with and without the amygdala Frédéric Gosselin1 (frederic.gosselin@umontreal.ca), Ralph Adolphs2, Philippe G Schyns3; 1Département de psychologie, Université de Montréal, Montréal, Canada; 2Department of neurology, University of Iowa, USA; 3Department of psychology, University of Glasgow, Glasgow, UK. — There is ample evidence that the amygdala plays an important role in emotion recognition. Bilateral amygdala damage severely impairs the recognition of fear from facial expressions (Adolphs et al., 1994, 1995; Brooks et al., 1998; Calder et al., 1996; Young et al., 1995), but the mechanisms behind this impairment remain unknown. Here, we used the Bubbles technique (Gosselin & Schyns, 2001) to shine new light on this issue. We compared the information used effectively to recognize emotion by SM, an individual with complete, bilateral damage restricted to the amygdala, with the information used effectively by 10 normal controls. Each subject was submitted to 3,072 trials. In a trial, one of four faces (a male and female face each of happiness and fear from Ekman & Friesen’s, 1976, set) was decomposed in the Laplacian pyramid space and sparsely revealed by randomly located Gaussian holes (see Schyns, Bonnar & Gosselin, 2002, for details). Subjects were asked to classify either the gender or the emotion of the image. Statistical analyses on the difference between the classification images of the normal controls and of SM revealed that SM appears to use information about the face normally when classifying gender. By contrast, when classifying emotion, she failed to make normal use specifically of the eye region of the face, an impairment most notable at spatial frequencies between 90 and 45 cycles per face.

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FR98
A hollow face does not express emotion Priscilla F Heard (priscilla.heard@uwe.ac.uk); Psychology, University of the West of England, Bristol, UK. — A hollow face does not normally look as it really is, hollow; but looks convex especially if viewed from a distance. It is difficult to recognize the identity and the emotional expression in an upside-down face. One explanation is that global face processing only occurs for upright faces. Here video faces expressing emotions are projected onto an upright and an upside-down structureless white mask. When the upright mask is viewed at close proximity with two eyes from the normal side, the facial expressions are clearly discernable. But when viewed from the hollow side - when it looks hollow - the emotional expression is not easy to read. Emotional expressions are not clearly discernable (as expected) when the upside-down mask is viewed either when normal or hollow. Experiments will be reported quantifying these effects.

FR99
Recognizing people from naturalistic video: The effects of facial motion and familiarity Dana A Roark (danar@utdallas.edu), Alice J O’Toole, Hervé Abdi; University of Texas at Dallas, USA. — To date, there is limited evidence to suggest that facial motion can improve recognition of unfamiliar faces above levels associated with static faces (Pike et al, 1997; Thornton & Kourtzi, 2002). However, facial motion cues are effective for recognizing familiar faces, especially when the pictorial information is degraded (e.g., Knight & Johnston, 1997; Lander & Bruce, 2000). Here we examined the combined effects of face familiarity and movement on person recognition when recognition was tested from whole-body gait videos.

Participants viewed either static face images or non-audible video clips of speaking faces, which were presented either once, twice, or four times during learning. At test, they viewed video clips taken in natural/variable illumination of people walking through a lobby. Participants were asked to indicate whether these videos showed people they had viewed previously.

We found that participants who learned moving faces recognized people from the gait videos more accurately than participants who learned static faces. Accuracy also increased with face familiarity. An interaction trend suggests that motion becomes more beneficial as familiarity increases. The findings indicate that the benefits of motion for recognizing relatively unfamiliar people may be confined to viewing conditions that challenge image-based generalizations. An additional intriguing finding of this study is that familiarization with the face alone is sufficient to improve recognition performance from the whole body gait videos.

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FR100
Spatio-temporal caricature effects for facial motion
Barbara Knappmeyer1 (barbara.knappmeyer@tuebingen.mpg.de), Martin A Giese2, Heinrich H Bülthoff3; 1Max-Planck-Institut für biologische Kybernetik, Tübingen, Germany, 2ARL, Department for Cognitive Neuroscience, University Clinic, Tübingen, Germany – Caricature effects (=recognition advantage for slightly caricatured stimuli) have been robustly established for static pictures of faces (e.g., Rhodes et al., 1987; Benson & Perrett, 1994). It has been shown recently that temporal or spatial exaggerations of complex body movements improve recognition of individuals from point light displays (Hill & Pollick, 2000; Pollick et al. 2001). Here, we investigate whether similar caricature effects can be established for facial movements. We generated spatio-temporal caricatures of facial movements by combining a new algorithm for the linear combination of complex movement sequences (spatio-temporal morphable models; Giese et al., 2002) with a technique for the animation of photo-realistic head models (Blanz & Vetter, 1999). In a first experiment we tested the quality of this linear combination technique. Naturalness ratings from 7 observers were obtained. They had to rate an average-shaped head model, which was animated with three classes of motion trajectories: 1) original motion capture data, 2) approximations of the trajectories by the linear combination model, and 3) morphs between facial movement sequences of two different individuals. We found that the approximations were perceived as natural as the originals. Unexpectedly, the morphs were perceived as even more natural (t(6)=4.6, p<.01) than the original trajectories and their approximations. This might reflect the fact that the morphs tend to average out extreme movements. In a second experiment 14 observers had to distinguish between characteristic facial movements of two individuals applied to a face with average shape. The movements were presented with three different caricature levels (100%, 125%, 150%). We found a significant caricature effect: 150% caricatures were recognized better than the non-caricatured patterns (t(13)=2.5, p<.05). This result suggests that spatio-temporal exaggeration improves the recognition of identity from facial movements.

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FR101
Matching faces in a prosopagnosic individual
Yunjo Lee (ychlee@yorku.ca), Hugh R Wilson, Joséé Rivest; Centre for Vision Research, York University, Canada – Last year, Rivest and Moscovitch (2002) introduced a prosopagnosic man (DC) who, despite his impaired face recognition, has intact object and word recognition. His face processing is here further evaluated using a face matching task developed by the Max Planck Society.

FR102
Gaze Manipulation Biases Preference Decisions
Claudiu Simion1 (claudius@caltech.edu), Shinsuke Shimojo1,2, 1California Institute of Technology, Pasadena, CA, USA, 2NTT Comm. Sci. Lab., Kanagawa, Japan – We continue our investigation of the relationship between preference judgments and orienting behavior. We reported (YSS ’01) an increasing, cascade-like gaze bias towards choice in preference tasks (cascade effect), when stimuli were either faces, or abstract, unfamiliar shapes. We proposed a model in which orienting behavior (active gaze) interacts with cognitive assessment of stimuli in a positive feedback loop leading to the decision.

If our model is correct, biasing observers’ gaze should influence preference. To assess the validity of this claim, we showed human faces, whose baseline attractiveness was matched, on a computer screen, while subjects were instructed to actively follow the display with their eyes. Faces were presented side by side alternatively, so that only one was present on the screen at any given time. We biased the fixation duration by presenting one face for a longer time (900 vs. 300 ms). This sequence was repeated 2, 6 or 12 times before subjects were allowed to respond which face appeared more attractive. The results show a clear bias towards the longer presented face when the number of repetitions was larger than 2 (59.0 % for 6 repetitions, 59.2% for 12 repetitions, both p<0.01), consistent with our model.

To exclude the possibility that the preference bias was due to mere exposure, we performed a control experiment in which the presentation sequence was identical, but both images were presented in the middle of the screen, at the point of fixation. Retinotopic exposure sequence was identical, yet this experiment did not reveal any preference for the longer exposed face. Moreover, to show that the effect was not due to general perceptual fluency, we repeated the original experiment asking subjects to report which face was rounder, instead of more attractive. No bias towards the longer shown face was found.

We conclude that orienting behavior, in the form of active gaze shift, is critical in deciding preference, directly influencing it.

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FR103
I See What You See: Gaze Perception during Scene Viewing
Mareike Wieth (wiethmar@msu.edu), Monica S. Castelhano, John M. Henderson; Department of Psychology & Cognitive Science Program, Michigan State University, USA – Looking where another person is looking can guide our attention and provide us with useful information about our environment. For example, sensitivity to another person’s gaze plays a functional role in social attention (Kleinke, 1986) and in the development of social awareness (Brooks & Meltzoff, 2002). Reflexive covert attentional orienting based on direction of gaze in schematic or photographed faces has also been shown to facilitate processing of visual stimuli in an observer (Friesen & Kingstone, 1998; Langton & Bruce, 1999). The current study investigated how another person’s gaze direction may affect the orienting of a viewer’s overt attention (i.e., eye movements). Participants’ eye movements were recorded while they viewed a sequence of photographs that portrayed a janitor cleaning an office and stealing supplies (shown on a computer monitor). Participants’ eye movements were compared between the actor’s face and the object the actor was looking at (focused object) versus the actor’s face and a non-focused control object (matched for size, saliency and general location in each picture). Results showed that when the actor’s face was fixated, the next fixation was more likely to be in the direction of the focused object than any other direction. Analyses of scan paths revealed that viewers were more likely to saccade directly from the actor’s face to the focused object than to the control object. Furthermore, when eye movement patterns did not show a direct saccade to the focused object, participants were nonetheless more likely to fixate the foreshortened object than the control object within close temporal proximity of fixating the face. We conclude that during real-world scene perception, viewers are sensitive to an actor’s direction of gaze and use it to help guide their own attention.
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FR104
(Eye-)Tracking the time-course of the interaction between linguistic and visual processes: the effect of verb-conceptual restrictions

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We present a study on the role of visual representations in the access to conceptual structure of verbs during sentence processing. In our study, we used an eye-tracking paradigm in which subjects heard sentences while looking at pictures of objects displayed on a computer screen. We controlled the time course of saccadic onsets to pictures of objects by holding and releasing the saccades at different points during and after the presentation of verbs and their complements. We contrasted two classes of linguistic constructions, a highly constraining causative construction in which there is a close conceptual relation between verb and direct object (e.g., The woman burned the candle), and a neutral one with a transitive perception verb (e.g., The woman admired the candle). As visual stimuli we used pictures of six types of objects, a target object (the referent of the noun grammatical object of the verb; e.g., candle), a semantic competitor (e.g., lamp), a phonological competitor (e.g., candy), an object with the same shape as the target, an object with the same color as the target, and a random object. We found significant differences between probe points and context types, with causative verbs engendering faster saccade onset times to their objects. This difference was more pronounced at the onset of the main verb. The magnitude of the saccade onset times for both sentence conditions, however, indicates that verb-conceptual effects occur after verb information is accessed. The results of these experiments are discussed in the context of modular and interactive cognitive architectures. We propose a model for the time-course of the interaction between linguistic and visual information in short-term memory.

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FR105
A formal model of visual attention in embodied language acquisition

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Most studies of infant language acquisition have focused on the role of purely linguistic information as the central constraint. However, several researchers (e.g. Baldwin) have suggested that non-linguistic information, such as vision and talkers’ attention, also plays a major role in language acquisition. In light of this, we implemented an embodied language learning system that explores the computational role of attention to build visually grounded lexicons. The central idea is to make use of visual perception as contextual information to facilitate word spotting, and utilize eye and head movements as deictic references to discover temporal correlations of data from multiple modalities. In the experiments, subjects were asked to perform three kinds of everyday activities (pouring water, stapling papers, and taking a lid off) while providing natural language descriptions of their behaviors. We collected speech data in concert with user-centric multisensory information from non-speech modalities, which included visual data from a head-mounted camera, gaze positions, head directions and hand movements. A multimodal learning algorithm identified the sound patterns of words and built grounded lexicons by associating object names and action verbs with attentional objects and hand motions. We compared our approach with the one that does not use eye and head movements to infer referential intentions. The results of the attention-based method are much better than the other approach (word spotting accuracy 86% vs. 28% and word learning accuracy 79% vs. 23%). The significant differences lie in the fact that there are a multitude of co-occurrences between words and possible meanings grounded in the environment, and inferences of speakers’ attention from their body movements can indicate which co-occurrences are relevant. This work provides a computational account of infant language acquisition and suggests the importance of visual attention in embodied language learning.

http://www.cs.rochester.edu/~yu/research.html

FR106
Saccadic targeting in the real world

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Vision in the real world requires the nearly continuous selection of fixation targets, and routines to program and execute accurate eye movements to those targets. Many models have been proposed for the target-selection mechanism, from bottom-up models based solely on local image statistics to high-level, object-based models that presume pre-defined objects have already been parsed from the surrounding scene. The oculomotor system evolved in a rich, dynamic environment, yet experiments designed to evaluate proposed models are typically performed by head-fixed subjects viewing small, static displays. Two experiments were performed to study saccadic targeting under more natural conditions.

In Experiment 1 subjects’ eye movements were monitored with a head-mounted eyetracker as they free-viewed color photographs on a large display subtending ~40 x 65 deg. While the conditions of Experiment 1 are arguably more natural than many experiments, Experiment 2 was designed to go beyond stationary observers viewing limited static displays. Subjects were fitted with a wearable eyetracker that allowed unrestricted eye, head, and whole-body movements. Eye movements were recorded as subjects walked down a hallway toward a room where they were to perform a task. Both experiments represent ‘free viewing’ in that there was no instructed task related directly to eye movements. Video records were analyzed to identify saccadic targets and to measure the amplitude of saccadic eye movements and the duration of the intervening fixations.

In addition to fixations covering a greater extent of the visual field, the amplitude of individual saccades increased with field size; median saccade amplitude exceeded 10 degrees in the walking task. Many of the fixation durations were shorter than anticipated in both tasks; fixations as short as 100 msec were common, and subjects’ mean fixation duration and mean saccade amplitude were inversely correlated.

FR107
Algorithm for comparison of 3D scanpaths in virtual reality

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String-editing scanpath comparison methodology, developed by Privitera and Stark, is one well-known and useful strategy for comparing the position and order of fixations made over a visual field, essentially resulting in correlation measures of fixation position and order (ordered scanpath correlations are usually much lower than those of fixation positions). This strategy has previously been employed to evaluate human and artificial (modeled) scanpaths over 2D images.

We have successfully adapted this strategy to examine the correlation between human and artificial 2D scanpaths in Virtual Reality (VR) (2D scanpaths obtained during stationary head positions). Artificial scanpaths, generated by a computer model of visual attention used to guide real-time ray-tracing in VR, surprisingly resulted in very low correlations with human viewing patterns. On further examination, human eye movements were found to be mostly restricted to the central 30 deg of the Head Mounted Display while algorithmic “fixations” were dispersed uniformly...
over the entire viewing area.
We have recently extended of our scanpath comparison methodology to 3D eye movements measured in Virtual Reality with no restriction on head movement. The algorithm calculates correlations of 1.0 for identical scanpaths, indicating correctness of the algorithm for these cases. The technique is applicable for quantitative comparison of novice and expert scanpaths in a Virtual Reality visual inspection training simulator.

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FR108 Spatial frequency modulates color selectivity of adaptation to contrast patterns

Genevieve M Heckman (gheckman@ucla.edu), Stephen A Engel; UCLA Department of Psychology, USA – Single-unit recordings in macaque V1 have identified two populations of color selective cells. One contains neurons that prefer low spatial frequencies and respond best to red-green (L-M cone contrast). Another contains neurons that prefer higher spatial frequencies; some of these cells respond best to L-M, but most respond best to “non-cardinal” directions (e.g., M cone contrast). The goal of this study was to identify perceptual mechanisms consistent with these two sets of neurons. We used a selective adaptation procedure with two types of adapting stimuli targeted to each set of neurons. Subjects adapted to Gaussian blobs and 2 cyc/deg Gabor patterns, each containing L-M or M cone contrast. After viewing a 3 deg adapting stimulus in one hemifield, subjects adjusted the contrast of a stimulus in the unadapted field to match the appearance of a test stimulus (either L-M, M, L or L+M cone contrast) presented in the adapted field. Adapting to Gabor L-M patterns reduced the apparent contrast of L-M tests more than the other tests. Similarly, adapting to a Gabor M pattern reduced the apparent contrast of M tests more than the others. Adapting to a Gaussian L-M pattern reduced the apparent contrast of the L-M test most, but, critically, adapting to a Gaussian M pattern reduced the apparent contrast of M and L-M patterns to an equal degree. Selective adaptation is most frequently interpreted as reduced responsiveness of a mechanism that prefers the most strongly affected test. Accordingly, our results indicate that adapting to Gabor stimuli can reduce the responsiveness of mechanisms that prefer non-cardinal directions. Adapting to Gaussian stimuli mainly reduces the responsiveness of mechanisms that prefer L-M, but does not appear to greatly affect non-cardinal mechanisms. Our data suggest that low and high spatial frequency patterns are encoded by two separable populations of color selective neurons, both of which contribute to color appearance.

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FR109 Independent directions in color space delineated by contrast-induced phase lags

Arthur G. Shapiro (shapiro@bucknell.edu), Anthony D. D’Antona; Bucknell University, USA – The cardinal directions of color space (S, L-M, and LUM) were originally defined by threshold elevations following prolonged contrast adaptation. We introduce a new super-threshold technique to delineate efficiently independent directions in color space. The technique is a variation of a simultaneous contrast demonstration with two physically identical circles (1 deg, 40 cd/m2), one surrounded by a dark annulus (2 deg, 20 cd/m2) and the other by a light annulus (2 deg, 60 cd/m2). In our variation, we sinusoidally modulated the color of both center circles along a line in color space (2 hz). Modulation along the same line in color space as the annular surrounds (in this case, the LUM cardinal axis) produced a compelling illusion that the two circles are modulated out of phase. Modulation along an independent orthogonal axis (in this case, the S or L-M axis) produced no such illusion; the modulated lights appear to be in phase.

We varied the color direction of surrounds from a mid-white center and measured the directions in which the modulating circles are independent of the surround effects (i.e., appear in-phase). The dimensions of the color space were expressed in threshold units measured for each observer. Results: 1) When the color direction of the surrounds was along the LUM axis, observers (n=7) set independent directions within 10 deg of the standard equiluminant line. Observers differed in the standard deviation of the in-phase settings. This inter-observer variability was similar across tasks (method of adjustment and method of constant stimuli) and suggests individual variation may be due to the tuning widths, and not the tuning directions, of the underlying mechanisms. 2) Within the equiluminant plane, independent directions of modulation were always 90 deg from the surround direction with no preference for the cardinal axes. The results will be discussed in terms of multiple higher color mechanisms and adaptive orthogonalization of the color mechanisms.

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FR110 Evidence that color contrast effects have a probabilistic foundation

Fuhui Long (long@neuro.duke.edu), Dale Purves; Department of Neurobiology, Duke University Medical Center, Duke University, Durham, NC, USA – Surfaces returning identical light spectra to the eye can elicit different color percepts when embedded in spectrally different surrounds. Although various theories have been put forward to rationalize these color contrast effects, there is no consensus about their basis. Here we tested the hypothesis that color contrast is generated by the probability distribution of the possible physical sources of spectral stimuli (see Lotto and Purves, PNAS 97:12834, 2001). The analysis used a database of 41 natural scenes in which the radiance spectrum of each point (i.e., the projected light spectrum for each pixel in the images) was known. The relevant reflectance spectra for corresponding points were computed by removing the influence of both the illuminant and scene geometry from the radiance spectrum. The illumination spectra for each pixel (which include the influence of both the illuminant and scene geometry) were then determined by dividing the radiance spectrum by reflectance spectrum. To facilitate the statistical analysis, the radiance spectrum on each pixel was converted into RGB tristimulus values. Each image in the database was sampled repeatedly with a center/surround template, and the probability distributions of the possible combinations of reflectance and illumination spectra that could have generated the relevant RGB values were determined. The probability distributions of the reflectance and illumination spectra of the central target varied as a function of the RGB values of the surround, indicating that the typical physical sources of target spectra differ when they are embedded in spectrally different surrounds. The color percepts predicted by these distributions were in good agreement with the percepts elicited by color contrast stimuli. This evidence supports the conclusion that color contrast effects are determined by the probabilistic relationship between ambiguous spectral stimuli and the distribution of their possible sources.

Acknowledgment: This work was supported by NIH and the Geller endowment.

FR111 Spatiochromatic properties of images of fruits and leaves from Kibble forest, Uganda

Carlos A Parraga1 (Alej.parraga@bris.ac.uk), Tom Troscianko2, Jolyn Troscianko3, David J Tolhurst4,5, Ute Leonard4; 1University of Bristol, UK, 2University of Oxford, UK, 3University of Cambridge, UK, 4University of Geneva, Switzerland – The human visual system (hvs), as well as that of other trichromatic primates, has different contrast sensitivity functions for chromatic and luminance stimuli. The spatial filtering is low-pass for chromatic stimuli and band-pass for luminance. Previous results have shown that a subset of natural scenes, namely those with red objects (e.g.fruit) on a background of leaves have spatial properties that correspond to this physiological spatial filtering (Parraga, Troscianko and Tolhurst; Current Biology 12, 483-487; 2000). Our original dataset on which these conclusions were based was consisted of English natural scenes. Here we analysed the spatiochromatic properties of a dataset of natural scenes obtained in Kibble Forest, Uganda, which is a natural habitat containing large numbers of wild trichromatic primates. We used the same calibrated digital camera as in the previous study, which delivers L,M,S
cone responses, and opponent-channel responses, for each pixel. We obtained 270 images of scenes, many of them containing red fruit, red leaves, red flowers and green leaves corresponding to the primate visual environment as seen from the ground and from the canopy. All the red fruit and leaves were confirmed as forming a significant part of the diet of trichromatic primates. Our results support the earlier finding (with English plants), namely that the luminance and chromatic Fourier spectra of pictures containing reddish objects on a background of leaves correspond well to the spatio-chromatic properties of the luminance and red-green systems in human vision, at viewing distances of the same order of magnitude as the grasping distance.

**FR112**

**Color constancy under illuminant and context changes** Kinjiro Amano (k.amano@umist.ac.uk), David H Foster; Visual and Computational Neuroscience Group, Department of Optometry and Neuroscience, University of Manchester Institute of Science and Technology, Manchester, United Kingdom – Two kinds of constancy underlie the everyday experience of surface color: its constancy under changes in illuminant and its constancy under changes in position. These two constancies seem to place conflicting demands on the visual system: to both take into account the local chromatic context and yet discount it. An experiment was performed in which observers binocularly viewed computer simulations on a color monitor of two illuminated Mondrian patterns, presented side by side, each consisting of 49 (7 x 7) abutting 1-deg square surfaces each drawn at random from the Munsell set. The two patterns, each subtending 7 deg x 7 deg when viewed at 100 cm, were illuminated by different uniform daylight illuminants of 6700 K and 25 000 K. The central and one other square surface in one pattern were interchanged in the other pattern, where they were illuminated by an independent local illuminant instead of the uniform illuminant. The observer adjusted the local illuminant so that the two patterns appeared to comprise the same surfaces but uniformly illuminated by different lights. Patterns were presented continuously. The degree of observers’ color constancy under simultaneous changes in illuminant and surface position was as good as under illuminant changes alone. This equality held with or without the presence of a bright surface in the scene that could have been used to estimate the change in illuminant. The visual system seems able to extract information about color relations over widely separated regions in an image under simultaneous changes in illuminant and, and this information may be more important than local chromatic context in determining surface color perception.

**Acknowledgment:** Supported by EPSRC.

**FR113**

**Selective biasing of correspondence matching in ambiguous stereograms** Ross Goutcher (ross@psy.gla.ac.uk), Pascal Mamassian; University of Glasgow, United Kingdom – Purpose: Constraints for resolving the stereo correspondence problem have been central to the success of models of stereovision. However, many such models use only one or two of the many matching constraints suggested in the literature. More specifically, models often utilise a nearest disparity (ND) constraint at the expense of a nearest neighbour (NN) constraint. Here we quantify the role of NN and ND constraints by putting them into competition.

Methods: We present a new wallpaper-type stereogram offering alternate percepts of a single, opaque surface or two-surface stereo transparency. By alternating the contrast of horizontally adjacent image dots we are able to selectively bias matching toward either of these percepts, which correspond to ND and NN matching, respectively. This allows us to quantify the relative strength of each constraint. Based on previous findings in the literature, we hypothesise that ND matching will exceed NN matching, and that NN matching will increase when such matches lead to the minimum disparity between surfaces.

Results: Points of subjective equality (PSE) between NN and ND matches were obtained for each observer. PSEs are biased towards the NN for most observers, indicating that the effects of ND matching exceed those of the NN. As hypothesised, the proportion of NN matches increases as the disparity between transparent surfaces decreases [cf. Zhang et al (2001), Vis Res, 41, 2995–3007].

Discussion: Utilising our new wallpaper stimulus we have selectively biased the correspondence matching process and obtained quantitative measures of the strength of matching constraints. This stimulus offers new possibilities for research into both correspondence matching and the bases of perceptual ambiguity. Our current results indicate that multiple constraints impinge on the stereo matching process and that ND matching is the strongest of these. We discuss how constraints may interact, and how our findings affect models of stereo matching.

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**FR114**

**Horizontal and vertical noise tolerance of binocular correlation in random dot stereograms** Martin J.M. Lankheet (m.j.m.lankheet@bio.uu.nl), Joost B Beltman; Functional Neurobiology, Utrecht University, Netherlands – Although our eyes are separated horizontally and binocular disparities are therefore mainly horizontal, binocular correlation tolerates substantial vertical disparities. To study the size of the vertical disparity range for binocular correlation, we measured the tolerance for both horizontal and vertical disparity noise, in detecting sinusoidal depth gratings in random dot patterns. We used dense, dynamic random dot stereograms and Gaussian distributed disparity noise. Trials consisted of two 0.8 s intervals, one containing the depth corruption (stimulus), the other containing the same disparity values randomly distributed across the window (reference).

For different grating parameters tolerance for vertical disparity noise was at least as large as for horizontal disparity noise. Moreover, the effects of horizontal and vertical noise added linearly, suggesting a horizontal-vertical isotropy.

To find out whether these results indeed reflect the size of horizontal and vertical ranges for resolvable disparities, we performed a parametric model analysis for binocular correlation. The model was presented with random dot stereograms of sinusoidal depth gratings, similar to those in the psychophysical measurements, and solved the correspondence problem by determining all possible matches of a pixel in one eye within an ellipsoid correlation area around the corresponding point in the other eye. An arbitrary, but highly efficient algorithm determined whether the stimulus or reference presentation provided the best match to a sinusoidal depth corrugation. A comparison of horizontal and vertical noise tolerance for the human observer and for the model revealed upper and lower limits for the vertical disparity range. However, psychophysical results could be reproduced with different combinations of horizontal and vertical disparity range, and therefore do not reflect a low level horizontal-vertical isotropy for binocular correlation.

**FR115**

**Temporal limit of the smoothness constraint for binocular matching** Zhi-Lei Zhang (zhang@spectacle.berkeley.edu), Tandra Ghose, Clifton M Schor; School of Optometry, UC Berkeley, USA – Purpose: Gabor patches have ambiguous binocular matching solutions that can either minimize their absolute disparity (nearest neighbor match-NN) or the relative disparity between adjacent patches (minimum relative disparity match-MRD) (Zhang, Edwards, Schor. VIS RES 41(23)). Minimum relative disparity matching solutions follow the smoothness constraint for binocular matches. Using time delays between adjacent stimuli, we have investigated the temporal interval over which binocular matches that follow the smoothness constraint can occur.

Stimulus conditions: A Gabor patch with a 1 cpd carrier was flanked vertically between two separated Gaussian windowed RDS, with a 0.5 edge-to-edge separation. The RDS and Gabor were each presented for 200 ms. The RDS preceded the Gabor patch with temporal delays (inter-stimulus intervals) varying from 0 to 400 ms. The RDS phase disparity was
fixed at 135 and Gabor disparity was varied. Subjects reported the depth ordering of the RDS and Gabor patches to indicate the matching solution (NN or MRD).

Analysis: Percent nearest neighbor match was plotted as a function of phase disparity of the center Gabor patch. These psychometric functions were used to estimate PSE that indicates the Gabor phase disparity value for which minimum-absolute-disparity and minimum-relative-disparity matching solutions had equal probability.

Results and Conclusions: PSE increased with temporal delay between the RDS and Gabor patch. As PSE increases, the minimum relative disparity between the RDS and Gabor decreases and the nearest neighbor matches increase. An exponential decay function described the plot of PSE as a function of temporal delay. Decay time constants ranged from 63 to 95 msec. The time constant estimates the temporal range of interactions between adjacent stimuli over which the smoothness constraint for binocular matches is applied.

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FR116

Stereo-slant adaptation involves both disparity coding and perceived slant
Eileen M Berends (eberends@spectacle.berkeley.edu), Clifton M Schor; School of Optometry, UC Berkeley, USA — The goal of this study was to investigate at which stage in visual processing that stereo-slant adaptation occurs. We tested the predictions of two different hypotheses utilizing a property of depth from binocular disparity, namely that slant scales with distance. If adaptation occurs at a low (disparity) level, then we predict that the after-effect expressed in units of disparity gradient will be independent of distance. If adaptation occurs at a high (perceived slant) level, then we predict that the after-effect, expressed in units of disparity gradient, will increase with decreasing test distance, because a particular slant requires a larger disparity gradient at a short distance than at longer distance.

Subjects adapted to a stereo-defined slanted surface at a viewing distance of 57 cm for five minutes. The slanted surface was random-dot pattern (30 x 24 deg) of which the two half-images, viewed by the left and right eye, were horizontally magnified relative to each other. The after-effect was measured by a nulling method. The subjects judged the direction of slant of a test stimulus (24 x 24 deg). In a sequence, presentation of the same adaptation stimulus (for 2 sec) was followed by presentation of a test stimulus (for 500 msec) of which the horizontal magnification was varied according to an adaptive method (MUEST). In different sessions, we presented the test stimulus at three different viewing distances (28, 57 and 85 cm). In order to have good binocular alignment, a fixation cross was presented for 1.5 sec between presentation of the adaptation and the test stimulus.

We found that the amount of horizontal magnification that was required to null the after-effect and perceive an unslanted test stimulus increased with decreasing distance. However, the change in distance (scaling effect) was smaller than the prediction that adaptation only occurs at a perceived slant level. Thus, adaptation occurs on both low (disparity) and high (perceived slant) levels.

FR117

Binocular rivalry between moving stimuli: The effect of surround motion
Chris LE Paffen (paffen@fsis.uu.nl), Ryota Kanai, Susan F te Pas, Frans A J Verstraten; Utrecht University, Helmholtz Research Institute, Psychonomics Division, the Netherlands — When two dissimilar stimuli are presented dichoptically, the percept generally alternates between the two monocular stimuli; a phenomenon known as binocular rivalry. The dominancy of a specific percept during rivalry can be affected by a surrounding stimulus. For example, if two discs containing bars with orthogonal orientations are both surrounded by an annulus containing bars with the same orientation as one of the two discs, the disc containing the bars orthogonal to the surround is more dominant ( Fukuda & Blake, 1992). Here, we investigate whether this preference for a stimulus deviant from its surround can also be observed for moving stimuli.

Stimuli: Two discs containing vertical sine-wave gratings, always moving horizontally in opposite direction, were presented dichoptically at the center of fixation. The discs could each be surrounded by an annulus containing a vertical sine-wave grating moving in the same direction as one of the two discs. The annulus was either presented to one eye [one-eye condition] or both eyes [two-eyes condition]. In the two-eyes condition, the annulus moved in the same direction. In the one-eye condition, the grating in the annulus moved in the same direction as the grating in the disc in the same eye, or in the same direction as the grating in the disc presented to the other eye. Observers had to continuously indicate the perceived direction of motion in the center disc.

Results: For both conditions, the disc containing the grating with a direction of motion opposite to the surround was more dominant. Most interestingly, for the one-eye condition, the disc containing the grating moving in the direction opposite to the motion in the annulus was more dominant, irrespective of its positioning (same or different eye as compared to the annulus). Thus, also during binocular rivalry of moving stimuli, the grating in the disc moving in the deviant direction, as compared to the motion direction in the annulus, is preferred.

FR118

How are visual inputs compared with memory representations in the change-detection paradigm? Joo-seok Hyun1 (jhyun@blueweeg.uwo.ca), Geoffrey F. Woodman2, Edward K. Vogel1, Adam T. Niese3, Steven J. Luck1, 1Department of Psychology, University of Iowa, USA, 2Department of Psychology, Vanderbilt University, USA, 3Department of Psychology, University of Oregon, USA — Change-detection paradigms have become a popular means of assessing the nature of visual working memory, but little research has addressed the mechanisms by which changes are actually detected. That is, how is the memory of the previous stimulus array compared with the perceptual representation of the current stimulus array? In the present study, we sought to determine whether the comparison process is limited or unlimited in capacity. To accomplish this, we made use of the fact that the detection of a change triggers a shift of attention to the changed object, as indicated by the presence of an attention-related ERP component (the N2pc wave) over the hemisphere contralateral to the changed item. If the comparison process is limited in capacity, then N2pc latency should increase as the number of items to be compared increases. However, if the comparison processes is not limited in capacity, then N2pc latency should be independent of the number of comparisons required.

Two change-detection experiments were conducted that required subjects to remember a sample array containing several oriented bars and compare it to a test array presented after a 900-ms retention interval. In the first experiment, the orientation of one bar changed on half the trials, and subjects reported the presence or absence of a change. In the second experiment, one bar always changed in orientation, and subjects reported whether this change occurred in the left or right hemifield. In both experiments, an N2pc component was elicited by the changed item in the test array, and its onset time (ca. 200 ms) was essentially constant across set sizes of one to four objects. These results indicate that the comparison between the memory representation of the sample array and the perceptual representation of the test array was rapid and unlimited in capacity.

FR119

Keeping track of objects while exploring an informationally impoverished environment: Local deictic versus global spatial strategies
Nicolas J. Bullot1 (nicolas.bullot@rsccs.rutgers.edu), Jacques Droulez2, Zenon Pylyshyn1, 1Rutgers Center for Cognitive Science, USA, 2Laboratoire de Physiologie de la Perception et de l’Action, Collège de France, France — This study investigates a new experimental paradigm called the Modified Traveling Salesman Problem (Bullot & Droulez, submitted). This task requires subjects to visit once and only once n invisible targets in a 2D
display, using a virtual vehicle controlled by the subject. Subjects can only see the directions of the targets from the current location of the vehicle, displayed by a set of oriented segments that can be viewed inside a circular window surrounding the vehicle. Two conditions were compared. In the “allocentric” condition, subjects see the vehicle move across the screen and change orientation under their command. The “egocentric” condition is similar except for how the information is provided: the position and orientation of the vehicle icon remains fixed at the center of the screen and only target directions, as indicated by the oriented segments, change as the subject “moves” the vehicle. The unexpected finding was that this task can be performed, in either condition, for up to 10 targets. We consider two possible strategies that might be used, a location-based strategy and a segment strategy. The location-based strategy relies on spatial memory and attempts to infer the locations of all the targets. The segment strategy is more local and focuses on the directional segments themselves, keeping track of the ones that represent already-visited targets. A number of observations suggest that the segment strategy was used, at least for larger numbers of targets. According to our hypothesis, keeping track of the segments requires one to use indexical reference for associating the segments with their status in the task – given by current status predicates Visited(x) or Not-visited(x) –, perhaps using visual indexes (Pylyshyn, 2001), deictic pointers (Ballard et al., 1997), or object files (Kahneman et al., 1992).

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FR120
The persistence of object-file representations Nicholas S Noles (Nicholas.S.Noles@yale.edu), Brian J Scholl; Yale University, USA – Coherent visual experience of dynamic scenes requires not only that the visual system segment scenes into component objects, but that these object representations *persist*, so that an object can be identified as the same object from an earlier time. Object-files (OFs) are visual representations thought to mediate such abilities: OFs lie between lower-level sensory processing and higher-level recognition, and track salient objects over time and motion. OFs can be studied with object-specific priming (OSP): discriminations of an object’s features are sped when an earlier preview of those features occurs on the same object, beyond general priming. Despite its popularity, many fundamental aspects of the OF framework remain unexplored. For example, though OFs are thought to be involved primarily in online visual processing, we do not know how long such representations persist: previous studies found OSP for up to 750 ms, but did not test longer durations. We explored this issue using a modified ‘object reviewing’ paradigm, and found that robust OSP effects persist for up to 5 times as long as previously tested values (at least 4 s), and possibly much longer. We will demonstrate such effects, and discuss manipulations that affect the duration over which OSP is observed. The fact that OFs persist for extended durations raises the possibility that they may be involved in other sorts of perceptual processing, across longer durations. These findings also bear on research in infant cognition, where OFs are thought to explain infants’ abilities to track and enumerate small sets of objects. Because such infancy experiments typically involve longer delays, the extended persistence we observe raises the possibility that the same OF representations may be operating in infancy and adult visual cognition. Object files may be involved primarily in momentary online processing, but they can also persist to support the identification of persisting objects across temporal gaps.

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FR121
Attentional inhibition determines emotional responses to unfamiliar faces Mark J. Fenske1 (m.j.fenske@bangor.ac.uk), Klaus Kessler2, Jane E. Raymond3, Steven P. Tipper4. 1University of Wales Bangor, United Kingdom, 2Heinrich-Heine-University, Germany – Complex abstract images that are ignored in a simple localization task are subsequently judged more negatively in an emotional evaluation task than previously unseen or attended images, suggesting that attentional inhibition may have affective consequences (Raymond, Fenske, & Tavassoli, in press). We examined the generality of this finding by asking whether inhibitory processes might also influence the generation of emotional responses to unfamiliar faces. To do this, we incorporated an emotional evaluation task within a paradigm that has been used to demonstrate long-term inhibition-of-return (IOR) of attention (Tipper, Grison, & Kessler, in press). On each 2-task trial, observers were first shown a unique pair of unfamiliar faces while performing a speeded go/no-go task. In this task, observers were required to withhold a response if there was an abrupt onset of an exogenous cue (no-go trials), and to make a response if a different stimulus was presented (go ‘catch’ trials). Following the completion of an intervening task, observers where asked to make an affective evaluation about the faces they had previously seen in the go/no-go task (e.g., Which of these people looks more friendly?). We found that observers were less likely to make positive affective responses to faces that attention had been exogenously drawn to in no-go trials than to faces to which attention had never been exogenously allocated. These results converge with our previous finding to suggest that inhibition may be associated with an episode encoded into memory, and that later retrieval acts to reinstate inhibitory processing. Importantly, our results suggest that this inhibitory processing involves affective devaluation, which may serve to encourage examination of new information.

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FR122
Sensory signals predict performance on a non-predictive cue-target task Jillian H Fecteau (jillian@eysml.queensu.ca), Douglas P Munoz; Department of Physiology, Queen’s University, Canada – After the appearance of peripheral, non-predictive cues, participants respond faster to targets appearing at the cued location when the time that elapses in between the cue and target is short and they respond more slowly when this time is longer. Traditionally, this pattern of early facilitation and later inhibition has been interpreted as indexing two separate, but related, components of orienting spatial attention. Namely, after the peripheral cue catches the participants’ attention (attentional capture), they are slower to reorient to this previously attended and unmeaningful location (inhibition of return). One problem with this interpretation is that inhibition of return can be observed when no evidence of attentional capture is obtained (e.g., Maylor, 1985). Here, we describe the neurophysiological correlates of these behavioral effects. The activity of single neurons in the superficial and intermediate layers of the superior colliculus was recorded while monkeys performed a non-predictive, cue-target task. In all experimental sessions, inhibition of return was obtained in behavior and was associated with attenuated target-aligned activity of visual and visuomotor neurons in the superficial and intermediate layers. In many sessions, attentional capture was also observed, which was associated with enhanced target-aligned activity because residual activity from the cue augmented the incoming activity from the target. In some sessions, however, attentional capture was not found. In these instances, the target-aligned signal tended to be reduced. Taken together, attentional capture, the absence of attentional capture, and inhibition of return arise from a continuum of sensory processing.

FR123
A performance deficit at the site of attentional cuing Cathy Clarke (cathy.clarke@brown.edu), Michael Paradiso; Department of Neuroscience, Brown University, Providence, RI. – The spatial structure of attention was studied using a 2AFC task in which human and monkey subjects reported the color of a peripheral flashed bar stimulus. Stimuli were presented at the location of a static peripheral cue on a majority of trials and at uncued iso-centric probe locations on the remaining trials. In different experiments, the probability of a target at the cued location ranged from 60–80%. Surprisingly, we found that sensitivity (d’) was
highest for locations approximately 1 degree from the cued target location, and significantly lower for stimuli that appeared at or within 0.5 degrees of the cued location. Sensitivity decreased for stimuli appearing further than 1 degree from the cue. This pattern of sensitivity was obtained using different cue types and stimulus shapes. Because a target at the cued location was more probable than at the probe locations, we considered the possibility that the unusual performance deficit at the cued location was due to adaptation. However, this seems unlikely as we used 6 different bar orientations at the cued location so that no individual target at that location was more probable (and thus more able to adapt receptors) than a target at a probe location. Also, the effect was similar in experiments with a relatively long inter-trial interval (2.5 sec). The deficit at the cued location did not appear to be due to inhibition of return (IOR), because we observed the same spatial pattern of sensitivity when the cue was flashed with a cue-stimulus onset asynchrony of 100 ms, a condition previously shown to not produce IOR. Our results suggest that visual performance is sometimes best a small distance away from the locus of attentional cueing rather than precisely at the cued location. At first glance our data appear to contradict the majority of work demonstrating peak performance at a cued target location. However, most previous cue-validity experiments did not probe performance at a scale as fine as in our study.

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FR124
Contrasting the resolution of exogenously and endogenously controlled attention
Lyndsey K Lanagan (LKL115@psu.edu), Kathleen M Moore; Pennsylvania State University – Attentional resolution (AR) is the precision with which one can discretely move attention among closely spaced items, and it is remarkably coarse given the precision with which people can perceive simply that there are multiple items present (He, Intriligator, & Cavanagh, 2001). One method of measuring AR is the attentional-walk task, which was developed by Intriligator and Cavanagh (2001). In this task, a start disk within an array is cued and the subject must shift attention, stepping between disks in the array, in accordance with a series of directional commands. A probe disk is then indicated and the subject’s task is to report whether or not his/her attentional walk ended on that disk. As the density of the array increases, subjects’ ability to attentionally walk through the array decreases, as measured by decreased accuracy on the probe task. In the present study, we sought to measure AR using an attentional-cuing paradigm in order to link AR to the existing literature on selective attention. In this task, an individual item was cued (e.g., by a brief luminance increase), and then a target stimulus was presented either at the cued location or at an uncued location. Results indicate that exogenously cuing attention to a single item even in dense arrays allowed the target to be identified more efficiently than when it appeared at uncued locations. The contrast between these results and those from the attentional-walk task suggests that the resolution of exogenously controlled attention may be finer than the resolution of endogenously controlled attention. Follow-up experiments using the attentional-cuing paradigm with endogenous cues are underway.

FR125
Covert attention alters visual appearance
Sarah Read (sr728@nyu.edu), Sam Ling, Marisa Carrasco; New York University, USA – Although it has long been established that covert spatial attention improves performance in a number of visual tasks, there is a long-standing debate as to whether attention actually alters appearance. When attention is allocated to a given location via a brief peripheral cue, contrast thresholds along the psychometric function are decreased for the target (Cameron, Tai & Carrasco, 2002). From such findings, it has been inferred that attention actually changes the appearance of an attended stimulus. In this study, we directly tested whether covert attention alters phenomenological appearance. Observers were presented with either a peripheral cue (a small circle flashed adjacent to the stimulus location to elicit transient covert attention) or a neutral cue (a small circle flashed at fixation) for 40 ms. Following a 60 ms ISI, two Gabor patches of either 2 or 6 cpd appeared for 100 ms at 4° eccentricity along the horizontal meridian. One of the Gabors was always presented at 6% contrast (Standard), and the other ranged from 1-12% in contrast (Test). The stimuli were tilted 45° to the left or right. Observers performed an orientation discrimination task for the Gabor that they perceived to be of higher contrast. We assessed appearance by determining which of the Gabor patches observers reported as appearing higher in contrast.

Consistent with previous studies, our results show a threshold shift in orientation discrimination accuracy across the psychometric function with attention. The results indicate that attention decreases threshold in the psychometric function not only in contrast sensitivity, but also in appearance. Although suggested by past studies, these results show that visual attention alters the phenomenological appearance of an attended stimulus.

FR126
Multiple object tracking is scene-based, not image-based
Geniva Liu1 (genivia@interchange.ubc.ca), Erin L Austen1, Mark I Rempel1, Kellogg S Boot2, Brian Fisher2, James T Enns1; 1Dept of Psychology, Univ of British Columbia, Canada, 2Dept of Computer Science, Univ of British Columbia, Canada – Multiple object tracking (MOT) is the ability to individuate a moving object based solely on its spatial-temporal history. We examined whether MOT is based on a scene-based (allocentric) or image-based (egocentric) representation. Observers viewed 16 objects moving in a depicted 3D wireframe box. On each trial, 2, 4, or 6 objects were briefly tagged as the ‘target’ class. All objects then underwent 10 s of random motion (1 or 6 deg/s) before stopping. A single object was then tagged, which the observer identified as a target or a non-target. Preliminary experiments established that MOT was impaired by increases in both size of the target class and speed of object motion. Next, the motion pattern of the 3D box was manipulated. Thus, in addition to varying the speed of objects relative to the center of the box (object motion), the motion of the whole box was varied (scene motion). Unlike variations in object motion, which had a large influence on accuracy, variations in scene motion had no measurable influence. This was true whether the scene underwent rotation, translation, zoom, rotation, or even a combination of all three motions (‘combined motion’).

To tax the ability to use a scene-based representation, we projected the ‘combined motion’ condition onto an obliquely viewed surface. This created retinal motions of the objects and box consistent with an orthogonal view, but the apparent motions underwent large changes because of the affine stretching of the projected image. Nonetheless, MOT accuracy was unaffected. Accuracy was only reduced when we projected the ‘combined motion’ onto a convex corner formed from the junction of two surfaces, the same conditions under which pictorial shape constancy is no longer possible.

These results imply that MOT is accomplished with a scene-based representation. It is motion of objects relative to the larger scene that determines performance, not motion of objects relative to egocentric landmarks like retinal location.

Acknowledgment: NSERC

FR127
Natural scene categorization in the near absence of attention: further explorations
Fei Fei Li (feifeili@vision.caltech.edu), Rajan VanRullen, Christof Koch, Pietro Perona; California Institute of Technology, Pasadena, USA – Subjects are able to detect quickly animals and vehicles in previously unseen cluttered scenes presented peripherally even when their attention is distracted. They are, however, unable to discriminate rotated letters (T/L) and bisected color disks (Red/Green) in the same conditions (Li et al, PNAS 02). We explore this phenomenon further by...
variations of the original experiment.

The first experiment was designed to further probe the extent to which natural scene categorization is possible in the absence of attention. Subjects were instructed to respond whether there was an animal in one of the two natural images presented peripherally in random locations, while concurrently performing an attentionally demanding central task. We could find no significant difference in performance between one and two images. This result strengthens the view that attention is not a critical resource in this task.

The second experiment was designed to verify whether T-L (or bisected color disks) discrimination was poor due to a lack of signal. The number of rotated letters (or bisected color disks) peripherally increased to four instead of one. Even though there were more potential "features" for subjects to detect (e.g., four T junctions than just one), our subjects still failed to discriminate between T's and L's (or between Red/Green and Green/Red disks) when attention was distracted.

In a third experiment we explored the nature of the mechanisms that are critical for the T-L task. We reasoned that rotated T and L presented peripherally differ from images of animals in that the do not constitute an "object class": we are trained to recognize upright letters in the central region of the visual field. While distracting attention we presented our subject with upright T-L discrimination tasks in either the periphery or in the center of the visual field. The performance of our subjects improved significantly.

Acknowledgment: NIH, NSF-ERC, Paul and Daisy Soros Fellowship

Inter-stimulus distance effects in visual search

Lavanya Reddy, Rufin VanRullen, Christof Koch; California Institute of Technology, USA; CNRS, France – In a previous study, we showed that the attentional requirements of a task, as revealed by the dual-task paradigm, do not necessarily determine whether visual search will be parallel or serial. For example, natural scene categorization can be performed “preattentively” in a dual-task situation (i.e. a single scene containing animals can be discriminated from non-animal scenes even while attention is occupied elsewhere), and yet visual search for an animal scene among a number of non-animal scenes is a serial process. We interpreted these findings as follows: a task can be performed preattentively if there exist specific neuronal populations selective to the target and distractor categories, independent of the level of processing involved (from V1 to IT); when such selectivities exist, visual search is parallel only if the receptive fields of the relevant neurons do not significantly overlap. When receptive fields are too large, target and distractors compete within the same field and search is serial.

It follows that search performance should improve if target and distractors can be separated enough to prevent them from falling into the same receptive field. We tested this prediction and found that for preattentive tasks that usually result in serial visual search (e.g.: color-orientation conjunction discrimination, upright vs. inverted face discrimination), search performance improved as inter-stimulus distance was increased. For preattentive parallel tasks (color discrimination, orientation discrimination), the effect of increasing inter-stimulus distance was negligible. These results support the idea that for preattentive tasks, competition within the relevant receptive fields can affect visual search performance.

Acknowledgment: NSF-ERC at Caltech

Change detection and heterogeneity

Elizabeth S Olds, Mark D Degani; Dept. of Psychology, Wilfrid Laurier University, Canada – Recent work in change blindness has shown that observers can detect changes in only a limited number of items at once (Rensink, 2000, Visual Cognition, 7, 345-376) and that homogeneity facilitates change detection (Rich & Gillam, 2000, Vision Research, 40, 1377-1384). Studies of visual search have also shown that homogeneity of distractors facilitates detection of static targets (Duncan & Humphreys, 1989, Psychological Review, 96, 433-458). The present study aimed to further examine the effects of homogeneity on detection of targets defined by change. We used a modified change detection task, in which a display consisting of an initial set of items was presented; then extra items were added to this display and then removed. The observer had to determine whether one of the initial, relevant items changed after the extra items were removed (in Experiment 1, on half the trials one of the initial items moved as the extra items disappeared; in Experiment 2, on half the trials one of the initial items disappeared when the extra items disappeared). The initial items were either homogeneous (all the initial items were the same colour) or heterogeneous (two colours of initial items). It was expected that homogeneity would facilitate detection of changes in the initial set of items, at relevant set-sizes larger than 5, but this was not the case. These results are discussed in relation to the literature and to the attentional mechanisms responsible for detecting change.

Acknowledgment: NSERC

Using eye movements as a measure of selective attention:
Evidence from a spatial negative priming paradigm

Dina Amso, Johnson P Scott; Cornell University, USA – In a spatial negative priming (SNP) paradigm, when a previously ignored location subsequently contains the target to be selected, responses to it are impaired, resulting in increased response times. Previous studies have measured SNP using simple button presses. In the present experiment, we asked whether the oculomotor system would exhibit a similar pattern of results: increased latencies to shift the gaze toward a location that previously contained a stimulus but was ignored (not fixated). Participants were presented with a cross-shaped grid containing four possible locations in which a stimulus could appear as we recorded eye movements with a corneal reflection eye tracker. Two conditions were presented randomly, ignored repetition and control, for a total of 48 trials. Each trial consisted of two parts, a prime and a probe, each lasting 2000 ms. In the prime trials, the target (an animated moving toy with accompanying sound) in one location was accompanied by a distractor (gray diamond) in another location. In ignored repetition probe trials, a target appeared next in the location that the distractor had previously occupied. Control trials were identical except that the probe target appeared in a different location than the distractor. The task was simply to fixate the target and ignore the distractor. We found that saccade latencies to the target were faster on control trials than on ignored repetition trials, (M=245.11ms, SD=37.97 for ignored repetition condition, M=187.9 ms, SD=23.46 for control condition; p < .05). These results suggest that selective attention mechanisms can be measured at the level of eye movements, and that the SNP effect may generalize across response domains.

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Where has object-based IOR gone?

Emily Skow-Grant, Mary A Peterson; University of Arizona, USA – We investigated object- and location-based components of the inhibition of the return (IOR) of attention. In Exp 1, we drew attention first to one of four boxes arranged around a center box and then back to the center. We introduced blank gaps (35, 70, 105 or 140 ms) before presenting a target in either the cued box or an uncued box. (In all experiments, targets appeared equally often in all peripheral boxes.) Following Gibson & Yantis (1994), we expected that the boxes would appear to be new objects after gaps longer than 100 ms, and therefore that the object-based component of IOR would disappear following long gaps. Latencies were longer to detect targets appearing at the cued location than at uncued locations (p<0.05), but this difference was unaffected by gap length. Thus, as indexed by the gap size manipulation with static displays, IOR was not object-based. In
Exp 2, we added color to each of the four peripheral boxes, so they could be distinguished as different objects. We drew attention to one of the peripheral boxes and then back to the center. Next, we rotated the peripheral boxes by 90° and then introduced a gap (0, 35, or 140 ms) before the target. IOR was observed only at the cued location, not at the location to which the cued object moved (p<0.05). Thus, Exp 2 again revealed location-based, but not object-based IOR. Is attention more likely to track the cued object if it is not drawn away before the cued object moves? In Exp 3 we rotated the peripheral boxes by 90° after cueing a peripheral box, but before drawing attention back to the center. After the motion stopped, we drew attention back to the center before presenting the target. No blank gaps occurred. Again, we observed IOR at the original cued location but not at the location to which the object moved (p<0.01). We consider the possibility that under most circumstances observers allocate attention to locations rather than to objects; hence IOR is predominantly location-based.

FR132
Do different systems mediate attention to space vs. objects?
James E Hoffman¹ (hoffman@udel.edu), Pamela Burton²; ¹University of Delaware USA, ²Human Engineering Laboratory, Aberdeen Proving Ground USA – Spatial attention paradigms typically require observers to monitor an empty location in space for the appearance of a target. Results generally support some variant of a spotlight of mind in which the target, as well as irrelevant nearby shapes, receive enhanced processing relative to ignored locations. In contrast, object-based attention experiments show that observers are quite good at selecting one of two overlapping shapes, a situation that would pose difficulties for a diffuse spotlight mechanism. Are these two kinds of attention carried out by separate mechanisms or by a single system operating in different modes? For example, one version of a single mechanism account assumes that object-based attention corresponds to allocation of spatial attention to the surface or contours of the object. We tested this account using event-related brain potentials (ERPs). Previous research has shown that attention to location results in an enhancement of the P1 and N1 components of the visual ERP. This pattern is not observed when subjects attend to other attributes such as color or size, suggesting that P1/N1 enhancement might serve as a "signature" of the operation of the spatial attention system. We compared ERPs for attended and ignored overlapping objects and found differences at latencies as short as 80 ms but comparable P1/N1 components suggesting that object and space-based attention are mediated by different systems.

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FR133
Constraints on task switching in multielement tracking and visual search
Jennifer S DiNaso¹ (jen@search.bwh.harvard.edu), George A Alvarez², Todd S Horowitz², Jeremy M Wolfe¹,²; ¹Brigham and Women's Hospital; United States, ²Harvard University; United States – Both multiple-object visual tracking (MVT) and inefficient visual search are held to demand visual attention. However, we have previously shown (ARVO 2000) that both tasks can be performed concurrently within a single trial with minimal performance loss on either task. How is this possible? Here we test the hypothesis that observers switch back and forth between MVT and search during a trial. Since our original search task was presented briefly during an extended MVT episode, observers may have stopped tracking long enough to search, then returned attention to the MVT items. Previously (VSS 2001), we showed that tracked items can disappear for up to 370 ms during a trial and be recovered with minimal loss of accuracy. In the present series of experiments, we show that observers can perform a difficult search task during this blank interval and still maintain tracking performance (Exp 1). Nevertheless, observers might be performing MVT and search simultaneously with separate resources. In Exp 2, we measured reaction time (RT) to a search task performed alone or concurrently with MVT. The RT x set size slope was unchanged by the addition of MVT, but the intercept increased by 500 ms, consistent with the task-switching hypothesis rather than complete independence. If observers can switch readily between MVT and search, can they perform two MVT tasks simultaneously? In Exp 3, we measured trade-offs between two simultaneous MVT tasks. We observed perfect trade-offs between these tasks. Observers cannot perform two MVT tasks (or two search tasks) at the same time. We propose that search and tracking can coexist because they can trade control over attentional resources. Information about the state of an MVT task appears to be maintained in a representation that enables attention to be deployed to the search task, and subsequently successfully redeployed back to the tracked items if the search episode is not too long.

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FR134
The relationship between object files and conscious perception
Stephen R Mitroff (Stephen.Mitroff@yale.edu), Brian J Scholl, Karen Wynn; Yale University, USA – Many aspects of mid-level vision appear to operate on the basis of representations which precede identification and recognition, but in which discrete objects are segmented from the background and tracked over time (unlike early sensory representations). It has become increasingly common to discuss such phenomena in terms of 'object files' (OFs) – critical mid-level representations which help mediate our conscious perception of persisting objects – e.g. telling us 'which went where'. Despite the appeal of the OF framework, it remains unclear to what degree OFs underlie consciously perceived object trajectories. Here we present at least one case wherein conscious perceptions of 'which went where' in dynamic displays diverge from the computation of 'which went where' in the OF system. Observers viewed an ambiguous 'bouncing/streaming' display in which two identical objects moved such that they could have either streamed past or bounced off each other. We measured two dependent variables: (1) an explicit report of perceived bouncing or streaming; and (2) an implicit object-specific priming (OSP) measure, wherein a 'preview' of information on a specific object – e.g. a letter that flashes inside a small box – speeds the recognition of that letter at a later point when it appears again on the same box (compared to when it reappears on a different box). When the displays were manipulated such that observers had a strong bias to perceive streaming (on over 90% of the trials), there was nevertheless a strong 'negative' OSP associated with the streaming motion, such that the OSP appeared to have 'bounced' even though the percept 'streamed'. Given that OSP measures have been taken as a hallmark of the operation of object files, this suggests that in at least some cases conscious perceptions of 'which went where' in dynamic ambiguous displays can override the mapping computed by the object-file system.

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FR135
Priming effects in multiple object tracking: An implicit encoding based on global spatiotemporal information
Hirokazu Ogawa (ogawa@keiwinet.ac.jp), Akihiro Yagi; Kwansei Gakuen University, Japan – Purpose: In this study, we explored whether the selective processing of randomly moving objects is affected by unattended information in multiple object tracking (MOT). We examined the effect of the trajectories of distractors and the effect of global pattern, using priming paradigm. Methods: Ten white circles were presented and five of these circles were flashed, designating them as the target objects. Then all objects began to move independently in random directions. Thirty-nine observers asked to track five target objects for 5 s and indicate five targets with a mouse. Experimental trials were paired so that a "prime" trial was followed by a “test” trial. There were five experimental conditions. In positive-all condition, the trajectories of both target and distractor items in the prime trial were repeated in the test trial. In positive-target condition, only trajectories of target items were repeated, but those of distractor items were changed in the prime and the test trial. In negative-all condition, the trajectories of all items were repeated, but assignment of targets and
distractors was reversed, so that both targets and distractors in the test trials were negatively primed. In negative-target condition, the trajectories of distractors in the prime trial were presented as targets in the test trial. Those of distractors in the test trial were reproduced. Therefore, only target items were primed in the test trial. In control condition, the trajectories of all items were changed between the test and the prime trial. The number of correctly tracked items was analyzed.

Results & Conclusion: We observed significant positive priming effect in positive-all condition. More importantly, there was negative priming effect in negative-all condition. No priming effect was observed in both positive-half and negative-half condition. These results suggest implicit encoding of target identities based on the global spatiotemporal information in MOT.

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FR136
Severe loss of positional information when tracking multiple dots
Srimant P Tripathy (s.p.tripathy@bradford.ac.uk); Dept of Optometry, University of Bradford, Richmond Road, Bradford, UK—Human subjects can simultaneously track up to 5 dots, when presented with an array of dots moving in a random manner (Pylyshyn & Storm, 1988, Spatial Vision, 3, 179-197). This study investigates to what extent positional information is degraded as the number of tracked trajectories increases.

In pilot experiments, on each trial, a single dot in apparent motion, followed a diagonal linear trajectory from the lower-left of the screen to the upper-right. At a horizontal position indicated by fixed vertical markers, the trajectory deviated either clockwise or anticlockwise; the observer reported the perceived direction of deviation. Using a method of constant stimuli, deviation thresholds at the 84% point were estimated. The length of the trajectories and the dot velocities were adjusted to obtain optimal thresholds (typically 2°).

In the main experiments, the actual number of dots moving (N) was varied, each having the optimal parameters determined above. The average orientation of the trajectories was fixed between trials, but within a trial the N trajectories were jittered about the average; deviation from parallelism could not be used as a cue. In one set of experiments each of the N trajectories deviated the same amount, and thresholds were only mildly affected by variation in N (typically 10° for N=10). In another set only one of the N trajectories deviated; here thresholds increased rapidly with N, with thresholds as large as 30° for N = 4, and with most observers performing unreliably when N was 6 or more.

Severe loss of positional information results when multiple trajectories are tracked. This cannot be attributed to inter-trajectory interference, since thresholds were only mildly elevated when all trajectories deviated. While the identity of up to 5 dots can be reliably tracked, memory of their trajectories is severely compromised. Tracking deviations in trajectories of dots is far more demanding on attentional resources than tracking their identities.
The extended Maxwellian view

Donald I. A. MacLeod (dmacleod@ucsd.edu), Dirk Beer; University of California San Diego, USA — In Maxwellian view, a lens forms an image of a compact light source in the eye pupil. The viewed field is brightly lit since light travels undispersed from source to eye. For typical computer-controlled displays, CRT monitors serve as both source and viewed field, so Maxwellian view is not feasible. But in most current electronic projectors, a compact lamp source illuminates LCD or DLP panels. These panels can be viewed in a Maxwellian configuration if the source, already imaged at the projector objective, is re-imaged in the pupil by a large Fresnel lens. A supplementary positive lens immediately in front of the projector objective makes the projected image coincide with and fill the Fresnel lens, a foot or two from the projector.

Such a setup yields intensities far higher than achieved with any CRT and, in fact, higher than typically wanted. However, by introducing a holographic diffuser in the plane of the projected image, light can be uniformly dispersed over a region around the pupil. This sacrifices (unneeded) intensity, and allows a less restrictive chinrest to replace the customary dental impression. The diffuser-extended Maxwellian image can even be big enough to allow binocular observation, while still providing pigment-bleaching light levels. In addition, the color gamut of this display system can be greatly enlarged (approaching the physical limits) by placing thin dichroic filters in the internal light path of three-panel projectors. We describe experiments that demonstrate the advantages of the new "BIGMAX" stimulator. Dynamic range, light level, color gamut and spatial and temporal resolution are all sufficient for demanding applications in vision research.

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Non-veridical perception in human amblyopia: perceptual evidence of neural changes in visual cortex

Arthur Bradley1 (bradley@indiana.edu), Brendan T Barrett2, Ian E Pacey2, Larry N Thibos3, P Morrill2; 1Indiana University School of Optometry, USA, 2Department of Optometry, University of Bradford, UK — Purpose: This study investigated the prevalence and nature of spatial misperceptions in human amblyopia. Methods: Thirty amblyopes with strabismus and/or anisometropia participated in the study. Subjects viewed sinusoidal gratings of various spatial frequencies, orientations and contrasts. Following inter-ocular comparison, subjects sketched the subjective appearance of those stimuli that had a non-veridical appearance. Results: Non-veridical visual perception was revealed in twenty amblyopes (~67%). In some subjects, misperceptions were present despite normal contrast sensitivity. Distortions were present in both anisometropes and strabismics but were not linked to the depth of amblyopia in a simple way. Errors in perception became more severe at higher spatial frequencies and extended to spatial frequencies far below the contrast detection acuity limit, but very low spatial frequencies were perceived veridically. The prevalence and severity of misperceptions was frequently found to depend upon the orientation of the grating. All of the varied perceptual errors previously reported in the literature were observed in our sample of amblyopes, indicating that the wide range of distortions previously reported reflect genuine inter-subject differences. In spite of the seemingly heterogeneous
nature of these perceptual distortions, almost all can be simulated by replacing the stimulus orientation with a combination of two oblique (relative to the stimulus) gratings. Conclusions: We propose that non-veridical perception in human amblyopia may have its origins in errors in the neural coding of orientation in visual cortex. Modeling shows that, due to the anatomical covariance of ocular dominance columns and orientation pinwheels, such errors in orientation coding are to be expected if the amblyopic eye’s ocular dominance columns are reduced in size.

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SA4

Tuning of expectancy effects indicates top-down attentional modulation of SF channels Paul T Sowden1 (P.Sowden@surrey.ac.uk), Emre Ozgen2, Philippe G Schyns2; 1University of Surrey, UK, 2University of Glasgow, Scotland— Recent work suggests that, for some tasks, selection among multiple narrow-band SF channels is determined ‘bottom-up’ by stimulus size (e.g. Majaj et al., 2002, V. Res., 42, 1165-1184). In contrast, work on spatial scale processing suggests that ‘top-down’ factors can determine the selection of spatial scale (e.g. Schyns et al., 2002, Psych. Sci., 13, 402-409). We have been exploring whether such effects result from top-down attentional modulation of early SF processing. When an observer was cued top-down to detect a sinusoidal grating presented at one SF their detection of an unexpected SF was impaired compared with when the same SF was expected. Further, the degree of impairment scaled with the difference between the expected and presented SF (Sowden et al., 2001, Perception, 30, 91a). Here we further explored tuning of ‘expectancy’ effects. On the first and last sessions, using ZEST, we measured 5 observers’ ‘baseline’ contrast sensitivity to sinusoidal gratings presented, in single frequency blocks, at one of 18 different SF’s spanning an 8-octave range: 2 ‘primary’ SFs (0.5 & 8 cpd) and 16 ‘test’ SFs (0.25, 0.5, 1 or 2 octaves above or below the cued primary). During 8 intervening ‘cuing’ sessions, each trial, a top-down cue signalled the observer to expect one of the two primary SFs, with a different cue for each. However, on 25% of trials one of the test SFs was presented. Compared to baseline, observers’ detection of the test SFs was relatively impaired. The degree of impairment increased as a function of difference in SF from the cued primary. The pattern of this tuning resembled the SF tuning seen in early visual analysis. Thus, our findings indicate that when explicit cues are used endogenous factors can induce attentional modulation of narrow-band SF channels in early vision. Further they suggest that the task dependent selection of spatial scale could similarly involve attention to diagnostic SF channels.

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SA5

Effects of flanking patterns on contrast detection and contrast discrimination Srinivasa L. Varadharajan (rajan@psych.ucsb.edu), John M Foley, Department of Psychology, University of California Santa Barbara, USA – A model of context effects on pattern vision must account for results from several paradigms. We measured the detection threshold for a Gabor pattern as a function of the contrast of flanking Gabor patterns, and the contrast discrimination function (threshold vs. pedestal contrast) with and without flanking Gabor patterns of different contrasts. All the patterns had the same spatial frequency (4 c/deg), space constant (0.25 deg), and orientation (vertical), and when flankers were present they were aligned with the target and presented simultaneously (80 msec). The target was always 4 degrees to the left of the fixation point. The detection threshold is a smooth “dipper-shaped” function of flanker contrast and it is well fitted by the nonlinear excitation divisive inhibition model (Foley & Chen, 1999). In the absence of the flankers, the contrast discrimination function is sometimes a smooth dipper-shaped function and sometimes has a second minimum at high pedestal contrast. This second minimum is accounted for by the intrusion of a second mechanism sensitive to the target. In the presence of the flankers, the contrast discrimination function changes in a complex way. When the flanker contrast is low, thresholds are reduced at low pedestal contrast; when flanker contrast is high, thresholds are increased at all except the highest pedestal contrasts. In addition there is a local maximum at a pedestal contrast about 4 dB below the flanker contrast and a local minimum near the pedestal contrast equal to the flanker contrast. All of these results can be accounted for quantitatively by an elaboration of the model that adds two processes to account for the flanker effects: 1) the flanker not only adds to the divisive inhibitory signal, but also increases or decreases the effect of the target and the pedestal, 2) the flanker produces a local decrease in the contrast response function around the contrast of the flanker.

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SA6

Effects of grey scale range on the detection of symmetry and anti-symmetry Sandra Mancini (mancini@eart2.concordia.ca), Rick Gurnsey, Sharon L Sally, Department of Psychology, Concordia University, Canada — PURPOSE. Points fix, y(x,y) and I(-x,y) are symmetrically placed with respect to the y axis. Zero-mean images possess the property of bilateral symmetry about the y axis if for all (x,y), I(x,y) = I(-x,y), and the property of anti-symmetry if for all (x,y), I(x,y) = -I(-x,y). Mancini, et al. (2001, ARVO) measured sensitivity to symmetry and anti-symmetry as a function of check size for patterns comprising black and white checks. Symmetry and anti-symmetry elicited similar sensitivities for large checks. As check size decreased sensitivity to symmetrical stimuli improved modestly whereas sensitivity to anti-symmetrical stimuli decreased dramatically. We wondered if this pattern of results would hold for the more general case in which stimuli contain a wider range of grey-levels.

METHOD. Symmetrical and anti-symmetrical stimuli were created with checks having intensities drawn from a normal distribution. Check widths ranged from 0.037 to 0.297 of visual angle and all patterns were windowed within a circular aperture of 9.5 in diameter. For each check size, noise masks were created by drawing from the same normal distribution and added to the stimulus. Stimulus contrast (c) and mask contrast (1 - c) summed to 1. Four subjects performed a 2IFC task. One interval contained random noise the other contained symmetry (or anti-symmetry) with some level of added noise; exposure durations and ISIs were 333 ms. Threshold was defined as the stimulus contrast (c) eliciting 82% correct responses.

RESULTS. In most cases thresholds were unmeasurable for the anti-symmetrical stimuli; i.e., even with c = 1 subjects rarely obtained 82% correct responses. For symmetrical stimuli thresholds ranged from 0.63 to 0.70 with no significant effect of check size.

CONCLUSION. Anti-symmetry is extremely difficult if not impossible to detect in the general case. With binary stimuli (Mancini et al., 2001) subjects may be able to detect anti-symmetry by employing attentional strategies.

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SA7

Spatial extent and eccentricity effects for detection of luminance-defined and contrast-defined blob stimuli Subash Sukumar (s.sukumar@apu.ac.uk), Sarah J Waugh; Anglia Polytechnic University, Cambridge, UK – Evidence from masking studies suggests that the detection of luminance-defined and contrast-defined spatial stimuli under foveal viewing conditions are detected by independent mechanisms (Schofield and Georgeson, 1999). Results also indicated similarly sized spatial integration regions for these foveal-viewed stimuli. The aim of this study is to further characterise spatial summation regions for the detection of luminance-defined and contrast-defined stimuli at the fovea and in the periphery.

Luminance-defined stimuli were constructed by adding random dot noise to a Gaussian profile, whereas contrast-defined stimuli were constructed
by multiplying random dot noise to a Gaussian profile. Random dot noise was dynamic and care was taken to eliminate unwanted artefacts. Blobs varied in size from a sigma of 0.06 deg to 2 deg and were presented for 400 msec. Detection thresholds for all sizes were measured at the fovea and at 2.5, 5 and 10 deg in the inferior visual field. A self-paced, temporal 2AFC paradigm was used to obtain performance estimates.

Spatial summation areas for contrast-defined and luminance-defined stimuli obtained under foveal viewing were similar in extent, confirming the previous result. However for all measured eccentricities, spatial integration areas for contrast-defined stimuli were larger than those found for luminance-defined stimuli. Detection thresholds obtained for single-sized stimuli at the different eccentricities also reveal a steeper rate of fall-off for contrast-defined stimuli than for luminance-defined stimuli. These results suggest that in peripheral vision, different underlying processes limit the detection of luminance-defined and contrast-defined spatial targets.

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**SA10**

A special case of the MacKay effect generates geometric hallucinations: Stochastic resonance in pattern formation driven by fractal (1/f) noise

Vincent A Billock\(^1\) (Vincent.Billock@upafb.af.mil), Brian H Tsou\(^2\), \(^1\)Veridian Engineering, Dayton, OH, \(^2\)U.S. Air Force Research Laboratory, WPAFB, OH – PURPOSE: We’ve been studying spatial opponency in flicker-induced geometric hallucinations (fan shaped “seeds” in a flickering field induce illusory concentric circles and vice versa). A version of the MacKay effect (Nature, 1957) shows a similar opponency – if white noise (e.g., TV static) is viewed through a geometric transparency (e.g., a set of concentric circles) the motion of the white noise appears to be orthogonal to the orientation of the transparency. However, we (VSS, 2001) found that illusory spatial patterns (e.g., rotating fans or pulsing circles) form in the noise viewed through the transparency, if the noise is not “white”. To study this effect we used dynamic fractal noise. METHODS: Three observers viewed noise that is 1/f^a in space and 1/f^b in time through a geometric mask that is either a set of concentric circles or a pattern of pie-like wedges. Subjects used the method of adjustment to find the lowest RMS contrast at which illusory geometric patterns appear in the noise. RESULTS: All subjects had much lower thresholds for filtered noise than for white noise; for most conditions pattern formation occurs most easily for spatial exponents of about 1.0-1.3 and temporal exponents around 1.0. DISCUSSION: There is a phenomenon known as stochastic resonance, in which noise has an effect on a nonlinear system or signal. In physics there are three kinds of stochastic resonance: noise amplification of a signal, noise induction of multistability, and noise induction of pattern formation. This last case has never been documented outside of mathematical systems; the effect we describe may be the first known physical manifestation of pattern formation by stochastic resonance. In all types of stochastic resonance, some nonlinear systems prefer 1/f noise and there is a strong link between 1/f spectra and pattern formation in many physical systems.

**SA11**

Reversed Cafe wall illusion

Yusuke Tani (tani8@L.u-tokyo.ac.jp), Kazushi Maruya, Takao Sato; Department of Psychology, University of Tokyo, Japan – Purpose: The main objective of this study was to examine the contributions of luminance (1st order) and higher-order components on Cafe wall illusion by comparing the illusion induced by stimuli with regular square wave (SQ) and missing fundamental (MF) gratings. Although the two types of gratings look alike, the lowest frequency component contained in MF is the third harmonic (3f component) of fundamental frequency of original square-wave. Experiments: We used two types of Cafe wall figure. One was a normal SQ, consisted of three square-wave gratings and two
gray mortars. In the other type, we replaced the square waves by MF gratings. Both stimuli subtended 10.2 (H) x 6.95 (V) deg, and presented at the center of a CRT screen. The spatial frequency for the gratings was 0.2 c/d. Subjects were asked to judge the direction of illusory mortar tilt (2AFC). In Exp. 1, we examined typical configuration where the phase difference (offset) between two adjacent gratings was 90 deg phase angle. In Exp. 2, we systematically varied the offset from 15 to 165 deg in small steps. Results: In Exp. 1, although both types of stimuli subjectively looked quite alike, they brought about tilts in opposite directions. In Exp. 2, the tilt direction was reversed twice for MF stimuli when offset was varied between 15 to 165 deg. No such reversal occurred for SQ stimuli. Conclusion: The tilt reversal found for MF stimuli can be related to 3f-wave components since a 90 deg shift for MF fundamental frequency corresponds to 270 deg (=-90 deg) for 3f components. The direction reversal in Exp. 2 can be also related to processing of 3f component. Although the MF stimulus subjectively appeared quite alike to regular square-wave pattern, the direction of the illusion was determined by invisible 3f component. These results, thus, clearly demonstrated that CFE wall illusion is dominantly a 1st order, luminance phenomenon.

**Acknowledgment:** HFSP

**SA12**

Ethanol-induced changes in Westheimer functions consistent with decreases in lateral inhibition

*Kevin D Johnston (kj johnston@ uwo.ca), Brian N Timney, University of Western Ontario, London Ontario Canada.*—Several studies have shown that alcohol modifies inhibitory neural interactions. We used the visual system as a model to determine the possible perceptual consequences of alcohol-induced reductions in inhibition. The rationale is as follows: if alcohol reduces lateral inhibition, then any visual phenomena that rely on such inhibition should show characteristic and predictable changes. We have already shown changes consistent with reduced inhibition in simultaneous contrast and the Hermann Grid Illusion. In the present studies we extended this logic to the Westheimer paradigm. The shape of Westheimer functions is assumed to depend on the relative contribution of the inhibitory surround in centre-surround receptive fields. We obtained these functions under two conditions: 1. consumption of sufficient alcohol to raise subjects’ BAC to .08%; 2. consumption of an equivalent volume of fruit juice. Subjects were required to detect a 0.02 s target flash superimposed on a luminance pedestal of varying diameter. The pedestal was superimposed on a background field whose luminance was set 1 log unit beneath that of the pedestal. Functions were obtained on backgrounds that were photopic (0.5 cd m-2), mesopic (0.05 cd m-2), and scotopic (0.005 cd m-2). We predicted that if ethanol reduced lateral inhibition, increment thresholds in the photopic and mesopic conditions should be increased at pedestal diameters within the sensitization and plateau portions of the Westheimer function. Because dark adaptation has been shown to eliminate lateral inhibition, we also predicted that the scotopic Westheimer function should be unaffected. Changes consistent with this prediction were obtained in each condition.

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**SA13**

Spatial noise provides new insights into the “receptive field” for Vernier acuity

*Roger Wing-Hong Li (rli@spectacle.berkeley.edu), Dennis M Levi, Stanley A Klein, School of Optometry, University of California, Berkeley, CA USA.*—Humans can make highly precise alignment judgments. There is a long standing question about how information is integrated along the length of the Vernier stimulus. In this study we introduce a novel classification image technique to explore the local contribution of each part of the stimulus to Vernier judgments. We used a two-segment Vernier stimulus in which each segment consisted of five Gabor patches (10 c/deg). We introduced spatial noise by perturbing the position of the individual patches of the ‘test’ segment. The observers’ task was to judge the position of the ‘test’ segment relative to the reference segment. An optimized version of the stimulus was used with binary spatial noise that allowed the number of possible noise combinations to be dramatically reduced. The segment separation was varied from abutting to widely spaced. A reliable classification image for each offset magnitude can be obtained from only 960 trials.

Human thresholds are about twice that of an ideal observer whose judgment is based on the mean of the patch locations. We found that human observers assign different weights to each patch comprising the stimulus. Intuitively the patch that is closest to the reference segment would seem to have the strongest influence. But this is not always the case. For subthreshold abutting stimuli, the second patch has a stronger influence than the first one. Observers tend to use the first four patches; ignoring the fifth. In some cases, the fifth patch even has a strong negative influence on Vernier alignment. We also find interesting contextual effects of interleaving offset stimuli on the classification images of aligned stimuli.

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**SA15**

In search of the early nonlinearity: no luck yet

*Rick Peterson (r.c.peterson@bradford.ac.uk), William McIlhagga, Optometry Department, University of Bradford, Bradford, UK.*—Most models of contrast discrimination consist of a linear filtering stage followed by a nonlinearity and a decision rule. It may be, however, that a local nonlinearity precedes the linear filtering stage. Kingdom and Whittle (1994) suggested an early decelerating nonlinearity (e.g. cone compression) to explain contrast discrimination for low spatial frequency gratings, where discrimination thresholds at high pedestal contrast were lower than at medium pedestal contrasts.

Here we report on an attempt to find direct evidence for such a nonlinearity. We looked for a nonlinearity by measuring the detection threshold of a thin vertical line (1’ arc gaussian cross-section) superimposed on a 1 cycle/degree high-contrast (80%) vertical sinusoidal grating. The grating could be at 0 degrees phase relative to the line (the line appeared at the grating peak) to 180 degrees phase (the line appeared at the grating trough). If contrast discrimination data can be explained by a
local nonlinearity, we would expect the line detection threshold to be smallest at 180 degrees phase, rising smoothly to a maximum at 0 degrees phase.

Instead, we found the smallest thresholds when the sinusoid was placed at 45 and 135 degrees phase. This pattern of thresholds is not consistent with a simple early nonlinearity. It may be explained by assuming there are two mechanisms, which measure contrast from two operating points at about 50% and ~50% contrast (for an 80% grating), and each of which follows Weber’s law for contrast discrimination. These mechanisms may be the retinal on and off channels, and the two-mechanism model may also explain Whittle’s (1986) data on increment and decrement contrast discrimination.


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SA16 Time of day and glucose modulate visual sensitivity Robert Barlow1 (barlow@upstate.edu), Mukhtar Khan1, Bart Farell1, 1Center for Vision Research, Upstate Medical University, Syracuse, NY, 2Institute for Sensory Research, Syracuse University – Glucose and oxygen power our visual system. Our metabolic state is not constant: blood glucose levels and utilization decrease at night. We investigated how time of day and metabolic state influence visual sensitivity. We used a 2AFC psychophysical paradigm to measure contrast sensitivity and multifocal ERG (mERG) to measure retinal sensitivity. We tested subjects day and night and in various metabolic states set by a Glucose Clamp Technique (GCT) or Glucose Tolerance test (GTT). Testing subjects over a 48h period, we found up to 4-fold increases in contrast thresholds at night. The threshold increases correlated with mild nocturnal hypoglycemia controlled by endogenous circadian oscillators. Inducing hypoglycemia and hyperglycemia artificially with GCT and GTT respectively, we found up to 6-fold decreases in contrast sensitivity evoked by moderate hypoglycemia (~50-60mg/dl) and up to 3-fold increases in sensitivity evoked by moderate hyperglycemia (~200mg/dl). Severe hypoglycemia (~40mg/dl) can transiently block central vision (~15deg). Preliminary mERG recordings show that moderate hypoglycemia can decrease the amplitude of the “b” wave generated by central retina (5deg) but not that generated by peripheral retina (>10deg). Moderate hyperglycemia, on the other hand, appears to uniformly up regulate retinal sensitivity. We conclude that metabolic state can modulate visual sensitivity and suggest that central vision may be more sensitive to metabolic stress (hypoglycemia) than peripheral vision. mERG recordings indicate that the metabolic modulation of visual sensitivity begins in the retina.

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SA17 Can a ‘dipper’ function model of primary visual cortex predict pattern discrimination processing? Mazvita Chirimuta (mz3250@cam.ac.uk), David J Tolhurst; Department of Physiology, University of Cambridge, UK – The dipper function is the typical result of psychophysical contrast discrimination experiments where just-noticeable-difference (jnd) of contrast is plotted against contrast of the grating. The dipper has been successfully modelled by assuming a non-linear contrast response function of a spatial frequency channel sensitive to the grating used in the experiment (Legge and Foley, 1980). However, the single channel model is not successful in modelling experiments in which the observer must perform contrast discrimination of gratings which differ in orientation or spatial frequency. Models which include inhibitory input from other channels have performed better on this count (Foley, 1994) but the results of our experiments, in which spatial frequency is altered, have features that are not accounted for by such models. We introduce a model which takes account of some recent neurophysiological evidence about the detailed structure of inhibitory connections in monkey V1. We show that this model does provide a better fit to the psychophysical data. Finally, we show how the model can be modified to fit data on the contrast coding of natural scenes.

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SA18 Linking visual masking effects with fMRI responses in early visual areas David E Nadell1 (nadell@stanford.edu), Barbara Zenger-Landolt1, David J Heeger2; 1Stanford University, USA, 2New York University, USA – Purpose: To measure the neural responses underlying visual masking. We tested the hypothesis that perception of a target stimulus is impaired because the mask suppresses the neural response to the target. Methods: Subjects performed a contrast discrimination task on a targetsrung which was superimposed on a 2D noise mask. The stimulus was restricted to an annulus (0.75 – 2.25 deg eccentricity), and the contrasts of the two components were independently varied. Using a block-alternation design, the fMRI responses, in early visual areas, to four target contrasts (5%, 10%, 20%, and 40%), each superimposed on three mask contrasts (0%, 25%, 50%), were measured with a 3T GE magnet. Retinotopic visual areas were mapped using standard techniques, and the analysis was restricted to the subregion that responded to the annular stimulus. Results: For a given mask contrast, the fMRI response increased with increasing target contrast. For a given target contrast, the fMRI response decreased with increasing mask contrast. Using a model to link the fMRI responses to the contrast discrimination thresholds, we found that the suppression predicted from the discrimination thresholds was similar to the observed fMRI suppression. In a control experiment, we used the same high contrast mask, but eliminating the psychophysical masking by temporally offsetting the mask. In these experiments, we found no suppression of the fMRI response. Conclusion: The pooled activity of neurons in early visual cortex potentially underlies the perceptual phenomenon of visual masking.

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SA19 Non-monotonic eccentricity effects explained by multiple scaling theory Rick N. Gurnsey1 (gurnsey@box2.concordia.ca), Frédéric J.A.M. Poirier1, 1Department of Psychology, Concordia University, Canada, 2Department of Psychology, Queen’s University, Canada – Introduction. In psychophysical experiments stimuli are sometimes scaled (magnified) at each eccentricity in an attempt to compensate for eccentricity-dependent resolution losses. Applying a preselected magnification factor in some cases leads to non-monotonic changes in performance as a function of eccentricity. We argue that such non-monotonic changes arise when performance at each eccentricity is limited by more than one type of resolution loss.

Methods. Poirier and Gurnsey (2002, Vision Research) proposed a method for characterizing the scalings needed to compensate for multiple, eccentricity-dependent resolution losses. This method generalizes several earlier scaling procedures (e.g., Watson, 1987, JOSA). In several experiments we have found that different sources of sensitivity loss may scale differently with eccentricity. Therefore, a stimulus magnified at each eccentricity by a predetermined scaling factor may be unresolved foveally by a one mechanism and unresolved peripherally by another mechanism. Performance may therefore vary non-monotonically over a range of eccentricities.

Results. Using the analytical framework of Poirier and Gurnsey (2002, Vision Research) we show how predetermined scaling factors lead to non-monotonic changes in performance in an orientation discrimination task (Poirier & Gurnsey, 1998, Spatial Vision). We also show how the analysis...
can explain non-monotonic changes in performance arising from unscaled stimuli; specifically, the central performance drop reported by Kehrer (1987, Spatial Vision) and a case of “reverse scaling” reported by Tyler (1999, Visual Neuroscience).

Discussion. We conclude that most eccentricity research can be explained by multiple scaling theory as extended here, where all underlying mechanisms in a task increase in size linearly with eccentricity, but not necessarily at the same rate.

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SA20
Perceiving edge blur: the Gaussian-derivative template model
Mark A Georgeson (m.a.georgeson@aston.ac.uk), Keith A May, Gillian S Barbieri-Hesse; Neurosciences Research Institute, Aston University, Birmingham, UK—We studied the visual encoding of edge blur in images. Our previous work (VSS 2001) suggested a model in which the visual system spatially differentiates the luminance profile twice to create the ‘signature’ of the edge, and then evaluates the spatial scale of this signature profile by applying Gaussian derivative templates of different sizes. The scale of the best-fitting template estimates the blur of the edge. Here we refine the model in the light of further blur-matching experiments. A staircase procedure adjusted the blur of a Gaussian comparison edge until it appeared to match the blur of test edges with different spatial profiles, lengths, contrasts and blurs. We also added a linear luminance gradient to blurred test edges. When the added gradient was of opposite polarity to the edge gradient, it made the edge look progressively sharper. Lower contrast edges also looked sharper. Both effects can be explained quantitatively by the action of a half-wave rectifying nonlinearity that sits between the first and second differentiating stages. This rectifier also accounts for a range of other effects on perceived blur. It segments the image into discrete regions of common gradient polarity around each edge. The effect of contrast arises because the rectifier has a threshold: it not only suppresses negative values but also small positive values. At low contrasts, more of the gradient profile falls below threshold and its effective width shrinks, leading to perceived sharpening. The refined template model has few free parameters, but is a remarkably accurate predictor of perceived edge blur and offers some insight into the role of multi-scale filtering by V1 neurons.

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SA21
Are human observers performing wavelet denoising?
William H Mellhagga (w.h.mellhagga@bradford.ac.uk); Dept of Optometry, University of Bradford, Bradford, England—Wavelet denoising (Donoho & Johnstone 1994) is a powerful method for removing noise from signals encoded by a set of wavelet coefficients. Many aspects of human detection and discrimination can be explained by assuming that the human visual system uses wavelet denoising in visual decision tasks. In wavelet denoising, coefficients less than a threshold sigma*sqrt(2log(n)) are assumed to be mostly noise, and set to zero (sigma is the noise standard deviation and n is the number of coefficients). Applying this procedure to vision, an image is represented as the outputs of a set of n V1 neurons, which may form a sparse wavelet-like code (Field 1994). V1 neurons with activity less than the threshold are ignored in decision-making.

The denoising threshold is identical to the decision threshold implied by Pelli’s (1985) uncertain observer. In Pelli’s model, the observer is correct when one relevant detector exceeds the maximum of M irrelevant detectors, having expectation sigma*sqrt(2log(M)) (Gallambos, 1985). Simulations of the denoising model show that it matches Pelli’s model. However, the denoising model can be extended in two ways. First, the noise threshold can be adapted to the frequency spectrum of the noise. Thus noise that differs substantially from the signal has little effect on detection. Second, the denoising model can be combined with template-based detection models, and this leads to a separation of intrinsic uncertainty (manifest through the denoising threshold) and extrinsic uncertainty (manifest through the use of multiple templates).

Field D.J. (1994) What is the goal of sensory coding? Neural Computation 6 559-601
Pelli, D.G. (1985) Uncertainty explains many aspects of visual contrast detection and discrimination, JOSA A2 1508-1532

SA22
Modelling foveal ganglion cell arrays in primates
Vladislav Kozyrev (vladyslav.kozyrev@student.uni-tuebingen.de), Jan Kremer; Dept. of Experimental Ophthalmology, University of Tuebingen Eye Hospital, Germany—In previous experiments we studied interactions between the center and the surround of receptive fields of neurons in the retinogeniculate pathway and their consequences for human visual perception. To be able to correlate the physiological and the psychophysical data, it is important to consider that a visual stimulus is encoded not by one cell, but by a cell array, the receptive fields of which have different locations relative to the stimulus. We have developed an algorithm with which the spatial distribution of the receptive fields of retinal ganglion cells within the primate fovea can be simulated. To calculate the positions of central points of the receptive fields, the model uses Delaunay triangulation with a superimposed jitter (Zhan and Troy, Visual Neuroscience 17, pp. 23-39). The resulting array is subsequently stretched according to the cell density variation with retinal eccentricity. Our model considers the literature data on the anatomical structure of the primate central retina. However, the model simulates the positions of the receptive fields rather than the locations of the ganglion cells’ bodies, which in the fovea might be different owing to the lateral displacement of the ganglion cells. For the human retina, the simulated patch has a diameter of approximately 3 degrees and contains about 500 ON- and 500 OFF-center magnocellular cells. Other cell subpopulations were also considered. Any array size can be chosen depending on the visual stimulus projected on the retina.

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SA23
Estimating retinal fixation location using fMRI
Sing-Hang Cheung1,2 (sing@eye.psych.umn.edu), Sheng He1, Thomas A Carlson2, Gordon E Legge3, Xiaoping Hu2; 1University of Minnesota, USA, 2Emory University, USA—Purpose. We are developing a method for retinotopic mapping of the visual cortex in people with central field loss. Retinotopic mapping based on polar coordinates uses rotating wedges and expanding rings, which assume stable foveal fixation. However, people with central field loss usually adopt a non-foveal retinal location for fixation and that location is typically unknown. Therefore, instead of using the polar-coordinate based mapping method, which requires a known origin, we developed a set of phase-coded mapping stimuli in Cartesian coordinates that will also allow us to estimate the fixation locations relative to the unknown fovea location. The current study aims to validate this new mapping procedure in observers with normal vision.

Method. High-resolution structural and functional MR images were acquired on a Siemens 3T system. Two mapping stimuli were used. Both were 2 deg wide checkered bars, which extended across the full-display. One was a vertical bar moving across the screen from left to right. The other was a horizontal bar that moved from top to bottom. In both cases, the bar traversed the display 4 times, each pass taking 72 s. Since the subjects fixated on a dot at the center of the display, the bars should cross the fixation at the mid-point of the 72-second period. This time point was compared with the time point when the bars cross the fovea, which was estimated by deriving the switch of V1 activation from one hemisphere to
the other hemisphere produced by the vertical bar, and from the lower bank to the upper bank of the calcarine sulcus produced by the horizontal bar. Results. With this new method, the estimated fovea locations were within 2 deg from the actual locations. Conclusions. Our new stimuli allow us to estimate the fixation location with acceptable precision. This new procedure may be useful for retinotopic mapping on people with central field loss.

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SA24

Decorrelation of neuronal responses during eye movements: possible implications for the refinement of V1 receptive fields

Michele Rucci1 (rucci@cns.bu.edu), Antonino Casile2; 1Department of Cognitive and Neural Systems, Boston, MA 02215, US, 2Max Planck Institute for Biological Cybernetics, Tübingen, Germany—In the receptive fields of V1 simple cells, the adjacent excitatory and inhibitory subregions receive selective input from ON- and OFF-center LGN neurons. Modeling studies have shown that before eye opening this segregation of geniculate afferent is compatible with a Hebbian mechanism of synaptic plasticity that operates on spontaneous neural activity. However, it is not clear how Hebbian plasticity could account for the refinement and maintenance of simple cell receptive fields after eye opening, when neural activity is shaped by the statistical structure of the visual input. Natural scenes are characterized by broad spatial correlations that presumably coactivate large pools of geniculate cells with similar polarity, a result that appears incompatible with a Hebbian segregation of geniculate afferents.

We have recently suggested that after eye opening the modulations of neuronal activity produced by oculomotor behavior may contribute to a refinement of cortical receptive fields. In a model of the cat's LGN, when natural scenes were scanned by sequence of eye movements, the instability of visual fixation due to fixational eye movements modulated geniculate responses in a way that was compatible with a Hebbian refinement of simple cell receptive fields. To examine the possible impact of these short-living patterns of synchronous activity in the LGN on the long-term correlation between geniculate and cortical cells, in this study we simultaneously simulated the responses of populations of LGN and V1 neurons during oculomotor activity. In the model, small fixational eye movements attenuate the neuronal sensitivity to the broad correlational structure of natural visual input, decorrelate neural responses, and establish a regime of neural activity that is compatible with Hebbian segregation of geniculate afferents to the cortex. This result is highly robust and does not depend on the precise characteristics of the model.

SA25

A model of the possible influences of eye movements on the maturation of cortical direction selectivity

Olga Parsons (oparsons@bu.edu), Michele Rucci; Department of Cognitive and Neural Systems, Boston, MA, US—Several features of the responses of cells in the striate cortex, such as orientation and direction selectivity, appear to develop before the exposure to pattern vision and are then refined by visual experience. It is a working hypothesis that the maturation of these neuronal characteristics relies on a Hebbian mechanism of synaptic plasticity that operates initially on spontaneous neural activity and later on visually induced responses.

To investigate whether the statistical structure of neural activity after eye opening may be compatible with a Hebbian refinement and maintenance of direction selective responses, neuronal activity was simulated in a computer model of the cat LGN and V1. Spatiotemporal filters were used to predict the responses of V1 and LGN cells while images of natural scenes were scanned in a way that replicated the oculomotor behavior of the cat. Kernels with inseparable spatial and temporal components were designed to replicate the initial directional bias of V1 neurons. The model of the LGN included neuronal populations with different timing characteristics as observed in the cat.

The specific patterns of correlated activity required for the maturation of direction selective cells were found during the periods of visual fixation when small eye movements occurred, but not when natural images were examined statically or scanned in the absence of fixational eye movements. In addition, simulations that replicated experiments in which kittens are reared under stroboscopic illumination produced a specific loss of direction selectivity, while preserving orientation selectivity, which is consistent with experimental findings. These results show that after eye opening a Hebbian mechanism of synaptic plasticity may account for the refinement of cortical direction selectivity and suggest a possible involvement of the oculomotor activity of visual fixation.

SA26

Is there a relationship between spike bursts in the lateral geniculate nucleus (LGN) and behavioral events?

David W Royal1 (david.royal@vanderbilt.edu), Gyula Sáry2, Jeff Schall3, Vivien A Casagrande4; 1Center for Molecular Neuroscience, Vanderbilt Vision Research Center, Vanderbilt University, USA, 2Dept. of Cell Biology, Vanderbilt University, USA, 3Center for Integrative and Cognitive Neuroscience, Dept. Psychology, Vanderbilt Vision Research Center, Vanderbilt University, USA, 4Vanderbilt Brain Inst., Dept. Cell & Developmental Biology, Dept. Ophthalmology & Visual Sciences, Dept. Psychology, Vanderbilt Vision Research Center, Vanderbilt University, USA—Cells in the LGN exhibit two modes of firing, burst and tonic. In the LGN, Sherman (2001) has suggested that burst mode may be used as a “wake up call” alerting an animal to relevant stimuli that are then analyzed further when LGN cells are in tonic mode. In this study we examined the presence of bursts under different behavioral conditions. Single LGN cells were recorded while monkeys made saccades freely in complete darkness (FREE) or to a target located in the LGN cell’s receptive field (GO). A change in fixation spot color signaled the monkeys to either remain fixated (red) or to shift gaze to the target (green). Bursts, defined as a series of spikes having interspike intervals of 4 ms or less preceded by a period of silence lasting at least 100ms, were recorded during both the fixation period and saccade period for both the GO and FREE tasks and also following the cue in the GO task. Bursts were seen in 94% of cells (59/63) recorded in the FREE task and 28% of cells (26/90) in the GO task. Bursts were seen in M, P and K (blue-ON) cells. The average number of bursts per second was 0.36 for cells recorded in the FREE task and 0.08 recorded in the GO task. Bursts were seen in all behavioral epochs in both tasks and burst number did not differ significantly between epochs. Our results demonstrate that although a significant fraction of LGN cells burst in the awake state, bursting appears more linked to behavioral state than to task demands, at least under conditions where monkeys are familiar with the task.

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SA27

Responses of macaque V1 neurons to fixational and voluntary eye movements correlate with receptive field properties

Igor Kagan1,2, (igor@eri.harvard.edu), Andrzej W Przybyszewski1, Moshe Gatt1,2; Max Snodderly1; 1Schenep's Eye Research Inst., USA, 2Technion, Israel—Natural viewing in primates consists of abrupt saccades followed by slower movements. We recorded the activity of single V1 neurons in response to a stationary bar while monkeys performed a fixation task or made voluntary saccades of different sizes. The classical receptive fields (CRFs) were mapped with drifting and flashing bars while compensating for fixational eye movements. Voluntary saccades were elicited so that the CRF would cross the stimulus bar, land on it, or leave it. Three characteristic patterns were found in response to both fixational and voluntary eye movements: 1) “Saccade” cells discharged transiently whenever the CRF was swept across, onto, or off the stimulus, but were not activated during inter-saccadic periods even when the CRF was constantly on the stimulus. They had transient responses to flashes and were tuned for relatively high velocity. 2) “Position/drift” cells did not respond to rapid crossings of the stimulus but fired continuously while the
stimulus was within the CRF. They had sustained flash responses, preferred low velocity, and tended to be selective for sign of contrast. 3) “Mixed” cells fired bursts of activity following saccades but also continued to fire at a lower rate during inter-saccadic intervals, if the CRF remained on the stimulus. Their properties were intermediate between “saccade” and “position/drift” cells. In many “mixed” and “saccade” cells, the response decreased or disappeared with increasing size of crossing saccades. It remains an open question what causes this effect: a high velocity cut-off, an active suppression, or both. Our results suggest that different V1 neurons selectively extract information about motion, change, position and visual detail.

Both fixational and voluntary saccades modulated neuronal firing in the absence of a visual stimulus, but the modulation was slower and much weaker than the visual response. Thus an extraretinal input to V1 is effective, even for the smallest saccades.

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SA28
The influence of spatial displacement between stimulus and receptive field upon the responses of LGN cells Jan Kremers (kremers@uni-tuebingen.de), Vladislav Kozynce; Dept. of Ophthalmology, University of Tuebingen Eye Hospital, Germany – In previous experiments, we found that the perception of flicker strength in a circular stimulus can be changed by altering the relative temporal phase of a simultaneously flickering surrounding annulus: weak flicker is perceived when the two stimuli are modulated approximately in phase; counterphase modulation of center and surround stimuli will result in strongly perceived flicker. The response amplitudes of LGN cells vary in a similar manner with relative phase, when the stimuli are spatially matched to the receptive fields (RFs) of the cells. From this it was concluded that the physiological basis of flicker perception is already present in the LGN. To strengthen this conclusion, it is necessary to study all responding cells, including those for which stimulus and RF do not match. We therefore studied the responses of marmoset LGN cells to the above mentioned combined stimuli varying the relative phase between center and surround and varying the spatial displacement between the stimuli and the RFs. It was found that, when the center and surround stimuli were modulated in phase (resulting in a full field stimulation), the responses of the cells don’t change strongly with changing spatial displacement. As a result, all cells that are covered by such a stimulus, will respond similarly. This might cause a weak perceived flicker in the center stimulus. On the other hand, the responses strongly depend upon spatial displacement when the temporal phase difference between center and surround stimuli is large. Thus, the responses of all cells covered by the stimulus can be very different, depending upon their spatial position. This may introduce a spatial signal for cortical cells and cause a strongly perceived flicker. The responses of the cells were compared with predictions assuming that the RF is a linear summation of center and surround Gaussians responsibility profiles. The actual responses and the predictions were in qualitative agreement with each other.

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SA29
Receptive field properties and laminar organization in the lateral geniculate nucleus of the gray squirrel (Sciurus carolinensis) Stephen D. Van Hooser (vanhoosr@brandeis.edu), Jan-Alexander F Heimel, Sooyoung Chung, Sacha B Nelson; Brandeis University, USA – Squirrels are diurnal rodents with large eyes, dichromatic color vision, large striate and extrastriate visual cortical areas, and good visual acuity. They are abundant, inexpensive, and offer many technical advantages in common with the poorly-sighted rat and mouse. We have characterized receptive field properties of single neurons in the lateral geniculate nucleus of the anesthetized gray squirrel using white noise, monochromatic and cone-isolating colored spots and annuli, and sinusoidal gratings. In the squirrel, the LGN contains five layers of cells with alternating retinal innervation, labeled (medial to lateral) 1, 2, 3a, 3b, and 3c, with 3c bordering the optic tract. The contralateral input is to layers 1, 3a, and 3c, while layers 2 and 3b receive ipsilateral input. Cells in layers 1 and 2 show very sustained responses to constant stimulation, and neurons in layers 3a, 3b, and 3c show more transient responses. Most neurons in layers 1-2 have response latencies between 20-30ms, and some cells in these layers show color antagonism between the center and surround. Cells in layers 3a and 3b are quite heterogeneous. About half of the cells in 3a and 3b show strong center-surround organization and have latencies around 20-30ms, while the other cells show less activity, long, widely distributed response latencies, and do not tend to show strong center-surround organization. While many properties of these short latency cells in 3a and 3b overlap those of cells in layers 1-2, the 3a-3b cells are more transient and show less linearity of spatial summation than cells in layers 1-2, which are quite linear. We discuss how these cell types and their laminar distributions compare to those observed in dichromatic primates and carnivores.

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SA30
Orientation selective responses to the offset of grating stimuli James Schummers (schummers@mit.edu), Miriganka Sur; Pioneer Center for Learning and Memory & Dept. of Brain and Cognitive Sciences, MIT, USA – It is well established that the responses of neurons in primary visual cortex (V1) are not static, but rather are influenced by recent stimulus exposure. Previous work has demonstrated strong effects of preceding stimuli on responses to subsequent ones (Nelson, 1991; Dragoi et al, 2000). We have examined the activity of neurons in V1 during the period after the removal of a grating stimulus, when no explicit stimulus was present (the screen was uniform gray). We find that orientation tuning curves taken during this interval (referenced to the previous stimulus) are generally tuned orthogonal to the tuning during the grating presentation (~66% of cells within 90°/ ~10 degrees). This orthogonal tuning is shaped by both a decrease in firing following the preferred orientations, and surprisingly, in ~30% of cells, by an increase in firing following orthogonal stimuli. This “offset response” has a similar latency to the grating onset response, and typically lasts longer than 500 msec, and can be more than half as large as the response to the grating itself. Interestingly, this behavior is more pronounced in complex cells than in simple cells. The selectivity of the tuning curve during the blank period was positively correlated with the selectivity during the grating period (r = .76). There is not a simple inverse relationship between the number of spikes fired during the two epochs; for many sharply tuned neurons, in which several grating orientations fail to elicit any response, only those orthogonal to the optimal elicited an offset response. This phenomenon may provide a means for highlighting temporal orientation contrast, and may be related to psychophysical phenomena such as orthogonal percepts following extended viewing, which have been attributed to a rebound from inhibition (Vidyasagar et al 1999).


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SA31
The effects of short periods of strabismus on cortical binocularity Hua Bi (hbi@baylor.edu), Bin Zhang, Jianghe Zheng, Ichiro Maruko, Eiichi Sakai, Earl L Smith, Yuzo M Chino; College of Optometry, University of Houston, Texas, USA – Background: Previously we reported that only 14 days of optically induced strabismus around 4 weeks of age were sufficient to disrupt the disparity sensitivity of neurons in V1 and to increase the prevalence of interocular suppression (Kumagai et al, 2000; Mori et al, 2002). In this study we investigated whether shorter durations of misalignment could disrupt the binocular response properties of V1 neurons. Methods: Strabismus was optically simulated in 4 infant rhesus...
monkeys using a prism-rearing procedure. Two infant monkeys were reared with prisms for 7 days and two additional monkeys experienced optical strabismus for only 3 days. The onset age was fixed at 4 weeks of age for all subjects. The microelectrode recording experiments were conducted immediately after the end of the rearing period (i.e., no recovery). Results: Seven days of strabismus (roughly equivalent to 4 weeks in humans) resulted in a high prevalence of binocularly suppressive neurons and a decrease in the average degree of binocular disparity sensitivity. However, these deficits were not as severe as those that occurred after two weeks of misalignment. Three days of optical strabismus had no obvious effects on the degree of disparity sensitivity of individual neurons. In contrast, the prevalence and magnitude of interocular suppression were greatly increased in the monkeys that experienced just 3 days of strabismus. Conclusions: The present results indicate that the first binocular response alteration in V1 that emerges following an ocular misalignment is interocular suppression, which is closely followed by a breakdown of binocular disparity sensitivity.

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SA32
Comparisons of interocular suppression in v1 neurons of normal neonatal and infant strabismic monkeys Ichiro Maruko (imaruko@aol.com), Hua Bi, Bin Zhang, Jianghe Zheng, Eiichi Sakai, Earl L Smith, Yuzo M Chino; College of Optometry, University of Houston, Texas, USA — Background: V1 neurons in neonatal monkeys (6-14 days of age) show a higher prevalence of interocular suppression than in adults to both interocularity matched (iso-oriented) and unmatched (orthogonally-oriented) gratings. However, the prevalence of these suppressive interactions rapidly decreases to normal adult levels by 8 weeks of age (Endo et al, 2001). In this study we investigated how early onset strabismus influenced this normal maturation of binocular signal interactions. Methods: Strabismus was optically simulated in 8 infant rhesus monkeys using a prism-rearing procedure. The onset of strabismus was at 2 weeks of age (before the know onset age for stereopsis), and 4 or 6 weeks of age (after stereopsis onset), and the duration was 14 days (short) and 4 or 8 weeks (long). Immediately after the end of the rearing period, we conducted the microelectrode recording experiments. Results: In all strabismic infants, the binocular signal interactions in V1 neurons were very similar to those that were found in normal neonatal monkeys. Specifically, the strabismic monkeys exhibited a higher than normal prevalence of interocular suppression and the prevalence of interocular suppression for the orthogonally oriented gratings was nearly identical to that for binocularly matched gratings. Conclusions: These findings suggest that the higher than normal prevalence of interocular suppression in V1 in both strabismic and normal neonatal monkeys has similar underlying causes. One possibility is that the effectiveness of excitatory binocular connections, both local and long-range, is reduced in strabismic subjects due to early conflicting binocular inputs or in normal neonates due to retinal and/or cortical immaturities, while inhibitory inputs are largely spared or, at least relatively, more mature (Sepigel et al, 1996; Smith et al, 1997; Kumagami et al, 2000).

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SA33
Characterization of Area 18 modulation from stimulation outside the receptive field of Area 17 cells in the cat Heather A Brown (heather.a.crouch@vanderbilt.edu), John D Allison, Jason M Samonds, Alicia M Thomas, A B Bonds; Vanderbilt University, USA — A stimulus placed outside the classic receptive field (CRF) of an Area 17 cell does not evoke an excitatory response. However if the CRF is stimulated to excite the cell, a second stimulus placed in the periphery modulates this baseline activity. Two questions address this phenomenon: 1) what CRF properties are modulated by these influences and 2) from where do they originate? In cats paralyzed and anesthetized with Propofol and N2O, we investigated which properties (i.e. orientation, spatial frequency, temporal frequency, contrast and diameter) of the Area 17 cells’ RFs were modulated by a peripheral stimulus and whether the modulation originated in Area 18. We inserted a tungsten electrode in Area 17 and a multi-barrel injection and recording pipette in Area 18 and identified restricted sites with non-overlapping RFs. Optimal stimulus parameters for the Area 17 cell were determined and control tuning curves for each parameter were measured. We then optimized stimulation parameters for the Area 18 site and verified that iontophoretic administration of GABA (0.5 M) silenced the response to that stimulus. To determine the influence of the peripheral site on the response of the Area 17 cell, both sites were stimulated simultaneously and each curve was remeasured. The spatial frequency and contrast responses generally remained unchanged, but the orientation (5/10), temporal frequency (4/10) and diameter tuning (4/10) curves decreased and/or shifted according to the 95% confidence interval. To determine if these influences came from Area 18, GABA was applied to the Area 18 site and the curves were remeasured using both stimuli. In half the cases, the responses returned to control levels indicating that Area 18 activity caused the modulation. This result supports our hypothesis that top down influences from Area 18 make a significant contribution to the widespread integration of information by Area 17 cells.

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SA34
A comparison of structurally and functionally defined human primary visual cortex Holly Bridge1 (holly.bridge@physiol.ox.ac.uk), Stuart Clare2, Peter Jezzard2, Andrew J Parker2, Paul M Matthews2; 1Dept of Physiology, University of Oxford, UK, 2FMRIB Centre, University of Oxford, UK — Early visual areas can be defined using fMRI on the basis of their retinotopic organisation. Recently, very high-resolution images of the human brain in vivo have identified areas of myelination within the grey matter, corresponding to the striate cortex (Barbier et al. 2002; Clare et al. 2002). This myelination has traditionally been understood to correspond to the human primary visual cortex (V1). To test this correspondence, we compared the location of visually identified striate in high resolution images with the location of functionally defined V1.

For imaging the myeloarchitecture, a magnetisation prepared 3D FLASH sequence was used as described in Clare et al. (2002). The resulting images had a resolution of 0.3x0.3x1.5 mm. Functional MRI was performed at a lower resolution of 3x3x1.5 mm using single shot EPI at the same 16 slice locations as the structural scan. Retinotopy data were collected using expanding ring and rotating wedge stimuli. The data were transformed onto a segmented (mrGray) and flattened (mrFlatMesh) T1-weighted scan (1x1x1mm). V1 was defined by locating the upper and lower field V1/V2 borders from the rotating wedge phase map.

From the high-resolution myeloarchitecture images, striate cortex was conservatively determined as those regions where a stripe was identified within the grey matter. These observer drawn maps of striate cortex were then transformed into flattened space to allow comparison with the functional data. A good level of correspondence was found between the striate cortex determined in the structural MRI and V1 determined by fMRI. While the striate cortex was not identified as a continuous band, it is hoped that more striate will be revealed by using multiple slice orientations in the same subjects. In the future these very high-resolution structural images will offer the opportunity to combine the study of myeloarchitecture with functional architecture in the living human cortex.

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SA35
The organisation of space and orientation preference in V1 of the marmoset monkey Niall P McLaughlin (n.p.mclaughlin@umist.ac.uk), Ingo Schiessl; Dept of Optometry and Neuroscience, UMIST, UK — The common marmoset monkey (Callithrix jacchus) is a small new world primate with excellent spatial vision. Previous electrophysiological studies have mapped the gross retinotopy of V1 and some of its response
properties (for example Bourne et al, Cereb Cortex 2002 12:1132-45; Fritsch & Rosa, J Comp Neurol 1996, 372:264-82). In this study we present the first optical maps of the fine retinotopic organisation of V1 along with maps of orientation preference from the same regions of cortex. Specifically, marmosets were anaesthetised and paralysed using standard procedures (McLoughlin & Blasdel, Neuroimage 1998, 7:326-336) and refracted so that they focused onto a computer monitor that contained our moving stimuli. Preference for orientation was mapped by collecting camera frames when the marmoset viewed moving bars of one orientation and subtracting these frames from camera frames collected during presentation of the orthogonal orientation. Images were then processed using a combination of first frame analysis and the extended spatial decorrelation algorithm (Schissel et al., IEEE Trans. on Biomed. Engin., 2000, 47:573-577). Retinotopic strips of space were imaged in a similar manner.

Our results demonstrate that V1 exhibits a smooth and regular retinotopic organisation with relatively isotropic cortical magnification, similar to that of the squirrel monkey (Blasdel & Campbell, J Neurosci. 2001, 8286-301). Vertical bands of space run parallel to the V1/V2 border (as determined histologically) with horizontal bands of space running at approximately right angles to the border. Strips of space aligned at 45 and 135 degrees run at intermediate angles. Orientation is mapped continuously over the surface of V1 but we find no obvious correlation between the retinotopic organisation of space and the organisation of orientation preference. This is in agreement with previous results of ours from V1 in the macaque monkey (McLoughlin & Blasdel, 1988; Soc. Neurosci. Abstr. 24:9).

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SA36

Visualotopic organization of bush baby primary visual cortex (V1) revealed by optical imaging Erik E Emerich1 (erik.emerich@vanderbilt.edu), X Xu2, J Mavito-Hudson1, M Galluccio3, A Thomas2, B Bahrami2, D Shima4, J Stefanis2, B A Bonds6,5, V A Casagrande1,2,3,1

Vanderbilt Vision Research Center, Vanderbilt University, 2Department of Psychology Vanderbilt University, 3Cell and Developmental Biology Vanderbilt University, 4Biomedical Engineering Vanderbilt University, 5Electrical Engineering, Vanderbilt University – The bush baby (Galago garnetti) is a small nocturnal prosimian primate with a smooth cortex. In this study, we used optical imaging to examine the visuotopic organization of V1, taking advantage of the fact that a significant portion of V1 is available to imaging on the dorsal and lateral surface in this species. For visual mapping, topographically limited horizontal and vertical grating stimuli were presented monocularly either within 2 rectangular windows or 2 patches at eccentricities ranging from 0 to 15°. Shifting the mapping stimuli by as little as 1 produced discrete shifts in activation foci in cortex. The visuotopic organization of bush baby V1 was similar to that previously reported based upon microelectrode mapping (Rosa et al., 1997). V1 shows a continuous representation of the visual field with the vertical meridian marking the V1/V2 border and the horizontal meridian bisecting V1. The cortical magnification factor (CMF) was calculated as the average mm distance in cortex for 1 deg of visual space. CMF systematically decreased with increasing eccentricity: CMF = -0.11 * eccentricity + 1.78 (R=0.67, P<0.0001), but was less steep than reported in macaque monkeys and did not show the vertical versus horizontal meridian anisotropy reported for macaque monkeys (Van Essen et al., 1984). The relationship was comparable to that described by Rosa et al. (1997). Taken together, these results indicate that: 1) the organization of bush baby V1 is analogous to that of other primates and 2) optical imaging can usefully be applied as an efficient and high resolution visual mapping tool.

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SA37

Functions confined in space and spatial frequency include Gabor-like functions as well as intrinsically two-dimensional functions resembling “non-Cartesian” gratings Bruce W Knight1 (brucewkn@rockefeller.edu), Jonathan D Victor2, 1The Rockefeller University, USA, 2Weill Medical College of Cornell University, USA – Established theoretical reasons recommend functions that are limited in space and spatial frequency as models for receptive fields of visual neurons. On the basis of an interpretation of spread as variance and via analogy to quantum mechanics, the Gabor functions are often stated to be maximally limited in space and spatial frequency (Daugman, 1985). Some Gabor functions indeed resemble receptive fields in V1, but this view provides little insight into why V1 receptive fields have only a small number of lobes, nor into receptive field shape beyond V1. Here we consider an alternative interpretation of “limited in space and spatial frequency.” We consider a function to be “confined” in space (or spatial frequency) if it is unchanged by windowing in space (or spatial frequency). While no function can be simultaneously confined in both space and spatial frequency, there is a rigorous sense in which the 2-dimensional Hermite functions achieve simultaneous confinement as nearly as possible. The 2-dimensional Hermite functions are a complete basis set and form a natural hierarchy. The first levels of this hierarchy contain functions that resemble Gabor functions with a small number of lobes, and thus resemble V1 receptive fields. Further down the hierarchy are intrinsically 2-dimensional functions, some of which resemble the non-Cartesian gratings, to which some V4 neurons respond preferentially (Gallant, 1996). In addition to their many interesting mathematical properties, the two-dimensional Hermite functions allow for efficient ("sparse") local synthesis of images, including natural scenes, faces, and letters.

While we make no claim that this view suffices to account for receptive field structure, we suggest that it provides a framework for a principled study of receptive fields, and that it is useful to think of receptive fields (along the V1-to-V2-to-V4 pathway) as not only expanding, but also increasing in their combined space-bandwidth aperture.

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Compound stimuli promote architectural reorganization in cat striate cortex

Alicia Thomas1 (alicia.m.thomas@vanderbilt.edu), Michael Galucchi2, Xiaomin Xie3, John Allsop4, James Stefanisu5, Daniel Shima5, Vivien Casagrande6, A B Bonds1; 1Department of Biomedical Engineering, Vanderbilt University, Nashville, TN USA, 2Department of Psychology, Vanderbilt University, Nashville, TN USA, 3Department of Electrical Engineering, Vanderbilt University, Nashville, TN USA, 4Department of Cell & Developmental Biology, Vanderbilt University, Nashville, TN USA — Striate cortical organization can be modeled either as static or as dynamically modifiable by complex stimuli. To study this issue we performed intrinsic optical imaging on cats anesthetized with N2O and Propofol and paralyzed with Pavulon. The influence of complex stimuli on orientation maps was examined by superimposing sinusoidal gratings. Four single gratings presented at 45 deg intervals and 56% contrast were used as control stimuli. These stimuli were then combined with a spatially congruent “mask” grating oriented at 30 deg and the mask was also presented alone. All presentations were interleaved to reduce motion artifact. After compensating for the presence of the mask, we constructed single condition maps (SCM) using cocktail blanks for each stimulus. These SCMs were compared with the controls to determine mask-induced changes in activation patterns. For orientations within ±45 deg of the mask, there was less activation in the compensated maps than in the controls and activation patterns were shifted. For orientations greater than 45 deg from the mask, the activation patterns of the control and compensated maps were similar, but there was less contrast in the compensated maps. An orientation preference map was created using the compensated SCMs and compared to the control orientation preference map. The mask caused shifts in regions of constant orientation, but these were confined to orientations within ±45 deg of the mask orientation. Iso-orientation domains were shifted away from the mask orientation. We found both creation and annihilation of pinwheel centers in the experimental map, but the loci of the orientation pinwheels that weren’t annihilated by the mask did not change. Our results suggest that the spatial organization of striate cortex can be dynamically modified by complex stimuli, which has impact on physiological models of visual function.

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A simple empirical law for a class of visually timed interceptive actions

James R Tresilian (james@hms.uq.edu.au); University of Queensland, Australia — People are highly skilled at intercepting moving objects and capable of remarkably precise timing—in the order of a few milliseconds. The timing of interceptions is constrained by two situational factors: the time available to plan and complete the action and the temporal precision required by the task. Recent research on interceptive actions indicates that a highly replicable relationship is likely to exist between movement timing and task constraints. This is analogous to the classic Fitts’ law relationship that relates movement time (MT) to task variables for movements aimed at stationary targets. We report two experiments that allowed a description of the relationship for an anticipatory interception task (without target pursuit). Two quantities that determine the required temporal precision were varied in experiment 1—target speed and size. Available time (viewing time, VT) was kept constant and relatively large (1.6 s). MT was found to decrease with increases in target speed and decreases in target size. These results conform to a specific empirical relationship between MT and the task variables. In experiment 2, VT and target speed were varied. MT was found to decrease monotonically with decreases in VT and the effect of target speed declined, becoming undetectable at the shortest VT (0.48). These results can be interpreted as providing direct information about the ‘rule’ used by the nervous system to pre-determine MT in anticipatory interceptions.

Acknowledgment: Support: NIH grant EY10534
How do we grasp (virtual) objects in three-dimensional space? Kerstin Stockmeier (kerstin.stockmeier@tuebingen.mpg.de), Heinrich Horton, Volker H Franz; Max-Planck-Institut für biologische Kybernetik, Tübingen, Germany – Jeanerod (1981,1984) studied extensively the relationships between object size and grasping parameters, which has been influential for the interpretation of grasping data. The maximum grip aperture (MGA) scales linearly with object size, but the slope is less than 1 (app. 0.82, cf. Smeets & Brenner 99). Here, we investigated if the location of the object in three-dimensional space influences the MGA. As well, we addressed the question if the grasping of virtual objects shows the same characteristics as natural prehension. Virtual environments could enable experimenters to easily vary objects after the movement onset and therefore to explore the mechanisms of online control in visually guided movements. A virtual disc (36, 40, or 44 mm in diameter) was rendered using stereo computer graphics in 27 positions in different heights and locations relative to the observer. Virtual, haptic feedback was given using two robot arms (PHANToM TM). One robot arm was connected to the index finger, one to the thumb. Ten participants grasped the discs and transported them to a goal area, where they dropped the discs. The stereoscopically rendered discs were viewed through a mirror, such that the visual and haptic feedback matched. The position of the finger tips was measured using the two robot arms and an Optotrak (TM), in order to test for the accuracy of the PHANToM devices.

The MGA was dependent on the distance of the object with respect to the observers body but not on the height of the disc. Participants scaled their movements relative to the object in three-dimensional space influences the MGA. As well, we investigated if the grasping of virtual objects shows the same characteristics as natural prehension. Virtual environments could enable experimenters to easily vary objects after the movement onset and therefore to explore the mechanisms of online control in visually guided movements. A virtual disc (36, 40, or 44 mm in diameter) was rendered using stereo computer graphics in 27 positions in different heights and locations relative to the observer. Virtual, haptic feedback was given using two robot arms (PHANToM TM). One robot arm was connected to the index finger, one to the thumb. Ten participants grasped the discs and transported them to a goal area, where they dropped the discs. The stereoscopically rendered discs were viewed through a mirror, such that the visual and haptic feedback matched. The position of the finger tips was measured using the two robot arms and an Optotrak (TM), in order to test for the accuracy of the PHANToM devices.

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Distorted shape perception impairs grasping of real objects
Raymond H Cuijpers (cuiipers@fys.fgg.eur.nl), Eli Brenner, Jeroen B J Smeets; Neuroscience, Erasmus University Rotterdam, The Netherlands—It is known that visual shape perception is distorted in depth, but it is unclear how this influences grasping. We measured how subjects grasp real cylinders that are placed at eye height under normal lighting conditions. The cylinders were 10cm tall with an elliptical base. One principle axis was always 5cm, whereas the other was varied between 2cm and 8cm in steps of 1cm. The cylinders were placed directly in front of the subject, at a distance of either 15cm or 45cm. Their orientation was varied from 0 to 150 in steps of 30°. Grasping performance was compared with that in a previous study in which the cylinders were placed well below eye height so that subjects had no difficulty judging their shape.

We found that subjects are less accurate at matching the orientation of their hand to that of the cylinders when the targets are at eye height. This often led to unstable grasps. Moreover the maximum grip aperture was about 2cm larger when the cylinders were placed at eye height. Nonetheless, the correlation between the hand orientation halfway through the movement and the final hand orientation was already about 70%. The correlation between the grip aperture during the movement and the final grip aperture was only 30% when half the distance was traversed, but it was still only 60% when reaching the object. These results indicate that the grasping movement uses incorrectly specified pick-up locations on the cylinder’s surface. Uncertainty makes the subjects increase their grip aperture, but we did not find evidence for increased online control.

Perceptual judgements and manual tracking are equally affected by an expansion/contraction illusion
Joan Lopez-Moliner (moliner@fys.fgg.eur.nl), Jeroen B J Smeets, Eli Brenner; Neuroscience, Erasmus MC, Rotterdam, The Netherlands—We measured perceptual judgements of lateral and sagittal extents of a target moving along an elliptical path, and manual tracking paths of a target moving along the same trajectory. Since the expansion/contraction was only modulated along the sagittal plane, we expect the illusion to affect both sagittal measures and not the lateral ones. The magnitude of the effect was the same for both tasks. Moreover, a significant correlation across subjects between the effect of the illusion on the perceptual and the motor task was found and no significant effect on the measures for the lateral dimension. We conclude that the equal effect of illusions on perception and action is not limited to contextual illusions.

Slow corrections to arm movements for target perturbations in depth
Eli Brenner (brenner@fys.fgg.eur.nl), Jeroen B J Smeets; Department of Neuroscience, Erasmus MC Rotterdam, The Netherlands—Reliable depth perception is essential for successfully guiding one’s hand toward objects. Binocular disparities are often considered to be the primary source of metric information about depth. Moreover, as the hand approaches the object, errors in initial depth judgments give rise to relative disparities that could be used to correct the movement. In the present study we examine whether people can quickly adjust their movements on the basis of information from binocular disparities.

The tactics and timing of smooth corrections in human arm movements
Mark Mon-Williams1 (monw@abdn.ac.uk), Susannah Murphy2, Paul Hibbard2; 1University of Aberdeen, Scotland, 2University of St Andrews, Scotland—Background. Human arm movements frequently need ‘on-line’ correction due to object movement and intrinsic inaccuracies in motor control. This study addressed four outstanding questions regarding how the nervous system adjusts arm movements in response to target displacement. A double-step paradigm was used with participants required to move to a target that changed its starting position (46cm along the midline) 10ms after movement initiation on 50% of trials (perturbation condition). The data from the trials where the target did not jump were compared to identical trials from a subsequent condition where the target was never displaced (non-perturbation).

Results. We discovered differences in the spatial path between conditions (presumed to be strategic) but the temporal characteristics of the movement were unaltered. It was found that the system could make smooth continuous corrections (defined as an absence of any visible inflection on the movement trajectory) in the perturbation trials. A study of the inter-trial variability across time suggested that the system implemented corrections in the deceleration phase of the movement (circa 230ms) although the system is capable of modifying a trajectory as early as 110ms. It was found that movement time to a displaced target was a function of both total distance travelled and the displacement distance.

Conclusions. These findings demonstrate strategic responses to statistically probable object movement. These strategies allow the system to respond smoothly to object movement occurring even after movement initiation. The corrections took place in the deceleration phase of the movement with the modifications impacting upon movement duration.

Eye-centered remapping in patients with bilateral parietal lobe lesions
Aarlene Z. Khan1 (akhan@yorku.ca), Yves Rossetti2; 1York University, Canada, 2Espace et Action, France—Previous studies have shown that normal subjects update visual space in eye-centered coordinates (Henriques et al. 1998). Furthermore, this remapping takes place in the posterior parietal cortex (Medendorp et al. 2002; Batista et al. 1999). Here we explore how updated information is retained in patients with bilateral posterior parietal lesions (optic ataxia (OA) patients). We recorded finger positions on two OA patients and five neurologically normal controls while they pointed to targets in the dark (head fixed). We compared two paradigms, 1) static, where Se pointed to the amplitude of the trajectory of the manual tracking were affected by manipulating the target’s apparent depth with perspective cues in the surrounding. In the present study we explore whether manipulating the apparent depth by expanding and contracting the object itself will also influence both tasks to the same extent. We measured perceptual judgements of lateral and sagittal extents of a target moving along an elliptical path, and manual tracking paths of a target moving along the same trajectory. Since the expansion/contraction was only modulated along the sagittal plane, we expect the illusion to affect both sagittal measures and not the lateral ones. The magnitude of the effect was the same for both tasks. Moreover, a significant correlation across subjects between the effect of the illusion on the perceptual and the motor task was found and no significant effect on the measures for the lateral dimension. We conclude that the equal effect of illusions on perception and action is not limited to contextual illusions.

Acknowledgment: The first author was supported by a grant from the MECD of the Spanish government, ref. EX2002-0301.
reminded peripheral targets and 2) dynamic, where Ss looked directly at a briefly presented target before looking away and then pointing to it. Ss performed these paradigms in two conditions, a) pointing immediately after the flashed target and b) pointing after a 3s delay. An eye-centered updating hypothesis predicts similarities in pointing errors between static and dynamic trials (slope of 1 when comparing the two) whereas a non-retinotopic hypothesis predicts a slope of 0. In controls, we found support for eye-centered updating during both immediate and delay conditions (average slope = 0.86) with no significant differences between the two. However, in our patients, we found significant differences between immediate and delayed trials with slopes of 0.41 and 0.76 respectively, indicating that although the patients could update information in an eye-centered frame, they could only do so after a certain time delay (five seconds). These results suggest that extra-PPC mechanisms (e.g. frontal cortex, superior colliculus) contribute to the updating of reaching space in an eye-centred frame, but cannot function optimally in the absence of the PPC.

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Thresholds for detecting a difference between seen and felt position of the hand  Daniel S McConnell (daniel.mcconnell@wisc.edu), Christopher Vallee, Michelle Munerow, Rouwayne Lee; Department of Psychology, Wichita State University, USA – Information about hand location is required to guide a reach to a target. Vision and proprioception are both understood to provide information about hand position. Information from these two modalities must be integrated, and the relative weighting of these two sources of information varies across many experimental conditions and tasks. Van Beers, Wolpert, and Haggard (2002) reported data consistent with the idea that these weightings coincide with the relative reliability of each source of information. Specifically, vision is more reliable at discriminating differences in direction as opposed to distance, and proprioception is more reliable at discriminating differences in distance as opposed to direction. In the current study, we examined this hypothesis by measuring thresholds for detection of a dissociation between the seen and felt positions of the fingertip. Two observers viewed a stereoscopically displayed virtual fingertip represented as a 1 cm-diameter sphere in a virtual environment using a head-mounted display (Virtual Research V8). Finger position was monitored using an electromagnetic motion tracker (Ascension Technologies Flock of Birds). The location of the finger was passively located at any of nine locations corresponding to a 3x3 grid on a tabletop. The visually specified location of the fingertip varied randomly at either 2, 3, 4, 5 or 6 cm to the left, right, front or back of the actual (felt) fingertip location, plus a twenty-first condition in which there was no dissociation between seen and felt position of the fingertip. The overall threshold for detecting the dissociation was approximately 5 cm. Furthermore, thresholds were lower when the perturbation was to the left or right, as compared to in depth. Also, perturbations were lower at the nearest distances, and along the body’s midline.

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Transient and steady-state phases of position computation for a moving target  Haluk Ogmen (ogmen@uh.edu), Kaan Canuiz, Saumil S Patel, Harold E Bedell; University of Houston, Houston TX USA – Purpose: To characterize the dynamics of position computation for moving targets in human vision. Methods. On a dark monitor, observers (N=3) viewed a rotating line that was straddled by two horizontally aligned flashes. The luminance of the rotating line was either 1.0 or 2.5 log units (LU) above its detection threshold. The luminance of the flashes varied from 0.2 to 4.0 LU above their detection threshold. To probe the steady-state phase of the position computation process of a moving target, we used the continuous motion (CM) paradigm, in which line rotation started long before the occurrence of flashes. To probe the transient phase of the position computation process, we used the flash-initiated cycle (FIC) paradigm, in which line rotation started concurrently with the presentation of the flashes. The observers judged the direction of spatial offset between the rotating line and the flashes at the instant when the flashes were perceived.

Results. For both luminances of the moving line, the perceived misalignment of the line was the same in the FIC and CM paradigms when the flashes were of relatively low detectability, but systematically grew larger in the FIC paradigm as the detectability of the flashes increased. For the brightest flashes, the difference in perceived flash misalignment between the FIC and CM paradigms reached 80 ms for the dimmer rotating line. For the brighter rotating line, the differences between the perceived misalignment in the FIC and CM paradigms were consistently about 25 ms less.

Conclusions. Because the latency of the flashes is expected to decrease as their detectability increases, the systematic luminance-dependent changes in perceived flash misalignment between the FIC and CM paradigms provide a quantitative characterization of differences between transient and steady-state phases of position computation for a moving target. Our findings are consistent with the differential latency hypothesis but not with the postdiction hypothesis.

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SA54
Flash lag Effect: Speeding up to get ahead?  Beenah Khurana1 (beenak@cogs.sussex.ac.uk), Katsumi Watanabe2, Romi Nijhawan1, 1Department of Psychology, University of Sussex, United Kingdom, 2National Institutes of Health, USA – In primates, visual processing takes place in a series of hierarchical steps. Cumulative neural delays should cause a moving object’s perceived position to lag its instantaneous physical position. However, there is a paradox: When a moving object’s instantaneous perceived position is measured by presenting a flash in spatial alignment with it, observers see the moving object as leading the flash. If delays in the processing of the moving and the flashed object are assumed to be the same, then the moving object must speed-up in order to be perceived ahead of the flash. Alternatively, the above stated “perceptual-lag-for-motion” premise entrenched in current thinking on neural delays requires re-examining.

Six observers first participated in a standard flash-lag experiment. The flash-lag effect measured for each observer in this first experiment was then used to calculate the magnitude of speed increment that the moving object would have to undergo in order to be seen ahead of the flash. Next the same observers participated in a signal detection task where the signal was the speed increment calculated from the first experiment. Observers’ performance was close to perfect in terms of distinguishing between trials with a speed increment from those without.

The results indicate that the flash-lag effect occurs in the absence of any perceived speed increment. These results strongly oppose the “perceptual-lag-for-motion” premise, and provide further support for a visual mechanism that corrects for the delays for moving objects.

SA55
Speed perception of flickering stimuli  Michael J Discip1 (discip@socrates.berkeley.edu), Karen K De Valois1, Tatsuto Takeuchi2, 1Dept. of Psychology, UC Berkeley, USA, 2NTT Communication Science Labs, Japan – Purpose: To examine how accurately observers can judge the speed of an intermittently presented linearly translating spot. Methods: Stimuli were moving white spots (0.3 deg, 5 cd/m2) on a dark background. Test stimuli moved at a constant velocity, but flickered on and off as they moved across the screen. Comparison stimuli moved at a constant velocity without flickering. Angular velocity of the test stimuli ranged from 4 deg/sec to 32 deg/sec at octave intervals. Test stimuli flickered at 2, 4, 8, or 16 Hz as square wave alternations. Subjects compared the forward speeds of translation of the two stimuli. An interleaved 2AFC staircase method was
used to determine the comparison stimulus speed that appeared to match the translation speed of the flickering spot. Direction of motion (left/right) and spatial position (upper/lower) of test and comparison stimuli were randomized on each trial. The distance traveled and starting location of each stimulus varied pseudorandomly. Results: The perceived speed of the test stimuli varied as a function of velocity and flicker rate. In general, the speed of flickering stimuli moving at a slow velocity (4 deg/sec) was either overestimated or accurately matched. Moderate and high velocities (8-32 deg/sec) tended to be underestimated, with the error increasing with increasing velocity. At the highest flicker frequency (16 Hz), the apparent speed of translation was consistently greater than for lower flicker frequencies. Conclusion: The perceived speed of intermittently presented stimuli depends upon both translation velocity and flicker rate, with slow velocities and fast flicker rates producing speed overestimation, while fast velocities and slow flicker rates lead to speed underestimation.

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SA56
The perceived speed of global flow Scott N. Watananitik (scott.watananitik@wright.edu); Wright State University, Dayton, OH USA – When an observer views a random-dot cinematogram (RDC) in which dots are assigned new directions of motion from a distribution spanning up to and even greater than 180 deg, the perception is that of global flow (Williams & Sekuler, 1984). The direction of this global flow generally corresponds to the mean direction of the underlying direction distribution. However, though every dot is displaced the same distance, and thus moves at the same speed, the perceived speed of global flow slows as the width of the underlying direction distribution increases. Here, we investigated the perceived speed of global flow for different width direction distributions. Observers viewed RDCs comprised of 256 dots, each assigned a direction from a uniform distribution of directions with a mean direction upwards (frame rate=60 Hz). Dots were displaced the same distance regardless of direction (constant step size). Each trial, observers were shown one interval containing a standard stimulus in which all dots moved in the same direction and speed (direction distribution width=0 deg) and another interval containing a test stimulus in which the underlying distribution of directions spanned 30, 60, 90, 120, or 180 deg. The speed of the standard stimulus was fixed at 12, 15, 18, or 21 deg/sec and the speed of the test varied from trial-to-trial. The point of subjective equality (PSE) was computed for each distribution width and standard speed. The perceived speed of global flow closely matched the speed of the computed average vector in the mean direction of the underlying direction distribution. Thus, the individual dot displacement for stimuli with wide direction distributions had to be larger than that of the standard for the slow for global flow speed to match that of the standard. These results suggest that for global flow, local motion vectors (direction and speed) rather than just local directions are integrated.

Acknowledgment: Supported by NSF Grant IBN-9983563

SA57
Frequency and space domain classification images for motion detection Abtine Tavassoli (atavasso@ece.utexas.edu), Chris R. Palmer, Lawrence K. Cormack; University of Texas at Austin, USA – We used two variants of the classification paradigm to reveal features and strategies used to discriminate motion direction (left vs. right). The stimulus consisted of a moving, temporally-windowed luminance increment embedded in dynamic white noise. 2-D classification images were computed on both the space-time and spatio-temporal frequency planes, i.e. classification images and classification spectra, respectively (the spatial direction orthogonal to the target motion was ignored). The stimuli were divided into four groups based on the target direction and the observer’s response. Two methods were used for the spectral classification: in one, the transforms were combined across groups in the complex domain; in the other, the average magnitudes were combined. The classification frequency spectra revealed two findings. 1) Both users seemed to be using off-velocity viewing. That is the orientation of the highest energy in their classification spectra was tilted slightly from the orientation of the maximum stimulus energy (this is puzzling since the task was a left-right discrimination rather than a velocity discrimination threshold). 2) One observer seemed to be attending to both directions, while the other was apparently making a right / not-right decision; there was no obvious template feature corresponding to rightward motion for this observer. The classification images revealed another curious finding: the noise masks that gave rise to incorrect judgments were not those that contained an excess of energy in the non-target direction, but rather those that contained a dearth of energy in the target direction.

SA58
The role of apparent contrast in the speed tuning of direction repulsion William Currán1 (w.curran@qub.ac.uk), Christopher P. Bentzen2; 1Queen’s University of Belfast, UK, 2University of Bristol, UK – A number of studies have investigated the speed tuning of direction repulsion. In these, the shift in perceived motion direction of a target is measured as a function of the speed of a distractor. Such studies have all used relatively narrow ranges of distractor speeds. We sought to obtain a more complete measurement of this speed-tuning function. Using translating, superimposed target and distractor planes of Laplacian of Gaussian dots, we measured perceived repulsion of the target (speed 2.5 deg/sec) as a function of distractor speed (0.625 – 15.0 deg/sec). Our results revealed an inverted U-shaped speed-tuning function peaking at about 5 deg/sec. This is what would be predicted if global motion extraction was performed by the two independent speed-tuned channels proposed by Edwards, Badcock and Smith (Vis. Res., 38, 1573-1580). However, it is known that repulsion magnitude is inversely related to distractor contrast, and that contrast sensitivity falls off rapidly at high temporal frequencies. Thus it is possible that the observed attenuation of target repulsion in the presence of high-speed distractors was a consequence of reduced distractor visibility. We measured motion direction detection thresholds for distractors drawn from the same speed range as before. We then repeated the speed-tuning experiment, setting the contrast of the target and distractor planes to ten times their contrast detection thresholds. Following this manipulation of stimulus contrast, we found that the attenuation of direction repulsion at high distractor speeds was almost entirely eliminated. Thus the reduction of repulsion magnitude in the presence of a high-speed distractor can be largely explained in terms of the reduced apparent contrast of the distractor. These results suggest that, if direction repulsion occurs at the level of Edwards et al.’s proposed speed-tuned channels, the two channels cannot be wholly independent.

SA59
Measurement of rate of expansion in the perception of radial motion Jeff D. Wurfel1 (jwurfel@usc.edu), Norberto M. Grzywacz1,2, Jose F. Barraza1; 1University of Southern California, Department of Biomedical Engineering, USA, 2University of Southern California, Department of Biomedical Engineering, USA, Neuroscience Graduate Program, USA – Previous studies have shown that humans can discriminate angular velocities of rotations, and speeds and directions of translations in optic flows. These types of motions are two of the few components that one can decompose optic flows generated by small rigid patches of surfaces. A third important component is radial motion. We wanted to test whether its parameters, namely, the rate and focus of expansion can be measured by the visual system. To test the discriminability of the rate of expansion, we used a two-alternative forced-choice paradigm, controlling for local-velocity cues by using solid disks of different radii. In turn, to test for the effects of the mislocation of the focus of expansion, we manipulated its position relative to the fixation point in an expanding random-dot field. The results showed that rates of expansion could be finely discriminated regardless of the relative sizes of the stimuli. The Weber fraction for this
Reducing contrast really can speed up faster-moving stimuli

Peter Thompson (pt2@york.ac.uk); Department of Psychology, University of York, UK—Purpose: It is well-known that reducing the contrast of a slow moving stimulus reduces its apparent speed. Thompson’s (1982 Vis Res) report of this finding also suggested that at speeds above 8 c/s reducing contrast increased perceived speed. However in a later report, Stone & Thompson (1990 Vis Res), using a more rigorous, forced-choice procedure, failed to collect reliable data at these higher speeds. I now report a thorough re-examination of the dependence of speed on contrast at higher rates of movement.

Method: Subjects viewed pairs of brief (500ms) sine-wave gratings, foveally presented in a 2 interval forced choice procedure. The speed of one grating (Variable) was stair-cased to match the perceived speed of the other (Standard). The gratings either shared the same contrast (10% and 70%) or differed in contrast, Variable 10%, Standard 70% & vice versa. 2 spatial (2 & 8 c/deg) & 5 temporal (2, 4, 8, 12 & 16 c/s) frequencies were investigated. 4 subjects completed all conditions 4 times.

Results: 1. At 2 c/deg, 10% contrast gratings appeared to move significantly slower than 70% contrast gratings at Standard speeds of 2 and 4 c/sec (by 27% & 12% respectively), but appeared to move faster at Standard speeds of 8, 12 & 16 c/s (by 12%, 21% & 20%). The cross-over point between a reduction and an increase in perceived speed with contrast reduction occurred around 6 cycles/s (3 deg/s). 2. At 8 c/deg the comparable figures are speed reductions at 2, 4 & 8 c/s (by 42%, 32%, 11%), speed increases at 16 c/s (17%). The cross-over point was much higher, around 12 c/s (1.5 deg/s).

Conclusions: These results, including the shift in crossover point at 8 c/deg, can be understood within a model that postulates that speed is computed from the ratio of a ‘fast speed’ (magnocellular) and a ‘slow speed’ (parvocellular) mechanism. These results may present problems for Bayesian models that assume a slow velocity ‘Prior’ to explain the effects of contrast on speed perception.

Detecting changes of velocity of smoothly moving objects

Jason Harrison1 (harrison@cs.ubc.ca), Ronald A Rensink1,2, Michiel van de Panne2; 1Department of Computer Science, UBC, Canada, 2Department of Psychology, UBC, Canada—Based on day to day experiences, computer graphics researchers have concluded that abrupt changes in velocity of a visual stimulus are easily detected. Meanwhile, vision scientists have shown that the human visual system does not have acceleration or ‘change of velocity’ detectors. The second view implies that attention to the movement of an object is required to detect changes in its velocity. We report the results of a set of experiments to test the sensitivity of the human visual system to smooth and abrupt changes in the base velocity of objects. These experiments are the temporal equivalent of spatial contrast sensitivity experiments performed using sine wave gratings many years ago.

Using 2AFC and PEST we determined the minimal amplitude of periodic velocity modulation (ie, the threshold of detection) of the base velocity of an object for three periodic waveforms (sine, square, and triangle), frequencies of modulation from 1 to 9 Hz and base velocities between 3 and 9 degrees/second.

Summary: the human visual system is able to detect each of the waveforms equally well with slightly better sensitivity to the square waveform -- implying that velocity discontinuities are largely irrelevant and it is the distance traveled that leads to higher sensitivity; the highest sensitivity is near 3 Hz with decreasing sensitivity and increasing variance away from 3 Hz; sensitivity is highest for lower base velocities and decreases as variance increases with base velocity.

Applications: Quantified limits on the ability of the human visual system to detect changes in velocity can help inform the design of algorithms for compressing motion data (important for computer games) as well as designing the interpolation methods commonly used in computer animation and simulation.

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Jason Harrison1 (harrison@cs.ubc.ca), Ronald A Rensink1,2, Michiel van de Panne2; 1Department of Computer Science, UBC, Canada, 2Department of Psychology, UBC, Canada—Based on day to day experiences, computer graphics researchers have concluded that abrupt changes in velocity of a visual stimulus are easily detected. Meanwhile, vision scientists have shown that the human visual system does not have acceleration or ‘change of velocity’ detectors. The second view implies that attention to the movement of an object is required to detect changes in its velocity. We report the results of a set of experiments to test the sensitivity of the human visual system to smooth and abrupt changes in the base velocity of objects. These experiments are the temporal equivalent of spatial contrast sensitivity experiments performed using sine wave gratings many years ago.

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Motivation: The ability of the human visual system to detect changes in velocity can help inform the design of algorithms for audio-visual integration, computer animation, and virtual reality. Detecting changes in velocity is also important for the study of the mechanisms underlying the representation of movement.

The ability of the human visual system to detect changes in velocity has been studied extensively. Thompson (1982 Vis Res) showed that the human visual system is able to detect changes in velocity of smoothly moving objects. However, little is known about the ability of the human visual system to detect changes in velocity of abruptly changing objects.

The aim of this study was to investigate the ability of the human visual system to detect changes in velocity of abruptly changing objects. We used a two-alternative forced-choice (2AFC) procedure to determine the minimal amplitude of periodic velocity modulation (ie, the threshold of detection) of the base velocity of an object for three periodic waveforms (sine, square, and triangle), frequencies of modulation from 1 to 9 Hz and base velocities between 3 and 9 degrees/second.

Summary: the human visual system is able to detect each of the waveforms equally well with slightly better sensitivity to the square waveform -- implying that velocity discontinuities are largely irrelevant and it is the distance traveled that leads to higher sensitivity; the highest sensitivity is near 3 Hz with decreasing sensitivity and increasing variance away from 3 Hz; sensitivity is highest for lower base velocities and decreases as variance increases with base velocity.

Applications: Quantified limits on the ability of the human visual system to detect changes in velocity can help inform the design of algorithms for compressing motion data (important for computer games) as well as designing the interpolation methods commonly used in computer animation and simulation.
Modeling the velocity tuning of macaque MT neurons

Charles H Anderson1 (char@shiffer.wustl.edu), Harris Nover2, Gregory C DeAngelis3;
1Washington University School of Medicine, USA, 2Caltech, USA – The direction and speed tuning of MT neurons has been well characterized physiologically. Direction tuning curves are generally Gaussian, whereas speed tuning curves are typically skewed toward higher speeds on a linear axis.

We show that the speed tuning curves of MT neurons are well fit (median R^2 = 0.97) by a Gaussian in log speed, \( q(|v|) = \ln(|v| + c)/v0 \), with center position \( v_c \) and standard deviation \( \sigma_s \). Speed is denoted by \( |v| \), \( v0 \) is a constant, and \( v_c \) denotes the preferred speed. The fits produced tightly clustered values for \( \sigma_s \) (mean = 1.22) and \( v0 \) (mean = 0.30 deg/sec) across a population of 501 MT neurons. Fixing both of these parameters causes only a modest reduction in the quality of the fits (median R^2 = 0.92), leaving only the preferred speed, \( v_c \), and amplitude of the tuning curve to vary across neurons. Thus, the speed tuning curves of the MT neurons are well-described by a single function that is simply shifted along the log speed axis by \( q(v_c) \).

We next generalized the expression for the velocity tuning of MT neurons in two dimensions by adopting a log-polar model (similar to that used to model the retinotopic map in V1) in which the 2D mapping from v to q is composed of neurons with a wide range of preferred direction and speed tuning curves. Thus, the speed tuning curves are typically skewed toward higher speeds on a linear axis.

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SA65

Similar temporal specificity of perceptual choice signals across a large pool of V5/MT neurons

Tamara L Curnow, Kristine Krug, Andrew J Parker; University of Oxford, England – In the awake macaque, MT neuronal firing to ambivaluously rotating cylinders is correlated with the reported direction of rotation when the stimulus is closely matched to the neuronal receptive field. We recently reported the existence of strong choice-related firing in MT, even when the orientation of the cylinder is sub-optimal for the neuron (Curnow et al. 2002, Neurosci. Abs.). It is not clear if the choice signal has the same source in both cases. Here, we have investigated whether the neuronal correlates of the perceptual decision showed similar temporal characteristics over the two second trial for both sub-optimal and optimal stimuli. We separated the trials according to the monkey’s choice and the stimulus orientation. For each neuron, all action potentials for each group of 2 second trials were assigned to 60ms bins and the histograms were normalised and averaged over neurons. The emergence of choice-related firing at sub-optimal orientations was similar to that found at optimal orientations. Choice-related differences in firing were not present before stimulus onset but emerged during the first 100-300ms. They then remained stable for the remainder of the trial. The stimulus orientation on the preceding trial did not affect firing rates but there was a relation between the preceding trial and firing rate in the first 500ms of the current trial. The similarity in temporal characteristics between choice-related firing at optimal and sub-optimal orientations suggests that the choice-signal is observed in MT stem from the same source. Thus the pool of MT neurons that carries a choice signal (and thus potentially contributes to the decision process) is composed of neurons with a wide range of tuning properties. This has significant implications for models of the neuronal coding of perceptual decisions.

Acknowledgment: The Wellcome Trust and the Royal Society

SA67

Two-dimensional motion signals in primary visual cortex of alert monkeys

Eli Leibovich, Steven P. Methot, Zeki Saitoh; Jaggi Desimone Center for Visual Science, Center for Neural Science, New York University, New York, USA. – We recently reported the existence of strong choice-related firing in MT (Curnow et al. 2002, Current Biol). It is not clear if the choice signal has the same source in both cases. Here, we have investigated whether the neuronal correlates of the perceptual decision showed similar temporal characteristics over the two second trial for both sub-optimal and optimal stimuli. We separated the trials according to the monkey’s choice and the stimulus orientation. For each neuron, all action potentials for each group of 2 second trials were assigned to 60ms bins and the histograms were normalised and averaged over neurons. The emergence of choice-related firing at sub-optimal orientations was similar to that found at optimal orientations. Choice-related differences in firing were not present before stimulus onset but emerged during the first 100-300ms. They then remained stable for the remainder of the trial. The stimulus orientation on the preceding trial did not affect firing rates but there was a relation between the preceding trial and firing rate in the first 500ms of the current trial. The similarity in temporal characteristics between choice-related firing at optimal and sub-optimal orientations suggests that the choice-signal is observed in MT stem from the same source. Thus the pool of MT neurons that carries a choice signal (and thus potentially contributes to the decision process) is composed of neurons with a wide range of tuning properties. This has significant implications for models of the neuronal coding of perceptual decisions.
macaques. Pack C Christopher (cpack@hms.harvard.edu), Margaret S Livingstone, Kevin R Duffy, Richard T Born; Harvard Medical School, USA – The one-dimensional nature of contours complicates the analysis of moving objects, because local velocity measurements become confounded with contour orientation. This “aperture problem” is relevant to neurons in the primary visual cortex, where small receptive fields permit only local measurements. The endpoints of contours, however, yield two-dimensional information, so they are not subject to the aperture problem. While the responses of cortical neurons to contours have been well studied, the processing of endpoints is more poorly understood. We recorded the responses of V1 neurons to sequences of flashed bars. Because the bars were much longer than the receptive fields, they generated potentially ambiguous motion signals (i.e. many more one-dimensional than two-dimensional motion signals). Using reverse correlation analysis, we obtained the neurons’ responses to the positions of single bars and to the directions of two-bar sequences. The single bar responses indicated that many neurons clearly responded only to the endpoints of the bars. These endpoint-responsive neurons were generally end-stopped: they responded poorly to long bars centered on their receptive fields. For these cells, the directional responses to two-bar sequences were only modestly affected by the ambiguous contour signals. Furthermore, these directional responses were largely independent of stimulus orientation. End-stopped neurons also exhibited a characteristic time-course: they initially responded to a bar positioned anywhere in their receptive fields, but after 20-30 ms they responded mainly to the endpoints of the bars. A similar time-course was observed in the directional responses of MT neurons to the 2-bar sequences. MT neurons initially responded to the ambiguous contour signals, but later responses encoded the correct two-dimensional motion. We conclude that end-stopped V1 neurons accurately measure the direction of moving edges, and that they respond to the ambiguous contour signals, but later responses encoded the correct two-dimensional motion. We conclude that end-stopped V1 neurons accurately measure the direction of moving edges, and that they probably provide two-dimensional motion information to MT neurons.

Acknowledgment: Supported by NIH NS07484 (CCP), NIH EY13135 (MSL) and NIH EY11379 and EY12196 (RTB).

SA68
The effect of stimulus size, speed and eccentricity on the motion responses in macaque visual areas. A combined fMRI and double label deoxyglucose (2-DG) study. Koen Nelissen1 (koen.nelissen@med.kuleuven.ac.be), Wim Vanduffel1,2, Roger Tootell3, Wouter van Beerendonk1, Guy A Orban1; 1Labo voor Neuro- & Psychofysiologie, KU Leuven Med. School, Leuven, Belgium, 2MGH/MIT/HMS Athinoula A. Martinos’ Center for Biomedical Imaging ctd., Boston, MA, USA, 3University of California at Riverside, CA – We investigated the effect of varying the size, speed and eccentricity of moving random textured patterns (RTP) on the motion processing cortical network in the awake macaque monkey. We used contrast-enhanced fMRI (Vanduffel et al., 2001) experiments as well as the 2-DG technique. Both techniques map functional activity in the whole brain, the former allows us to investigate a wide range of stimulus parameters, while the latter yields excellent spatial resolution. After an i.v. injection of a contrast agent (MION, 7-11 mg/kg), we acquired GE-EPI whole brain volumes in a 1.5T MR scanner in 2 awake macaques. Stimuli consisted of moving or static RTP’s varying in size (3, 7, 14 and 28 diam.), speed (1, 2, 4, 8, 16 /sec) or eccentricity (central 4 or annulus 14-28 ). In the 2-DG experiment, metabolic activity evoked by a moving RTP (30, 4 /sec) was labeled with 3H-DG and that related to a static RTP (control condition) with 14C-DG.

In agreement with earlier results (Vanduffel et al., 2001), we found motion responses in visual areas V1, V2, V3, MT/V5, FST, VIP and FEF. In the STS however, we found an additional motion responsive site which was located on the posterior bank of the middle STS, 11 mm anterior to MT/V5. Furthermore, area MStd showed a clear increase in motion response with increasing stimulus size, while the opposite was true for area VIP. Both latter areas showed a preference for higher speeds, as did FST.

These results indicate that the STS contains more motion sensitive regions than classically described. The results obtained by the two functional mapping techniques were highly comparable. This suggests that local hemodynamic signals as measured by fMRI and local cerebral glucose consumption as measured by 2-DG are colocalized. Since DG uptake is primarily linked to pre-synaptic activity (Sokoloff et al., 1977), this result is in agreement with the finding by Logothetis et al. (2001) that fMRI signals primarily reflect ‘pre-synaptic activity.

SA69
Acceleration sensitivity and habituation in PMLS neurons. Michael R Ibbotson (ibbotson@rsbs.anu.edu.au), Nicholas S Price, Colin W Clifford; Visual Sciences, RSBS, Australian National University, Australia – The cat postero medial lateral suprasylvian area is a cortical region implicated in the analysis of visual motion during locomotion. Its cells show a population preference for centrifugal motion. We have found that cell responses habituate to repetitive stimulation with constant speed stimuli. This is not consistent with PMLS’s hypothesised role because sustained motion during locomotion would strongly attenuate responsiveness.

We tested PMLS neurons with moving sine-wave gratings using a range of constant accelerations or decelerations (0 to 5, 10 or 20 Hz in 0.5, 1 or 2s; 0.025-0.2cpd) and a range of constant velocity stimuli (0-25 Hz). The stimulus sequence was: stationary grating, moving, stationary, blank screen. The stationary and blank periods ranged from 0-10s, allowing the effects of adaptation and habituation to be studied. We found that in many cells with peripheral receptive fields, accelerating stimuli evoked much higher firing rates than constant velocity stimuli. This was the case for velocities throughout the entire range experienced during the accelerating phases. Repetitive velocity ramps separated by 0-1s rest periods did not cause the same level of adaptation as repetitive stimulation by constant velocity stimuli. For constant velocity stimuli, response strength decreased rapidly over the first 4-8 presentations of a stimulus. Some cells responded more strongly to constant speed than to accelerating stimuli but still habituated to the former but not to the latter.

The responses suggest that some PMLS cells are better stimulated by novel stimuli such as speed changes. This is consistent with the region’s purported role in locomotion analysis, since it could provide sensitivity to transient movements or objects moving against the background. Sensitivity to velocity changes could also explain how the cells continue to respond during locomotion, despite their rapid adaptation.

Procedures were approved by the ANU Animal Experimentation Ethics Committee.

SA70
Perception of heading in abstinent MDMA and THC users. Matthew Rizzo3 (mattew-rizzo@uiowa.edu), Caroline TJ Lamers4, Nicole Skaar5, Craig VV Sauer3, Jan Ramakers2, George J Andersen2; 3The University of Iowa, Iowa City, USA, 2The University of Maastricht, Maastricht, The Netherlands, 3University of California at Riverside, CA – Purpose: Assess residual effects of MDMA (Ecstasy) and THC (marijuana) on perceived trajectory of travel.

Methods: 42 licensed drivers (ages 21-42) participated: 12 MDMA/THC users, 15 THC users and 15 non-drug users. Drug use besides MDMA/THC was similar in both drug groups. There were no age, acuity (Sloane) or contrast sensitivity (Pelli-Robson) differences between groups. Perception of self-motion, or heading, from optical flow patterns was tested with stimuli comprising random dot ground planes presented at 3 densities (.035, 243 and .451 dots/ square degree) and 8 heading angles (1.2, 4 and 8 deg to the left or right). On each trial, subjects reported if direction of travel was to the left or the right relative to a vertical post whose position varied with respect to body midline (Warren et al., 1989). Right and left heading angles were combined into one score, as we expected no lateralized performance difference. Dependent measure was % correct.

Results: Performance in all groups improved as heading angle increased; density had little effect. Plots of % correct vs. degrees of heading angle
showed worse performance in both drug groups compared to controls at all but the 8 deg heading angle (P<0.05). The MDMA/THC group performed worst, especially at lower heading angles.

Conclusions: Psychoactive agents appear to adversely affect visual perception, even in recently abstinent users, and appear to be additive in MDMA and THC. Precise mechanisms are unknown, but may involve serotonin and acetylcholine receptors in visual pathways. Residual effects may impair performance on driving-related tasks.

Acknowledgment: Supported by: NIH PO NS-19632 and NIA AG 17177

SA71
Screen curvature does influence the perception of visually simulated ego-rotations Jörg Schultz-Pelkum (joerg.sp@tuebingen.mpg.de), Bernhard E. Riecke, Markus von der Heyde, Heinrich H Bülthoff; Max-Planck-Institut für biologische Kybernetik, Tübingen, Germany — In general, the literature suggests that visual information alone is insufficient to control rotational self-motion accurately. Typically, subjects misperceive simulated self-rotations when no vestibular or proprioceptive feedback is available (see Bakker et al., 1999; 2001 - these studies were done with HMDs). On the other hand, Riecke et al. (2002) found nearly perfect turning performance when a curved, half-cylindrical projection screen with a large FOV of 180° was used. So far, no study has systematically looked at the effect of screen curvature on ego-motion perception.

To investigate whether screen curvature influences turning performance, we had 14 participants perform visually simulated ego-rotations either using a flat projection screen (FOV 86° x 64°) or a curved projection screen (radius 2m) with the same FOV in a within-subject repeated-measures design. Subjects saw a “star field” of limited lifetime dots without any landmarks, and they used a joystick to control instructed turn angles between 45° and 270° (steps of 45°). No feedback about accuracy was provided. A repeated-measures ANOVA revealed a significant effect of screen curvature, and also an interaction between curvature and turn angle: While target angles were undershot on the curved screen (gain factor 0.84), a surprising overshoot was observed for the flat screen (gain factor 1.12). Subjects’ verbal reports indicated that on the curved screen, the simulated self-rotations looked more realistic than on the flat screen. This may have led them to overestimate turns on the curved screen (thus undershoot turn angles) and to underestimate turns on the flat screen (thus overshoot turn angles). A possible explanation is that rotational laminar flow on the flat screen was misperceived as translational flow rather than rotational flow. Results indicate that screen curvature is a critical parameter to be considered for ego-motion simulation and vection studies.

SA72
The contribution of higher-order motion on vection and body sway Takeharu Senoo (senosann@yahoo.co.jp), Takao Sato; Tokyo University, Japan — Purpose: We examined contributions of first- and higher-order motion components on vection and body-sway by using compound sinusoidal 2f+3f gratings. The stimulus comprised of second (2f) and third (3f) harmonics of non-existent fundamental frequency (f). When it was shifted by 90 deg of fundamental frequency, directions of first- and higher-order motions were opposite, while perception was dominant in the direction of higher-order motion. Method: The 2f+3f gratings with a fundamental frequency of 0.3 c/d were used. Regular, luminance defined feedback is available (see Bakker et al., 1999; 2001). When what extent does image motion alone contribute to the perception of surface reflectance? To isolate the contribution of motion from the spatial image statistics we define “spatial flow” to be the 2D image motion of a reflected scene. To explore the effect of dense specular flow on the judgment of material properties, we develop novel random-dot stimuli of simple 3D scenes in which monocular image features move according to the 2D specular flow. In natural scenes object surfaces typically exhibit both specular and Lambertian reflectance and thus relative motion between the observer and such a surface results in an optic flow field containing both diffuse and specular components. To model this, we generate random-dot stimuli containing both diffuse and specular flow. Neither set of stimuli are perceived as reflective even when subjects form the correct 3D interpretation of the object and the specular motion. This suggests that spatial image cues are critical for the perception of surface reflectance. To what extent the specular flow of extended spatial image cues contributes to the interpretation of material properties remains an open question.

Acknowledgment: This work was supported in part by a grant from the National Science Foundation (#78441).

SA74
Estimating lighting models in a scene through lightness judgments Michael J Tarr1 (Michael.Tarr@brown.edu), Daniel J Kersten2; 1Department of Cognitive and Linguistic Sciences, Brown University, USA, 2Department of Psychology, University of Minnesota, USA — To interpret the effects of illumination (e.g., shading, shadows, and specularities), observers must estimate the direction, the intensity, and the number of sources in a scene. How this is accomplished is largely unknown, but there is some evidence for a “multi-local” representation that assumes an interaction between local elements (e.g., a moving object and a cast shadow), but no integration into a single coherent lighting model. This allows for multiple point lights that may not be globally consistent, yet taken as a whole, provides an approximation of a global lighting model that reflects the complexity of natural illumination. Such models provide a means for discounting shadows that alter the perceived lightness of surfaces. We investigated this process using lightness judgments in a simple scene composed of a cylinder casting a shadow over a target rectangle centered in a grayscale mondrian pattern. The target patch was entirely in shadow (Exp. 1), or partially in shadow with the remainder covered by a penumbra (Exp. 2) or completely uncovered (Exp. 3).

Observers adjusted the lightness of a reference square (embedded in different mondrian patterns) so that “the target and the reference square were cut from the same piece of paper”. Observers viewed the complete scene, a scene with the cylinder removed (shadow intact), a scene with the cylinder and all information beyond the mondrian pattern removed...
(shadow cropped), or the cropped pattern from a head-on viewpoint. Observers always perceived the target patch as darker than it actually was in the scene, regardless of the information available about the lighting conditions. However, additional information about the lighting conditions did bring observers closer to constancy, with the largest improvement found for intact shadows (whether the casting object was visible or not). Thus, mechanisms for lightness constancy take into account complex, multi-local scene features in the derivation of a lighting model.

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SA75 Cortical dynamics of surface lightness anchoring, filling-in, and perception
Simon Hong (yshong@cns.bu.edu), Stephen Grossberg; Dept. of Cognitive and Neural Systems, Boston University, Boston, MA, USA – This study proposes how the visual cortex may process natural images under variable illumination conditions to generate surface lightness perceptions. It is known that visual representations can adapt to a million-fold change in luminance. How such adaptation also "anchors" percepts of surface lightness to use the full dynamic range of neurons remains an unsolved problem. Such an anchoring of lightness helps to make an image look natural. Anchoring properties include articulation, insulation, configuration, and area effects (e.g., Gilchrist et al., 1999). A cortical model is developed that quantitatively simulates such psychophysical data, as well as psychophysical data about discounting the illumination gradient and the Cornsweet effect, among others. The model is also consistent with a range of anatomical and neurophysiological data about how the brain may use boundary representations to gate the filling-in of surface lightness via horizontal cortical interactions. The model filling-in mechanism runs a thousand times faster than mechanisms of previous biological filling-in models, and thereby helps to clarify how filling-in can occur at the speeds shown in perceptual experiments. The model can process natural images even under dim moonlight and dazzling sunlight. Application of the model to color domain illustrates that it is also able to process natural color images.

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SA76 Interaction of chromatic and achromatic surfaces in lightness perception
Tiziano Agostini (agostini@univ.trieste.it), Igor Castellarin; Department of Psychology, University of Trieste, Italy – Lightness perception has been mainly studied in the achromatic domain. We started to explore how lightness perception works with achromatic and chromatic stimuli when they are perceived together. The general question we started to answer, exploring also the chromatic domain, concerns how lightness perception works when coloured and grey surfaces are presented at the same time. Following the concepts proposed by the anchoring theory (Gilchrist et al. 1999) we examined at first if the anchoring and the scaling rules worked as the same as with grey surfaces alone. We replicated the five squares Cataliotti and Gilchrist's experiment by using the conditions of low articulation and Gelb light. We substituted in each condition an achromatic surface with a chromatic one of the same luminance. We found that scaling is not precise and the lightness of the considered surfaces is compressed, but we also found that scaling is affected differentially compared to the achromatic condition, when the yellow, replacing the white, is present in the visual scene. In another experiment, subjects have been asked to judge a black surface in three different conditions: 1) classic Gelb (only the black surface is present), 2) grey surfaces (classic staircase Gelb effect), and 3) coloured surfaces (chromatic staircase) of the same luminance of the grey ones. We found a significant difference among the 3 conditions. Other experiments have been driven showing the importance of better understanding the relation which occurs between colour and luminance variations in lightness perception.

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SA77 Is luminance contrast necessary to perceive lightness?
Alexander D Logvinenko (a.logvinenko@qub.ac.uk); The Queen’s University of Belfast, UK – The same luminance border can be perceived as a lightness edge homogeneously illuminated, or an illumination edge (a shadow) over a surface of homogeneous lightness (e.g., Logvinenko & Menshikova, 1994 Perception 23, 1007-1023). In this report I show that such a phenomenon can be observed even when contrast of the edge equals zero. Observers looked at a grid of vertical strips made of white paper which was presented against a large black background the illumination of which was set so as to make it equiluminant (100 cd/m2) with the strips. The strips looked white but dimly lit. The background looked dark grey but highly illuminated. This is a typical “lightness constancy” result. The Munsell scale was used to measure the lightness of both. So, two adjacent equiluminant areas (with no luminance contrast between them) were perceived as areas of different lightness and different apparent illumination. In other words, zero luminance contrast invokes a lightness edge and an apparent illumination edge, which cancel each other. It follows that luminance contrast is not necessary for perceiving lightness. Note that a pattern of apparent illumination (as one of the “intrinsic images”) was rather different from the luminance pattern. Hence, segmentation into strips and background was not based on the luminance contrast between them (as it was zero). The strips and the background emerged as different areas because of the abundant illumination cues that signalled that there were two differently illuminated areas. When observers looked through the grid, fixating the background, the wallpaper illusion was observed. The strips were seen at the same distance as the background, appearing attached to the background. Belonging now to the background they seemed to have the same apparent illumination as the background. As a result of such “misjudgement of illumination” the strips appeared to be of the same lightness as the background (dark grey).

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SA78 Perceptual grouping in illumination-independent lightness constancy
Alessandro Soranzo; University of Trieste, Italy – Introduction. In a two frames of illumination stimulus, illumination-independent lightness constancy is improved by adding equal reflectance surfaces in each field of illumination. (Soranzo & Agostini, ECVP 2002). We suggested that the number of luminances having different values but leading to the same luminance ratio, could be the relevant factor for the increase of illumination-independent lightness constancy. In this context, we performed a new experiment where a two fields of illumination display has been used to measure the effect of perceptual grouping on illumination-independent lightness constancy. Experiment. We systematically manipulated two factors under controlled conditions: i) the strength of belongingness between surfaces having the same reflectance and standing in both fields of illumination, and ii) the number of surfaces crossed by the illumination edge. Results. We found that 1) lightness constancy increases as the strength of belongingness increases, and 2) lightness constancy do not depend from the number of surfaces crossed by the illumination edge. Conclusions. The results of this experiment confirmed that the number of luminances having different values but leading to the same luminance ratio, increases the degree of illumination-independent lightness constancy. This effect depends on the belongingness relationship between surfaces sharing the same luminance ratio rather than on the number of surfaces crossed by the illumination edge. We conclude that the number of different surfaces that strongly belong to each other and share the same luminance ratio of the biperlite field is strongly interpreted by the visual system as a change in the illumination rather than as a change in the reflectance.
SA79 Shape recipes: scene representations that refer to the image
William T Freeman (wtf@ai.mit.edu), Antonio Torralba; Massachusetts Institute of Technology, Artificial Intelligence Laboratory, USA – The goal of low-level vision is to estimate an underlying scene (e.g., shape or reflectance) from an observed image. Real-world images and scenes can be very complex, conventionally requiring high dimensional representations that are difficult both to estimate and to store. We propose a low-dimensional representation, called a scene recipe that relies on the image itself to describe the complex scene configurations. The scene recipe is a formula telling how to transform the local image information to the desired scene quantities. In many situations, scene and image are closely related and it is possible to find such a functional relationship.

Shape recipes are an example: these are the regression coefficients that predict the bandpassed shape from local image data (in some cases, after a point non-linearity). This representation can have appealing properties such as slow variation over space and scale. We show how to exploit the slow variation over scale by first learning the recipes relating image to shape at low spatial frequencies, then applying those recipes at high spatial frequencies to infer high resolution shape, improving the initial shape estimate. Shape recipes implicitly contain information about lighting and materials and they may also be useful for material segmentation.

These scene representations always require that the image be available in order for the scene recipe to compute the shape or other scene quantity. In that sense, they are consistent with theories that suggest that the visual system uses the world as a visual memory, not storing in the brain what can be obtained by looking.

SA80 The Five-Square Gelb Illusion Revisited Daniele Zavagno1 (dzavagno@danzava.org), Vidal Annan2, Zhi Liu3; 1NEC Laboratories America, Inc., USA, 2Rutgers University, USA, 3UCLA, CA, USA – Purpose. In the staircase Gelb illusion, five adjacent and coplanar squares, ranging from white to black (30:1 reflectance ratio), are suspended in midair and illuminated by a spotlight. The perceived lightness ranges from white to light-middle gray (3:1 perceived ratio), which is a dramatic compression of the actual range. This compression decreases (5:1 perceived ratio) when the squares are rearranged into a Mondrian pattern. According to the anchoring theory (Gilchrist et al, 1999), this decrease is due to a configuration effect that would make Mondrians stronger local frameworks with respect to the global framework, with the result of better lightness constancy. Here, we tested this claim by maintaining the original linear arrangement but rearranged the positions of the squares. Our hypothesis is that the difference in perceived ratio’s between Mondrian and linear configurations may depend on local interactions among luminances rather than on a global configuration effect.

Methods. The display was five Munsell Neutral Value Scale papers (7x7 cm each), in which the luminance of the black square was 217 cd/m2. The position of the white square was systematically varied in each condition. In a between-subjects design, matches were made using an extended 31-step Munsell scale.

Results. i) The white square darkened its immediate neighbors. ii) The position of the white square, relative to the black, was highly critical. When the two squares were adjacent to each other the perceived lightness ratio (10:1) was greater than that of the Mondrian pattern (5:1) above.

Conclusions. Our results challenge the hypothesis that full range Mondrian patterns produce better lightness constancy. We discuss our findings in the context of current lightness theories (Gilchrist et al., 1999; Kingdom et al., 1996; Bressan, in press).

SA81 Spatial decay of achromatic color induction differs for lightness and darkness induction processes Iris K Zemach (ikz@u.washington.edu); Michael E Rudd; University of Washington, Seattle, WA, USA – We previously proposed a quantitative model of achromatic color induction based on the idea that underlying lightness and darkness induction signals fill in from borders in separate neural filling-in networks before being combined to create an achromatic color signal (Rudd, 2001; Rudd & Arrington, 2001; Rudd & Zemach, 2002). A key innovation of this model is the concept of induction signal modulation; Induction signal strength is altered when the signal crosses an intervening border by an amount that depends on the log luminance ratio of the crossed border. We show here that signal modulation depends on the induction signal type (i.e., lightness or darkness) and the contrast polarity of the crossed border, and we investigate the spatial falloff of the induction signals that are generated by borders of different contrast polarities. Our psychophysical experiments were based on a lightness matching paradigm. The stimuli consisted of two disk and ring patterns presented side-by-side on a flat-panel monitor. The luminance of the right disk was fixed and its surround luminance was varied to manipulate the disk lightness. Three observers adjusted the luminance of the left disk to achieve a lightness match to the right disk. Four experiments were performed in which the rings had either higher or lower luminance than the background and the disks had either higher or lower luminance than the rings. Each experiment was repeated with rings of different widths to study the effects of changing the distance between the test disk and the outer border of the ring. The results both support and generalize our earlier findings suggesting the existence of separate underlying lightness and darkness induction processes. The spatial falloff in induction strength follows a different function for the two types of induction signals. Lightness induction falls off with distance, whereas darkness induction strength remains roughly constant over the range of distances tested (up to 2.5 degrees).

SA82 The effect of spatial frequency on the White, shifted White and checkerboard illusions: Data and modeling Barbara Blakeslee (Barbara.Blakeslee@ndsu.nodak.edu), Mark E McCourt; Psychology Department, North Dakota State University, Fargo ND – In White’s effect (White, 1979) equiluminant gray test patches placed on the black and white bars of a square-wave grating appear different in brightness. The gray patch on the black bar is brighter than the gray patch on the white bar, independent of the aspect ratio of the test patch. Unlike other contrast and assimilation effects, this means that the White effect does not correlate with the amount of black or white border in contact with the test patch or in its general vicinity. White (1979) concluded that the effect must therefore depend on the directional (orientation) properties of the inducing grating. The effect of spatial frequency on the White effect, the shifted-White effect (White, 1981) and the checkerboard illusion (DeValois & DeValois, 1988) was measured for four subjects using a brightness matching paradigm. The data indicate that the White effect is similar at all spatial frequencies and confirm White’s observation (White, 1979) that the magnitude of the effect is greater at high spatial frequencies. The shifted-White and the checkerboard stimuli, however, produce brightness effects that reverse direction as a function of spatial frequency. These reversals represent a difficult challenge for brightness explanations based on mid-level and high-level grouping characteristics since such explanations should not be sensitive to simple changes in spatial scale. Interestingly, the brightness effects are predicted by an oriented-difference-of-Gaussians (ODOG) model (Blakeslee & McCourt, 1999) and, therefore, may not require an explanation beyond low-level multiscale spatial filtering and response normalization.

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SA83 Statistical concatenations of luminance can explain lightness/
brightness percepts. A number of recent studies have indicated that perceptions of brightness are determined by the probabilistic relationship between the luminance in the retinal stimulus and the possible physical sources (reviewed in Purves and Lotto, “Why we see what we do,” Sinauer, 2002). To date, these analyses have relied primarily on qualitative paradigms, or limited quantitative arguments to rationalize the brightness/brightness percepts elicited by Cornsweet edges, stimuli that elicit Mach bands, or the reduced cue conditions used in brightness scaling experiments. Considering the linkage between stimulus luminances and brightness/brightness percepts more broadly, however, the visual system must instantiate a more fundamental set of underlying statistical relationships to generate brightness/brightness percepts in any and all circumstances. Given the high dimensionality of real-world effects on the probability distribution of brightness/brightness sources, it seems inevitable that the relevant statistical instantiations entail the conditional probabilities of concatenations of luminance values in retinal images with respect to the underlying natural sources. Accordingly, we have explored whether anomalies of brightness/brightness can be explained in these terms by analyzing the distribution of luminance in 4200 images of natural visual environments in the so-called Netherlands database (hlab.phys.rug.nl). A large number of samples were generated using various templates in which the pattern of light was similar to the basic unit in several well-known brightness/brightness stimuli that generate unusual percepts (e.g., the Hermann grid, the Wertheimer-Benary pattern, White’s stimulus and the Hermann cross-like figures with luminance-gradients, as introduced first by Zavagno and Caputo (Perception, 2001, 30 : 209-22). These stimuli can be modulated so that they produce a percept of luminosity or reflectance without changes in the luminance of the area which is seen as self-luminous (sources of light), as distinct from those elements which appear to reflect light. Stimuli were cross-like figures with luminance-gradients, as introduced first by Zavagno (Perception,1999, 28 : 835-8) and Zavagno and Caputo (Perception, 2001, 30 : 209-22). These stimuli can be modulated so that they produce a percept of luminosity or reflectance without changes in the luminance of the area which is seen as self-luminous or reflecting. Additional stimulus types were used to control for effects induced by the use of luminance gradients, and to distinguish possible luminosity-sensitive regions from brain regions that are sensitive to general luminance differences. Data were analysed with SPM’99. A group analysis revealed bilateral activation in the posterior part of the occipito-temporal sulcus that was specific for glowing stimuli. Individual analysis showed bilateral activation in 8 and unilateral activation in 4 of the 12 subjects. We conclude that a region in the human posterior occipito-temporal sulcus seems to be specifically activated by glowing objects. This region does not increase its activity with increasing luminance.

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SA84  
Brightening prospects for “early” cortical coding of perceived luminance  
Mark E. McCourt1 (mark.mccourt@ndsu.nodak.edu), John J Fox2; 1Department of Psychology, North Dakota State University, Fargo, ND, USA; 2Cognitive Neurophysiology Laboratory, Nathan Kline Institute for Psychiatric Research, Orangeburg, NY, USA – Establishing the computational rules and neural substrates of brightness coding is a topic of both historical and contemporary interest. Two major classes of explanations for brightness illusions, such as brightness contrast, can be traced to Hering and Helmholtz. Hering’s legacy is a low-level account in which brightness contrast results from obligatory lateral inhibitory interactions occurring at some level(s) in the visual system. Helmholtz offered a high-level account, positing a causal role for factors such as perceptual grouping, inferred illumination, and the extraction of surface properties such as orientation and reflectance. The tension between these theoretical viewpoints persists unabated to date. Intracranial electrophysiological recordings have revealed that brightness is represented in the firing rates of striate neurons, a fact consistent with low-level explanations. However, since the time-course of brightness-related responses relative to the onset of striate activity is undisclosed, it remains possible that striate activation might be temporally and hierarchically secondary to the outcome of higher-level computational processes. Knowledge of the timing of brightness-related neural activity is thus crucial to both constrain and adjudicate between these competing theories. We utilize high-density electrophysiological recording and a tachistoscopic brightness discrimination task to measure the time-course and scalp topography of brightness-related electrical potentials in human observers. Brightness perception is correlated with electrical activity at the earliest stages of visual cortical processing. These findings are interpreted to support Hering’s low-level account of brightness, and the results are discussed in the context of current theories of brightness perception.

SA85  
A cortical region for luminosity perception - An fMRI study  
Ute Leonard1 (ute.leonards@bristol.ac.uk), Vicente Iranzo1, Daniele Zavagno2, Mohamed Seghier3, Tomasz Trscianka4; 1Dept. of Psychiatry, University Hospitals of Geneva, Chêne-Bourg GE, Switzerland; 2Laboratory for Psychophysics, NEC Research Institute, Princeton NJ, USA; 3Department of Radiology, University Hospitals of Geneva, Geneva, Switzerland; 4Department of Exp. Psychology, Bristol University, Bristol, England – The amount of light reaching the eyes can be affected by changes in the level of illumination or by changes in the reflectance of external surfaces. It is well known that, at the retinal level, such a distinction loses its meaning, since there are only changes in luminous flux and spectral composition at this level. However, information about the two types of changes is recovered by the visual system at the perceptual level, allowing us e.g. to easily distinguish between self-luminous and reflecting surfaces. Surprisingly, the neural mechanisms underlying this distinction are largely unknown, even though the perceptual correlates are compelling. Using fMRI, we investigated in twelve healthy volunteers the neural basis for the perception of elements of the visual field which appear to be self-luminous (sources of light), as distinct from those elements which appear to reflect light. Stimuli were cross-like figures with luminance-gradients, as introduced first by Zavagno (Perception,1999, 28 : 835-8) and Zavagno and Caputo (Perception, 2001, 30 : 209-22). These stimuli can be modulated so that they produce a percept of luminosity or reflectance without changes in the luminance of the area which is seen as self-luminous or reflecting. Additional stimulus types were used to control for effects induced by the use of luminance gradients, and to distinguish possible luminosity-sensitive regions from brain regions that are sensitive to general luminance differences. Data were analysed with SPM’99. A group analysis revealed bilateral activation in the posterior part of the occipito-temporal sulcus that was specific for glowing stimuli. Individual analysis showed bilateral activation in 8 and unilateral activation in 4 of the 12 subjects. We conclude that a region in the human posterior occipito-temporal sulcus seems to be specifically activated by glowing objects. This region does not increase its activity with increasing luminance.

SA86  
Lightness Estimation in Three-Dimensional Scenes with and without Specular Cues  
Jacqueline L. Snyder1 (jsnyder@cns.nyu.edu), Laurence T. Maloney1,2; 1Dept. of Psychology, New York University, New York, NY, USA, 2Ctr. for Neural Sci., New York University, New York, NY, USA – Purpose: We report two experiments measuring how observers estimate the albedo (“lightness”) of achromatic, matte surfaces at different depths in three-dimensional, rendered scenes. In each scene, illumination intensity varied with depth. We examined whether observers compensated for this variation in estimating albedo. Stimuli: Each scene consisted of two small rooms juxtaposed along the observer’s line of sight. Scenes were viewed binocularly. The observer could see the interior of the near room and part of the interior of the far room through a doorway. All surfaces of the rooms were tiled with achromatic, matte Mondrians that varied randomly across trials. Light sources were placed in the far room and behind the observer and were never directly observable. This design was modeled on Gilchrist (1977, 1981).

Methods: We used an asymmetric lightness matching task to measure observers’ “equivalent illuminant intensity (EII)” (following Brainard et al, 1997) at each of ten different depths (signaled by binocular disparity) within the two-room scene. Nine observers made ten matches per depth level.

Experiment 1: Illumination was intense in the far room and dim in the near room. We found that EII’s for 8 of 9 observers’ matches did vary significantly with depth, but we found no clear relationship between observers’ EII and the actual illuminant intensity at each depth in the scene.

Experiment 2: A possible explanation of the results of Experiment 1 is that observers had difficulty in estimating illumination intensity changes across depth. We repeated experiment 1, with the addition of small
specular spheres to the scene. The location of the spheres varied randomly from trial to trial. We then found that observers’ equivalent illuminants at each depth were roughly proportional to actual illuminants with a constant of proportionality of 0.5. Observers substantially discount changes in illumination intensity with depth.

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SA87
Spatial representations in posterior cingulate cortex  
Heather L Dean (dean@neuro.duke.edu), Michael L Platt; Duke University, USA – Posterior cingulate cortex (CGp) is thought to participate in sensorimotor transformations linking visual stimuli with saccades. CGp is strongly connected with visual and premotor cortical areas, and CGp neurons respond following saccades. The activity of CGp neurons has previously been shown to be modulated by the position of the eye in the orbit as well as by saccade direction and amplitude. The goals of this study were to establish whether or not the timing of CGp responses depends on the timing of task events; to determine if the spatial structure of CGp responses can be quantified using gaussian or planar functions, as in other visuomotor areas; and to determine quantitatively which coordinate framework CGp neurons use to encode spatial information. To address the first two goals, single CGp neurons were studied while monkeys (M. mulatta) performed reaction-time and delayed-saccade trials guided by targets located throughout the central 36° of visual space. CGp neurons responded after contralateral target onset as well as after contraversive movement onset. Plots of firing rate against horizontal and vertical saccade amplitude (response fields) were well-described by tilted planes. To determine the coordinates in which CGp responses are anchored, subjects performed delayed-saccade trials initiated from different starting positions to targets appearing along an axis passing through the neuronal response field. Neuronal activity was measured during 11 sequential epochs on each trial, segregated by fixation position, and plotted as a function of both movement vector and final eye position. For most CGp neurons, tuning curves were better aligned when plotted as a function of final eye position than movement vector, suggesting that CGp encodes information in a head- or world-centered coordinate framework. In order to differentiate between these possibilities, tuning curves were then compared before and after rotating the monkey with respect to the visual display.

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SA88
Eye movements during directed visual search: the effects of background versus target-distractor confusability  
Janna M Simola (simola@helsinki.fi), Ilpo V Kojo; Center for Knowledge and Innovation Research, Helsinki School of Economics, Helsinki, Finland – We have measured observers’ eye movements in a directed visual search task, with a varied complexity of the search matrix. The stimuli were complex 20x20 matrices in which distraction items were T-characters rotated by steps of 45°, and target items were arrows pointing to four directions (up, down, left, right). Both items were randomly placed in straight lines and rows. The task was to find a path consisting of 15 arrows. Each path started from the middle of the left side of the matrix and ended in the middle of right side of the matrix. The observers had to find the paths by moving their gaze to the directions pointed by the arrows. The matrix complexity was varied in four conditions. Either the background of the matrix or the target–distractor confusability was varied. The background was either grey Gaussian noise or contained randomly rotated small strokes added to the background. In target–distractor confusability conditions, the T-characters were either rotated by random angles or the sizes of the T-characters varied. It was found that reaction times, fixation durations and the number of fixations were significantly higher in background conditions than in distraction item conditions. The results indicate that the background difficulty has stronger effects on processing efficiency than target–distractor confusability. Noisy background apparently distracts saccadic planning more than the confusability of targets and distractors.

SA89
Visual search: saccade parameters depend on the shape of the search area  
Eelco A B Over (e.a.b.over@phys.uu.nl), Ignace Th C Hooge, Casper J Erkelens; Utrecht University, Netherlands – Search performance can be improved by restricting search to regions relevant to the task: no time is lost then to search in areas that certainly do not contain targets. Cognitive or physical borders can define relevant regions. We examined how the shape of search areas affected saccadic amplitudes and directions. We recorded eye movements during search in areas having one of three shapes: circular, squared or triangular. The areas were presented in a randomly mixed design. Subjects were instructed to find an unknown number of targets. Search areas were uniformly gray shapes and targets were slightly brighter spots. The results show that mean saccade amplitudes appeared to scale with the largest cross-section of the area. Saccade directions were mainly parallel to the borders of the search area. We constructed a simple model to describe the results. The model assumes a circular visual span of constant size around the fixation location. Within the visual span targets are detected. New fixation locations have to meet two conditions: 1) they must be inside the search area, 2) the visual span should not overlap previously searched areas by more than a certain percentage. The new fixation location is selected randomly from all possible remaining locations. The process is stopped when the visual spans cover 90% of the total area or when there are no fixation locations anymore. Saccades follow from the model as vectors between two successive fixation locations. The model has two parameters: 1) the size of the visual span, 2) the percentage of overlap. Saccade directions from the model showed distributions that were similar to those of recorded directions, although the latter distributions were always more peaked. In conclusion, we found that the shape of the search area strongly influenced saccade generation. The effects were partially described by a simple model whose major components were a constant visual span and an imperfect memory.

SA90
The role of torsional viscosity in saccadic listing’s law  
John Porrill1 (j.porrill@sheffield.ac.uk), Paul A. Warren2, Paul Dean1; 1The University of Sheffield, UK, 2The University of Glasgow, UK – PURPOSE: During saccadic eye movements the torsional state of the eye satisfies Listing’s law to good accuracy (e.g. Tweed & Vilis, 1990). Although various models have been proposed to account for this behaviour (e.g. Tweed & Vilis, 1987; Raphan, 1997) they rely on several simplifying assumptions, in particular isotropy of ocular viscosity. We show here that elevated torsional viscosity can ensure Listing’s saccades in a model with fixed muscle pulleys. This result has implications for the interpretation of recent findings on muscle pulley movement (Kono, Poukens & Demer, 2002). METHODS: We use the Eyelab model of ocular mechanics (Porrill, Warren & Dean, 2000). Eyelab closely emulates Orbit (Miller & Shamaeva, 1995) and currently implements fixed muscle pulleys. Eyelab saccades between the vertices of a 60 x 60 degree square centred on primary position were generated by sending matched pulse-step commands to agonist muscles while temporarily de-innervating antagonist muscles. RESULTS: Under the assumption of isotropic viscosity, saccades in eccentric positions showed large torsional deviations from Listing’s law. However approximately doubling torsional viscosity produced saccades consistent with empirical data in all positions. CONCLUSIONS: The hypothesis that there may be substantial anisotropy in effective ocular viscosity is not unreasonable since (i) the environment of the globe is anisotropic and (ii) an important component of viscosity in move saccades comes from the extraocular muscles which are themselves anisotropic. Since a fixed pulley model can produce Listing’s saccades with an appropriate value for torsional viscosity, we argue that quantitative interpretation of pulley movement is premature in the absence of firm
viscosity data.

SA91
The relationships among oculomotor resting states and computer monitor positioning
Jeffrey Andre (andrej@jmu.edu), Joseph Dunsmoor, Marissa Waite; School of Psychology, James Madison University, Virginia, USA—Previous researchers (e.g., Owens & Leibowitz, 1980) have shown large individual differences in measures of the resting states of accommodation (dark focus; DF) and vergence (dark vergence; DV). However, no useful relationship has been found between these two resting measures. The present study investigated whether either of these measures were related to the third resting state of eyes, namely resting gaze elevation (in the dark; GE). All three resting states were measured in the dark from 74 college-aged participants. DF was measured using a Seiko WV-500 autorefractor, DV was measured in using a Vergamatic nonius alignment technique, and GE was measured using a briefly presented light and a modified binary search psychophysical procedure. No significant correlations were found between the three resting states: r (DF/DV) = .017, r (DE/GE) = -.001, and r (DV/GE) = -.123. The last correlation was somewhat surprising given that both involve the extraocular muscles and perhaps are related to the Heuer effect.

To investigate whether DF, DV, or GE were related to the preferred computer monitor position for a given individual, a subset of the participants (N = 25) were asked to play a computer game of mini-golf. A 15-inch Dell flat screen monitor was mounted on a fully adjustable Ergotron mounting arm. Participants were able to position the monitor precisely where they wanted (viewing distance and monitor height) and could change the position during the game if desired. Directly after playing the game, the participant’s viewing distance and monitor viewing angle (from eye level) were measured. Monitor viewing distance was not related to DF or DV distances. A correlation of r = .297 was found between GE and the monitor viewing angle but did not reach significance due to sample size. It did indicate that participants with lower resting gaze elevations tended to prefer a lower monitor location.

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SA92
Curvature of Saccade Trajectory: The Dynamic Interaction of Anticipation-based and Stimulus-based Movement-related Activation
Shun-nan Yang (syang3@brain.riken.go.jp); Laboratory for Perceptual Dynamics, Brain Science Institute Riken, Japan—The curvature of saccadic eye movements is often observed when a certain region of the movement field is deactivated due to inhibition. Different explanations of this phenomenon have been offered. One of such explanations emphasizes the dynamic movement of activated areas during the process of saccade execution (the moving-hill hypothesis) and that the deactivation of a certain region forces the dynamic encoding of eye position to be altered in relation to the deactivated area.

This explanation predicts that when there is more than one source of saccade-related signal encoded in the movement field, the existence of one source may interact with the execution of a saccade controlled by another source. This should result in the dynamic change of saccade trajectory as determined by the relation of these two sources.

The current study investigates the predicted dynamic change of saccade trajectory by asking subjects to fixate at a visual target that changes its position periodically in a horizontal direction. Occasionally the new position of the target will deviate from the anticipated horizontal position vertically. The latency, landing position, and trajectory curvature of saccades were measured.

The results show that the trajectory of critical saccades following target deviation can be divided into three categories: When the latency of saccades is short, the eye is first sent to the anticipated location and then the deviated location; when the latency is long, the eye is sent to the deviated location directly; an intermediate latency leads to curved saccades, with the direction and degree of curvature being predicted by the relative position of the anticipated and the deviated location. These results support the moving-hill hypothesis, showing that the modification of activated movement field may be directly related to saccade execution. Further directions of research on saccade encoding and execution are discussed.

SA93
Subthreshold microstimulation in the primate superior colliculus alters both the latency of saccades and target choice in a 2-AFC task
Christopher D Carello1 (carello@usc.edu), Rich J Krauzlis2; 1University of California, San Diego, 2Salk Institute, La Jolla CA—PURPOSE: The superior colliculus (SC) plays an important role in the control of voluntary gaze shifts toward visual targets. Tonic neural activity preceding a saccadic burst appears to be related to the probability that a given object will be chosen as a saccade target. To test whether an alteration of this presaccadic activity can alter a monkey’s target choice, we microstimulated in the SC during a 2-AFC task. METHODS: We trained two macaque monkeys to saccade to one of two 0.2 x 0.4° bars (one white, one gray) which appeared on opposite sides of a central fixation point at fixed horizontal eccentricities (3.5°). During the fixation interval, a central cue flashed either white or gray, specifying the color of the upcoming target. After a 1 – 1.7 s delay, both bars appeared; the monkey was rewarded for making a saccade directly to the bar matching the color of the cue. During randomly interleaved microstimulation trials, biphasic current was applied to the SC beginning either 100 or 200 ms prior to target and distracter appearance and persisting for ~ 400 ms. We chose subthreshold stimulation parameters (10-30 μA, 100-200 Hz) to minimize stimulation-evoked saccades. RESULTS. Although somewhat variable, the effects of stimulation depended in a predictable way on the stimulation intensity and the site of stimulation with respect to target location. Saccades to bars ipsilateral to the site of stimulation had longer latencies than contralateral saccades. Stimulation resulted in an increase in the number of correct responses when the target was contralateral to the site of stimulation and a decrease in correct responses when the target was ipsilateral. CONCLUSION. Using the 2-AFC design, we found that microstimulation can change target choice in addition to the well-known change in saccade metrics. These results demonstrate that presaccadic activity in the SC is causally related to the probability that a given object will become a saccade target.

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SA94
Pursuit of the ineffable: perceptual and motor reversals during the tracking of apparent motion
Laurent Madelain (madelain@salk.edu), Richard J Krauzlis; Systems Neurobiology Lab, Salk Institute for Biological Studies, La Jolla, CA, USA—PURPOSE: Previous studies have shown that pursuit can be guided by the perceived rather than the physical motion of a stimulus, but the temporal relationship between motion perception and pursuit is unknown. Using combined psychometric measurements and eye movement recordings during tracking of an apparent motion stimulus, we compared the timing of perceptual reversals in motion direction to the timing of pursuit reversals in smooth eye velocity. METHODS. We used an apparent motion stimulus consisting of a horizontal row of evenly spaced Kanizsa illusory squares (1.44 deg2). The circular inducers rotated by 90° on each frame, so that the illusory squares appeared at the exact midpoints of the illusory squares presented in the previous frame. Each frame was presented for 66 ms, producing bi-directional apparent motion of the illusory contours (21.5 deg/s) that could be changed at will. We measured eye movements in 5 subjects asked to 1) track the motion of the illusory squares, and 2) reverse the perceived direction while continuing to track the squares. For this second experiment, we measured the timing of the volitional perceptual reversals and compared this to the time course of the reversal in tracking
direction. RESULTS. Subjects could track the apparent motion without saccades. When asked to reverse the perceived direction, subjects could also produce saccade-free reversals in pursuit velocity. The time course of these reversals in pursuit velocity closely followed the psychometric measurements of the perceptual reversal. Both reversals spanned approximately 378 ms and, on average, the perceptual reversals preceded the pursuit reversals by 54 ms. CONCLUSIONS. The perceived motion of an object can drive pursuit, even when the motion is perceptually bistable and the object itself is illusory. Smooth pursuit and the perception of motion direction are in temporal register, indicating that pursuit can provide a real-time readout for the state of motion perception.

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SA95
A model for the adaptation of saccades by the cerebellum
Masatiko Fujita (fujita@k.hosei.ac.jp); Dept Indust & Sys Eng, Hosei Univ, Koganei, Japan – Lesion studies of the cerebellar vermis (Optican and Robinson, 1980) and the fastigial nuclei (Goldberg et al. 1993) showed that the cerebellum is responsible for the saccade adaptation. The adaptive modification of the vestibulo-ocular reflex was explained by a model (Fujita, 1982) which introduced the long-term depression (LTD) and potentiation (LTP) of the transmission efficacy from parallel fibers (pf) to Purkinje cells (P-cells). LTD and LTP were demonstrated to be responsible for changes in the receptive field of the P-cells (Fornell and Ekerot, 2002). Here we present a cerebellar model with the same LTD and LTP mechanism to explain the saccade adaptation in the amplitude as well as direction by repetitive intrasaccadic target displacement (McLaughlin, 1967, Miller et al. 1981, Deubel, 1987).

We assume the followings:
(1) When the image of a target is outside the fovea at the end of a saccade, it evokes a climbing fiber response retinotopically on the contralateral cerebellar vermis. It reflects a simple perceptual, not cognitive process.
(2) Pf responses appears bilaterally and extensively on the vermal areas.
(3) Projection from the P-cells to target neurons in the fastigial nuclei is anatomically and functionally fixed.
(4) Projection from the fastigial cells to burst neurons in the premotor areas for the vertical and horizontal saccadic components as well as to the superior colliculus is also anatomically and functionally fixed.
(5) Synaptic efficacy from pf to P-cells or inhibitory interneurons is modified by the LTD and LTP.

Above-mentioned physiological data and the five assumptions leads us to successful computer simulation of the saccade adaptations both in the amplitude and direction. The more elaborate mechanisms for the selective adaptation of the human saccades (Fujita et al. 2002) remained unresolved.

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SA96
Target-switching by pursuit and saccades guided by shifts of attention
Garth A Fowler (garp@salk.edu), Richard J Krauzlis; Systems Neurobiology Laboratory, The Salk Institute, La Jolla CA – Purpose. Selecting and tracking a moving visual target requires coordination between pursuit and saccades. Because eye movements are preceded by shifts of attention, a likely mechanism for this coordination is the common role of attention in target selection by the two systems. Most studies have examined target selection using suddenly appearing stimuli, likely confounding attention-based selection with stimulus-evoked changes in attention. To eliminate this problem, we used a novel task that required target switching during steady-state tracking with minimal changes to the visual display. Methods. Human subjects (n=3) initially fixated a central fixation cross. Horizontal dot arrays (50 0.3 dg gray squares spaced 0.5 dg apart) were presented above and below fixation at one of three eccentricities (0.15, 0.3 or 0.6 dg). After presenting a color cue specifying the target, the arrays changed color (one to the cued color, both 34 cd/m2) and began moving in opposite directions at 14 dg/s. On 50% of the trials, the arrays switched color during the trial but were otherwise unchanged. The subject’s task was to track the array of the cued color; when the arrays switched color, subjects had to switch tracking to the other array. Results. The latency of pursuit to the target-switching averaged 233, 257 & 271 ms for the 3 subjects. The switch in tracking to the other array could occur in the complete absence of saccades, and the frequency of saccades accompanying the target-switching (25, 60, & 90%) depended on the vertical separation between the two arrays (0.3, 0.6 & 1.2 dg, respectively). Conclusions. Switching tracking to a new target does not require a saccade. The long latency for target-switching by pursuit likely reflects the slow time course associated with endogenous shifts of attention. The shorter latencies historically associated with pursuit may reflect the speeding of attentional shifts caused by visual transients typically included in pursuit paradigms.

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SA97
Learning Optimal Gaze Decomposition
Eric Wiewiora1 (evieweiro@cs.ucsd.edu), David Berg1, Jochen Triesch1, Tomonori Hashiham1,2; 1UC San Diego, USA, 2City University, Nagoya, Japan – When the head is free to move, subjects frequently engage in coordinated head and eye movements to bring a target object to the fovea. Freedman and Sparks (1997) found that the relative contribution of head and eye movements to the total gaze shift are a non-linear function of initial eye position and total gaze displacement. Freedman (2001) and Wang et.al. (2002) have recently proposed descriptive mathematical models for the decomposition of total gaze shift into head and eye movements. It is however an open question a) if and how this decomposition can be seen as resulting from an optimality principle, b) if this decomposition strategy is learned during development and c) if so, what learning mechanisms are responsible for its acquisition. We propose a model for the simultaneous learning of the calibration of goal directed head/eye movements and the optimal gaze shift decomposition based on a reinforcement learning mechanism (Schultz et.al., 1997). We show that the rather complex behaviorally observed gaze decomposition can be understood as the result of optimizing a simple cost function. In our model, the cerebellum plays a key role in learning a gaze shift decomposition that accurately brings the desired target to the fovea while at the same time minimizing this cost function. Our model is consistent with the known anatomy and physiology of oculomotor control systems. The model efficiently learns gaze shift decompositions observed experimentally and makes a number of testable predictions. The model is also implemented and tested in an anthropomorphic robot head that autonomously learns the optimal gaze decomposition.

References:

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SA98
The contrast dependence of eye-movement latencies
Jeffrey B Mulligan1 (jmulligan@mail.arc.nasa.gov), Scott B Stevenson2, 1NASA Ames Research Center, USA, 2University of Houston College of Optometry, USA – The eye-movement latency to a randomly moving target varies with target color and contrast (ARVO '98). Here we confirm the results for achromatic stimuli, and extend them to binocular viewing. Subjects viewed a display through the optics of a binocular dual-Purkinje image eye tracker, and independent motion trajectories were presented to each eye. Four targets were used: 1) a simple spot; 2) a slowly-changing textured field; 3) binocularly correlated dynamic random noise; and 4) a second-order stimulus consisting of binocularly uncorrelated dynamic random noise that was contrast-modulated with a binocularly correlated bullseye pattern. Independent temporal responses for version and vergence in the
horizontal (H) and vertical (V) directions were obtained by reverse correlating the measured eye velocity with the corresponding stimulus velocity, and response latency was estimated using the time of peak correlation. The H version response is generally the fastest (100 msec), followed within 10-20 msec by V version. Vvergence responses are delayed by an additional 50-70 msec, with V vergence 10-20 msec faster than H vergence. Responses to the spot are delayed 20 msec with respect to the response for an extended texture, while the pure disparity stimulation provided by the dynamic noise (vergence only) produces an additional delay of 50-80 msec. Varying texture contrast produces a delay of approximately 50 msec / log unit, for all types of eye movement. The pure second-order stimulus produces a response delayed approx. 100 msec (compared to the same stimulus with a small amount of luminance contrast added to the modulator), except for the case of vertical vergence, which does not respond at all to the second-order stimulus. The results are consistent with a neural architecture in which the contrast-dependent delay is introduced before the segregation of binocular visual signals, and multiple visual mechanisms contribute differentially to each type of movement.

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SA100
Attentional and oculomotor inhibition  Jan Theeuwes (j.Theeuwes@psy.vu.nl), Richard Godijn; Vrije Universiteit Amsterdam The Netherlands – After presenting a peripheral cue, a subsequent saccade to the cued location is delayed (inhibition-of-return; IOR). Furthermore, saccades typically deviate away from the cued location. The present study examined the relationship between these inhibitory effects. Even though the results suggested a relationship between oculomotor IOR and saccade trajectory deviations, a dissociation was found in their time course. Saccade trajectory deviations were rapidly reduced as the time between cue and saccade increased. In contrast, IOR was found at longer delays between cue and saccade. Additional experiments show that objects presented at previously inhibited location do not compete for selection anymore. We propose that oculomotor IOR is caused by inhibition in the attentional system and saccade trajectory deviations are caused by inhibition in the oculomotor system. The findings are in line with a recently suggested competitive integration model of saccade programming (1) which assumes that endogenous and exogenous saccades are programmed in a common saccade map. The model incorporates a lateral interaction structure in which saccade-related activation at a specific location spreads to neighboring locations, but inhibits distant locations. In addition, there is top-down location specific inhibition of locations to which the saccade should not go. This inhibition results in saccades that deviate away from the inhibited location. The superior colliculus seems to incorporate all the functionality necessary for a saccade map. The FEF and the dorso-lateral prefrontal cortex (dlPFC) are prime candidates for attentional location specific top-down inhibition that is applied to the SC.


SA102
Behavioral and electrophysiological measures of aging in visual pathways  Jonathan W Page (jpage@unr.nevada.edu), Michael A Croganale; University of Nevada, USA – We examined behavioral and electrophysiological (VEP) changes with aging in the chromatic and achromatic visual pathways. Forty-five subjects, ranging from twenty to eighty-nine years of age, participated. Isoluminance was determined for the L-M and S+(L-M) pathways for each observer. Contrast thresholds were also found
for each observer and used to equate contrast across pathways. VEP responses were measured to isoluminant and achromatic sinusoidal gratings (1.0 cpd) that were multiples of threshold (eight times threshold) presented in an onset/offset mode. Colors for the chromatic gratings were chosen to preferentially modulate the L-M and S(L-M) pathways. Results show that the chromatic pathways aged similarly, but differently from the achromatic pathway. VEP amplitudes decreased and response latencies increased with age in the chromatic pathways. No significant change with age was found for VEP amplitudes or VEP response latencies in the achromatic pathway. Correspondence was found when comparing VEP responses to behavioral responses (perceptual contrast thresholds) across age, suggesting the VEP accurately reflects changes with age in the visual pathways.

SA103
A study of the phenotypic differences manifested in blue-cone monochromacy
Michael F Fry (Gravitonfry@uiol.com), Jennifer R Highsmith, Michael A Cregula; University of Nevada at Reno, USA — Blue-cone Monochromacy (BCM) is a rare X-linked recessive disorder characterized by poor color discrimination, poor visual acuity ranging from 20/50 to 20/300, and some photophobia. BCM can be caused by a mutation on the q28 region of the X chromosome. Mutations in this region can inactivate red- and green- pigment genes, but in some cases of BCM residual red- and green- pigment gene function is detectable. Nathans et. al. (1993) conducted genetic experiments that classified the cause of BCM into two genetic categories that produce any one of twelve different genotypes. We conducted a study that compared the phenotypic differences between two males with distinctly different genetic mutations both causing BCM. A number of standard color vision tests as well as other psychophysical tests were used to determine the perceptual differences between these subjects. Results indicate that subjects have different degrees of color perception and discrimination. Further, results indicate that both subjects exhibit residual red- and green-pigment cone function. A discussion of possible sources of these differences is included.


SA104
Seasonal variations in the color statistics of natural images
Yoko Mizokami (yokok@unr.edu), Sherniaz M Webster, Michael A Webster; University of Nevada, Reno USA — The distribution of colors in natural images can vary widely across different environments or within the same environment over time. We have examined how color distributions at a single location can vary with changes in seasons. A large set of digital images were collected from a rural valley in Maharashtra India during monsoon (wet) and winter (dry) months. Each image included a reference palette of known reflectance (MacBeth color checker measured with a spectroradiometer), which allowed the rgb values to be calibrated to derive the cone excitations at each pixel. The seasonal changes in rainfall and consequent changes in vegetation result in large changes in both the mean chromaticity of the images and the dominant chromatic axis along which color signals vary. Mean color shifts were largely along the L-M chromatic axis (shifting toward +L for drier environments). This average mean chromaticity of the images and the dominant chromatic axis along the LM axis to a bluish-yellowish axis intermediate to the L-M and S(LM) axes. These shifts are consistent with previous measurements sampled from different environments (Webster and Mollon, Vision Research, 1997). Both the mean changes and the axis changes are many times larger than the differences resulting from variations in the illumination, and have important implications for understanding how visual coding might be matched to particular environments.

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SA105
Interactions of chromaticity and luminance in edge identification depend on chromaticity
Vivianne C Smith (ossmith@uchicago.edu), Joel Pokorny; Visual Science Laboratories, University of Chicago, Chicago, IL USA — Purpose: The goal of this work was to study interactions of chromaticity and luminance in edge identification. Previous studies have revealed chromaticity/luminance interactions in detection and perceptual, but not edge-related tasks.
Methods: Two horizontal spatial sawtooth patterns, one with positive and the other with negative harmonics, were compared in 2-AFC. The observer identified the pattern with the sharp upper edge. The fundamental frequency was 2 cpd, with 5 cycles presented in a 2.5 deg square field. The pattern was presented as a 1 second raised temporal cosine, replacing part of an 8 deg, 115 td background. Stimulus presentation order was random. Stimuli were specified in a cone troland (l, s, Y) chromaticity space, with correction for individual equilumiance at a nominal 115 td, and tritan direction. A preliminary set of interleaved staircases established edge identification for the six directions. (+/-l, +/-s, +/Y). Three compound sawtooth stimuli combining two directions were chosen and included with the chosen directions in five randomly interleaved staircases, using a 3- correct/1-incorrect reversal rule.
Results: For combinations of Y with l-chromaticity, or l- with s- chromaticity, probability summation was observed. Combinations of Y with s-chromaticity revealed opponency. Data for +s, +Y and –s, -Y were sub-additive; data for +s, -Y and –s, +Y were additive. Control studies using detection rather than edge identification revealed probability summation for all combinations.
Conclusions: Luminance edges did not enhance stimuli with l- chromaticities. There was an interaction of luminance edges with s- chromaticities. Dim “blues” and bright “yellows” showed linear summation. Bright “blues” and dim “yellows” showed opponency. This result may reflect a higher-level optimization to natural colors.

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SA106
A chromatic test of shadow compatibility and equal cone excitation ratios
James Schirillo (schirija@wfu.edu), Genevieve Heckman, Thomas Barr; Department of Psychology, Wake Forest University, USA — Three chromatic versions of Adelson’s (1993) wall of blocks stimuli were made either shade compatible or shade incompatible to test Logvinenko’s (2001) hypothesis that shadow compatibility is required to generate the perception of shadows and concomitant lightness illusion. Stimuli consisted of CRT simulations of Munsell gray surfaces under 2854 deg. K (yellow) to 20,000 deg. K (blue) illuminants. The three sets were (1) either all yellow or all blue surfaces that varied only in lightness (i.e., a monochromatic version of Logvinenko’s achromatic stimuli), (2) alternating regions of yellow and blue surfaces, (i.e., to appear like adjacent chromatic neutral density filters when shade compatible), and (3) surfaces of different yellows and blues that varied only in chromaticity (i.e., a chromatic transformation of Logvinenko’s stimuli). An additional condition altered the surface colors slightly to equate cone excitation ratios across the shadow borders, which Foster & Nascimento (1994) claim can enhance color constancy. Observers varied the hue, saturation and chromaticity of cube tops in one ‘transparent’ region to match the cube tops in another. Arranging surfaces to be shadow compatible created the expected Adelson-Logvinenko illusion in all stimulus sets. Interestingly, the cube tops within either the all yellow or all blue dark shadowed regions (set 1) appeared both lighter and bluer. Only when the stimuli contained both chromatic and luminance shadow borders (set 2) were equal cone excitation ratios effective, suggesting that a purely chromatic shadow (set 3) is not enhanced by equating cone excitation ratios.
SA107
Nonlinear adjustment of visual sensitivity balance in a real world Ichiro Kuriki (kuriki@apollo3.brl.ntt.co.jp); NTT Communication Science Laboratories, Japan — [Introduction] Shifts in the visual sensitivity introduce shifts in color appearance, which is often experienced under changes in illuminant chromaticity. A few previous studies suggested that the shift in color appearance could be explained by applying a set of fixed coefficient to each cone response, regardless of lightness level. The present study tested whether a set of fixed coefficients is applicable to a wide range of lightness. [Methods] The observer made achromatic settings in a real room with variable-chromaticity illuminant on the ceiling. A matching stimulus was presented on a CRT screen, placed behind a small hole (5cm x 5cm) in a gray-painted wall. The illuminant chromaticity changed from white (D65) to blue, orange, green, and purple. The observer adapted to the illuminant for at least 5 minutes and then started the achromatic settings for five luminance levels of stimulus. Observer repeated the settings for five times in a random order. The results were assessed with relative M-cone weight (Ahn and MacLeod, 1994). [Results] The achromatic point shifted monotonically toward D65, as the stimulus intensity increased. The shifts in achromatic point were fitted nicely with linear regressions on a log-cone-contrast vs. log-luminance-contrast plane. After a careful analysis for the three cone classes, systematic shifts were also found in the slopes and intersections of the fitted lines. [Discussions] The previous reports, including ours (Kuriki, et al., 2000), suggested that a set of fixed coefficient is sufficient to estimate the shift in color appearance under a change in illuminant chromaticity. However, this was an oversimplification. After a precise examination for L and M cones, they show slight but consistent change in the degree of nonlinearity (slope in a log-log plot), as well as S cones. This nonlinearity may explain the appearance of Land's two-color projection, which appears trichromatic, even though it is composed of dichromatic lights.

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SA108
Readability of chromatic transparent text on a patterned background Joongnam Yang (joongnam@eos.arc.nasa.gov), Jeffrey Mulligan; NASA Ames Research Center, USA — PURPOSE: We wish to discover the visually-optimal method of displaying textual information on a patterned background display, such as might be used on an aircraft head-up display. METHOD: Three blocks of randomly selected words were rendered in a fixed color (green) over a chromatic noise background. Observers searched for one of two target words, and response time was measured. Four rendering algorithms were used, and all produced subjective impression of transparency. For each algorithm, the ‘strength’ of the text component was varied. RESULTS: Response times varied from 4 to 20 seconds. Four predictors of text readability were used: text contrast, background contrast, and relative text contrast (text contrast divided by background contrast), all solely based on luminance, and pooled cone contrast of the text relative to the background. Spearman rank correlation was calculated between the predicted and observed response times. For all algorithms, response time decreased with increasing contrast, as expected. Of the four predictors, cone contrast (r=-0.61) was better correlated with response time than relative text contrast (r=-0.38), text contrast (r=-0.31) or background contrast (r=-0.32). CONCLUSION: Although we can not rule out the possibility that a model based solely on luminance contrast could explain the data, the fact that we obtain the highest rank correlation using pooled cone contrast suggests that chromatic factors may be significant. We plan to investigate whether a model of human perception of chromatic transparency may better explain the data.

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SA111
Achromatic settings in three-dimensional scenes with two light sources differing in chromaticity  
Huseyin Boyaci1,2, (boyaci@cnst.nyu.edu), Katja Doerschner1, Laurence T Maloney1,2; 1Dept. of Psychology, New York Univ., New York, NY USA, 2Ctr. for Neural Sci., New York Univ., New York, NY USA.  
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On the initiation and spreading of interocular suppression from binocular vertical contours  
Teng Leng Ooi1 (tlooi@pco.edu), Zijiang Ji1, He2; 1Pennsylvania College of Optometry, USA, 2University of Louisville, Kentucky, USA.  
Acknowledgment: Supported by PCO Research Fund  

SA113
Modeling the cortical specialization for horizontal stereoscopic disparities  
Jenny Read (jcr@sr.nei.nih.gov), Bruce Cumming: National Institutes of Health, USA — Stereoscopic vision is possible because our eyes are displaced horizontally. As a consequence, for any given position of the eyes, the variation due to scene geometry causes a much larger range of horizontal disparities than vertical disparities. Yet until recently, there was little evidence that this anisotropy was reflected in the brain. Now Cumming (2002: Nature 418:633) has shown that cells in V1 respond to a wider range of horizontal than vertical disparities, irrespective of their orientation preference. This presents a challenge to existing models of disparity-sensitive cells, which predict that the sensitivity to vertical/horizontal disparities should depend on the orientation tuning (eg, cells tuned to vertical orientations should respond to a wider range of vertical disparities than horizontal, which is not observed). We present some ways in which existing models can be extended to account for these observations. One possibility is that a given complex cell receives input from many binocular subunits with different horizontal position disparities but similar vertical position disparities, so that the envelope of the sum is horizontally elongated. Another is that endstopping in monocular subunits suppresses the response to disparities with a significant vertical component. New experiments will be needed to reveal if these suggestions are correct.  

SA114
Coarse-to-fine or fine-to-coarse?  
Simone Li (simone_li@isr.syr.edu), Bart Farell; Institute for Sensory Research, Syracuse University, USA.  
If stereo channels of different scales were truly independent of each other, the components of a surface with a large disparity would appear smeared out across space. Instead, we see a single solid surface. To identify factors behind this perceptual coherence, we investigated interactions among the components of a squarewave grating. The target stimulus consisted of squarewave components with independently manipulated disparities. The fundamental (F) was placed in one depth plane, while the higher frequency components (mF—missing fundamental) were placed together in another depth plane. The task was to compare the perceived depth of the whole target stimulus to that of a conventional squarewave with the same spatial frequency (0.4 cd/p) and contrast (20%) but varying disparity. For all four observers, F and mF cohered in depth: The appearance of the target was indistinguishable from a conventional squarewave when F and mF were in cyclopean phase. The perceived depth of the target was consistent with the disparity of mF. Randomizing the relative phase between F and mF changed the appearance of the target, but not its perceived depth. Removing the 3F component from mF changed the appearance of the target but did not alter the coherence. For one of the two observers, this switched the perceived depth to be consistent with the disparity of F. But increasing the contrast of the 5F component re-established the dominance of the higher harmonics. Perceived depth is determined by interactions among stereo spatial frequency channels. These interactions can be either coarse-to-fine or fine-to-coarse. The direction of the interaction depends on the relative salience of all the competitive scales. Therefore, Marr and Poggio's coarse-to-fine direction of interaction is not unique.  

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http://weblab.syr.edu/~lali/
Temporal Pooling of Vertical Size Disparity for Slant Perception

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Temporal Pooling of Vertical Size Disparity for Slant Perception

Kazuo Fukuda (fukuda@isl.titech.ac.jp), Kazunichi Matsunami, Hirohiko Kaneko; Imaging Science and Engineering Laboratory, Tokyo Institute of Technology, Japan

In the first experiment, two sets of random dot stimuli with vertical- or horizontal-size disparities producing two different slants were presented alternatively in one presentation. The results showed that, for the presentation having vertical size disparity, the subjects perceived the averaged slants of the two sets if the temporal frequency of alternation was high, whereas they perceived two slants if the temporal frequency was low. For the presentation having horizontal size disparity, two slants were always seen. In the second experiment, the stimuli with uniform vertical size disparity were divided into many pieces, and these pieces were presented sequentially. The results showed that the perceived slant increased as the area presented within a certain duration increased.

These results indicated that vertical disparities are temporally and spatiotemporally pooled for slant perception. The similarity between the duration of temporal pooling found in this study and the duration of fixation in normal viewing is consistent with the notion that vertical disparity is used the retinal information of eye positions.

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Interocular transformational apparent movement in HMD misalignment detection

Jukka Hakkinen (Jukka.Hakkinen@Nokia.com), Philip A Duke (pduke@yorku.ca), Ian P Howard; York University, Canada—To generate accurate representations of 3D scenes from binocular disparity, horizontal disparities must be interpreted using estimates of eye position. These are derived from extraretinal signals and vertical disparities. Vertical disparities are pooled over an area of about 20 deg. However, previous studies have considered only the 2D configuration of a scene. Here we examined how vertical disparities appropriate for different fixation distances in 2 superimposed arrays of dots at different depths affects the interpretation of horizontal disparities in the displays. In experiment 1 we examined the effect of vertical disparities of arrays of dots at different depths on superimposed arrays without vertical disparities. Observers viewed 2 arrays of dots with horizontal disparities and vergence corresponding to frontal surfaces. One was a central, horizontal row of dots at the fixation distance (45cm) and the second was a field of dots with added horizontal disparity of up to +40 arcmin. The vertical disparities of the field of dots corresponded to convergence nearer or beyond the fixation distance, producing apparent concave or convex curvature in depth around the vertical meridian. Subjects matched a subsequently viewed comparison field of dots with adjustable curvature to the apparent curvature of each of the two test arrays. When the two superimposed test arrays had the same depth, the horizontal disparities of the dot row were processed in the same way as the horizontal disparities of the field. However, disparity processing became increasingly depth-specific as the depth separation of the arrays increased up to a horizontal disparity of around +20 arcmin. In experiment 2, we examined vertical disparity pooling in depth with 2 superimposed arrays of dots, evenly distributed in 2D, with different vertical disparity manipulations. We conclude that, although vertical disparities are pooled over sizeable 2D regions, they are pooled only over a narrow range of depth.
SA119

Different temporal frequency tunings in different spatial frequency stimuli for depth perception
Seungbae Lee (color_leeb@graduate.chiba-u.jp), Satoshi Shioiri, Hirohisa Yaguchi; Chiba University, Japan – Purpose: Multiple channels with different spatial frequency tunings have been suggested to contribute to stereopsis. We investigated whether the different channels have different temporal frequency tunings.

Method: We measured contrast threshold with various disparities and disparity threshold with various contrasts for depth discrimination, to characterize the sensitivity profile of the depth detection mechanism concerned at a given spatiotemporal frequency. The stimulus display consisted with four squares filled with sinusoidal gratings arranged in a 2x2 array with gaps to separate them. The gratings in the upper right and lower left squares had the same disparity that was opposite of those in the other two squares. The observers responded which pair appeared to be closer in depth. All the gratings drifted in the same direction, either left or right, and the direction varied from trial to trial randomly. Contrast threshold as a function of disparity (CD curve) was obtained for each combination of six temporal frequencies (0.15 – 20.0 Hz) and four spatial frequencies (0.23 – 3.75 c/deg). Disparity thresholds provided portions of the curve at small disparities and contrast thresholds provided portions of the curve at large disparities.

Results: DC curves were similar with the highest contrast sensitivity at about the same disparity for all temporal frequencies for a given spatial frequency. Changes in temporal frequency shifted the DC curve along the contrast axis. The relative shift of the curve, which corresponds to relative frequency. Changes in temporal frequency shifted the DC curve along the disparity for all temporal frequencies for a given spatial frequency.

SA120

Pedestal depth discrimination for contrast modulated noise
Lew Stelmach (lew.stelmach@crc.ca), Athena Buckthought; Communications Research Centre Canada and Carleton University, Canada – Binocular depth perception depends on the matching of features in the two eyes. Matching can be based upon first-order, luminance defined features, or second-order features such as the contrast-envelope. Binocular matching of the contrast envelope allows depth perception to proceed even when the contents of the contrast-envelope (i.e. the carrier) contain many false matches. However, the robustness of this matching process has only been evaluated for stereocuity. In the present work, we studied the robustness of contrast-envelope matching at larger pedestal disparities. This was done in two stages. In the first stage, we found that depth discrimination using a shifted contrast envelope was relatively easy for a large range of pedestal disparities. By comparison, when the envelope was not shifted, and only the carrier had disparity, then depth discrimination was much harder at the same range of pedestal disparities. In all stimuli, the carrier consisted of bandpass filtered noise. In the second stage, we produced a new type of stimulus in which the contrast envelope and the carrier had different disparities. On the hypothesis that the shifted envelope would be used to compute disparity and that the carrier would be ignored, performance should be relatively easy for a large range of pedestal disparities. On the alternative hypothesis, matching of the carrier would be more important in computing disparity, and performance would be relatively lower. We found that the data supported the alternative hypothesis, showing that the carrier could not be ignored in computing disparity. These findings were especially evident for large pedestal disparities.

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Arbitrary; the one with lower frequency determines the resolution.

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SA123

Depth from monocular images Ian P Howard (ihoward@cvc.yorku.ca), Phil Duke; Centre for Vision Research, York University, Canada – Nakayama and Shimojo coined the term “Da Vinci stereopsis” for the impression of depth caused by parts of a display seen by only one eye. In displays used to illustrate Da Vinci stereopsis the magnitude of depth is unspecified because the viewer has no information about the size of the occluded object.

We have designed displays that remove this ambiguity. In one display a square has the same colour as a transparent background. For one eye, the square just fills a slit in the background so that its lateral edges are not visible. For the other eye, the square is displaced relative to the slit. For this eye, both lateral edges of the square are visible because the background is depicted as transparent. We refer to this depth cue as “monocular transparency”. We measured the depth produced by our display relative to that produced by an adjacent disparity depth probe. For most subjects, the perceived depth of the transparency display matched that of the probe. Thus, monocular transparency can create good quantitative depth in the absence of binocular disparity. We have also produced quantitative depth in displays resembling Panum’s limiting case and show that Da Vinci stereopsis and Panum’s limiting case are essentially the same. Our effects cannot be due to vergence-induced disparity because they occur when both images are symmetrical and because depth in both directions occurs at the same time.

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SA124

Depth from rapidly alternating disparities Elena Gheorghiu (e.gheorghiu@phys.uu.nl), Casper J. Erkels; Utrecht University, Helmholtz Institute, Utrecht, The Netherlands – We observed that two disparity-defined depth planes were perceived at a single depth when disparity alternated rapidly between two values. We investigated quantitatively how depth of the plane depended on the temporal frequency of disparity. We alternated the two disparity values between 9 Hz and 35 Hz, which is above the limit of stereomotion. We used two types of dynamic random-dot stereograms. In one stereogram, a single pattern alternated between two disparity values. In the other stereogram, we alternated two uncorrelated patterns each having one of the two disparity values. We employed a depth discrimination task between the plane with alternating disparity and a plane with constant disparity presented against a static background. The psychophysical results show that the perceived depths depend on the type of stereogram: i) temporal averaging of depth occurs in the temporally correlated stereogram; ii) depth is always close to one of the two depths that are associated with alternated disparities of the temporally uncorrelated stereogram. We speculate that the differences are caused by the involvement of monocular coherent motion signals in stereoscopic depth perception.

SA125

Perceived depth from veridical and aliased binocular phase disparities in a random-dot (RD) stimulus Saumil S Patel (saumil@sstell.net), Harold E Bedell; University of Houston, USA – A horizontal position disparity (PD) in a broad band stimulus introduces binocular phase disparities that increase systematically with the spatial frequency (SF) of its spectral components. However, for e.g. with crossed disparities, only phase disparities between 0 and 180 π/phase/deg veridically signal the direction of stimulus depth. Spectral components with phase disparities beyond this veridical range are aliased and signal a reversed direction of depth. Here we investigate how aliased phase disparities are used in the perception of stereoscopic depth.

Observers (N=2) fused a pair of RD images on the 2 sides of a monitor, presented to the 2 eyes using paired polarizers. Each eye’s image consisted of a 1-deg inner square (IS) of RDs centered in a 3-deg outer square (OS) of RDs. Identical OSs in the 2 images provided a reference plane for phase disparities that were introduced in the IS. Phase disparities equivalent to -16 to +16 min PD were produced in the 2 ISs by manipulating each image’s Fourier phase spectrum. Observers reported if a 4x4 min bright probe was in front or behind the IS in 3 conditions, based on the SF components in the IS: SFs with disparities in the veridical range (1), in the aliased range (2), and all SF components (3). From trial to trial the PD of the probe varied randomly.

The perceived depth of the inner square, obtained from a psychometric function, was identical in the veridical and all-SF conditions for all equivalent disparities. In the aliased condition perceived depth was bistable, corresponding to an inner square perceived in front or behind the outer square.

The presence of SF components with aliased phase disparities does not affect the perception of veridical depth in a broadband stimulus. Perception of the veridical direction of depth in one of the bi-stable depth planes when only the aliased SF components are present suggests that the gradient of phase disparity with respect to SF may contribute to the computation of stereoscopic depth.

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SA126

Spatial resolution of stereopsis Sergei Geg.czhesteho1 (sergeg@uclink.berkeley.edu), Martin S Banks2, Michael S Landy3; 1School of Optometry, University of California, Berkeley, CA, USA, 2Dept. of Psychology and Ctr. for Neural Sci., New York University, New York, NY, USA – Spatial resolution for modulations of stereoscopic depth is much worse than resolution for modulations of luminance. Resolution for disparity modulations has been measured with random-dot stereograms (RDS). The sampling pattern of random-dot stimuli constrains the range of spatial frequencies that can be represented. We examined the degree to which the observed low resolution for the detection/discrimination of disparity modulations is caused by stimulus constraints as opposed to neural limitations. Observers viewed RDSs depicting sinusoidal depth corruptions. We measured the highest spatial frequency (Fmax) at which observers could reliably discriminate two corrugation orientations at peak-to-trough amplitude of 16 min disparity. We made the measurements across a broad range of dot densities at different modulation amplitudes. We found that performance is scale-invariant (Fmax is proportional to the square root of density) across 2 log units of dot density. In the scale-invariant range, Fmax is predicted by the 2-d Nyquist limit of the sampling dot pattern (although ideally the task requires far fewer dots than the Nyquist limit). At the highest densities, Fmax reached asymptote at 1-2 cdp. This asymptote corresponded to a disparity gradient of ~1 (measured from peak to trough, i.e., a peak gradient of nearly 3.14). When the modulation amplitude was reduced by a factor of three, the Fmax asymptote increased to 2-3 cdp (corresponding to the peak-to-trough disparity gradients of 0.35-0.55).

Improving the optical quality of the stimuli led to a further slight improvement in Fmax in some observers, but all observers exhibited asymptotes up to ~3.5 cdp. Thus, three factors limit spatial resolution to disparity modulations: sampling density, the disparity gradient, and another factor at high dot densities that probably reflects spatial averaging required to reduce noise from false matches in the correspondence process.

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SA127

Bistability in stereoscopically perceived slant about a horizontal axis Loes C J van Dann (L.C.J.vanDann@phys.uu.nl), Raymond van Ee; Utrecht University, The Netherlands – We exposed the visual system to an ambiguous 3D stimulus consisting of a grid for which monocular and
binocular cues could specify different slants about a horizontal axis. Observers were asked to estimate the slant of the grid in 3D space. Monocular and binocular specified slants were varied independently across stimulus presentations. When monocular and binocular cues specified similar slants (no conflict) observers perceived a single orientation. However when the difference between the specified slants was large (cue-conflict), observers were able to select either a monocular or a binocular dominated percept. This result corroborates what van Ee, van Dam and Erkelens (Journal of Vision, 2002, 2, 597-607) reported for slants about a vertical axis.

The slant estimates were described by a Bayesian model in which the different cues were implemented as different likelihoods. To describe the bifurcation in the data, two different modes were used in our model. One in which the monocular likelihood is dominant and the other in which the binocular likelihood is dominant.

Further, observers were able to flip between percepts more or less at will, although spontaneous flips occurred frequently. Eye movement measurements revealed that (1) the flipping between percepts can occur under strict fixation and (2) when eye movements are allowed, there is no clear correlation between eye movements and perceptual flips: flips occur during long fixations as well as just after saccades or blinks. Therefore we suggest that perceptual flipping of the bistable grid stimulus is a central process in which eye movements are not necessarily involved.

**SA128**

**Diminished discriminability of motion in depth after adaptation to frontoparallel motion**  
Julian M Fernandez (julian_fernandez@isr.syr.edu), Bart Farell; Institute for Sensory Research, Syracuse University, USA — There are two possible binocular mechanisms for the detection of motion in depth (MID). One is based on disparity change over time and the other is based on inter-ocular velocity differences (IOVD). It has previously been shown that disparity change over time can produce the perception of MID. However, demonstrating the same for IOVD has proved elusive because of the difficulty for isolating this cue from disparity change (the inverse can easily be done). Thus, studying the contribution of IOVD to MID relies on indirect cues. Existing psychophysical and physiological data are inconclusive as to whether IOVD is used in primate vision. To study the contribution of IOVD to the perception of MID, we used motion adaptation. Adapting to frontoparallel motion can enhance speed discriminability or diminish it, depending on the adapting and test stimuli. If IOVD contributes to MID, we would expect that discriminability of the speed and direction of MID will be also affected after adaptation, because IOVD is basically a comparison between two monocular frontoparallel motion signals. In two experiments using random-dot stereograms, we compared discriminability with and without previous binocular adaptation to horizontal frontoparallel motion. The only difference between the adaptation and no-adaptation conditions was that in the latter the adapting motion was random instead of horizontal. In the first experiment we tested MID direction discrimination (approaching vs. receding). In the second experiment we tested MID speed discrimination along the line of sight. In both experiments we found that discriminability was lower after adaptation. No change was found in a disparity discriminability control test. We conclude that IOVD contributes to the perception of MID.

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**SA129**

**Spatial and non-spatial attention effects in the activity of macaque posterior parietal cortex neurons**  
Alessandra Fanini1 (alessandra.fanini@univr.it), Caselli Luma1, Bertini Giuseppe2, Giovanni Mirabella2, Leonardo Chelazzi1; 1Department of Neurological and Vision Sciences-University of Verona-Italy, 2Department of Morphological and Biomedical Science-University of Verona-Italy — Posterior parietal cortex (PPC) has long been implicated in the control of spatial attention. Recent studies have also suggested a role of PPC in other forms of attention, like attention to object features and task switching. We investigated this by recording single neurons from area 7a of one monkey engaged in spatial and non-spatial attention tasks. Non-spatial attention was explored by instructing the animal to discriminate either the color or the orientation of a small bar presented inside the neuron’s receptive field (RF). To explore spatial attention, we compared responses to the same stimuli when the monkey discriminated their color or orientation vs. when attention was directed outside the RF. Firing rates were determined both in a visual response (V) epoch (120-320 ms after stimulus onset) and in a prestimulus (P) epoch (500 ms before stimulus onset). Out of 42 neurons, 34 in the V epoch and 23 in the P epoch showed a significant difference in activity depending on whether attention was allocated inside or outside the RF. Moreover, for 17 cells in the V epoch and 15 in the epoch, activity to identical targets depended on the stimulus feature the monkey was discriminating, revealing non-spatial attentional effects. Importantly, spatial and non-spatial effects often coexisted in the same neuron. Finally, in a new sample of neurons (n=33) we manipulated the order of presentation of color- and orientation-discrimination trials during the session. In the “repeat” condition, the monkey performed the same task for blocks of consecutive trials before switching, while in the “switch” condition the task varied randomly on a trial-by-trial basis. Preliminary data show that in both trial epochs 1/3 of the cells were significantly affected by the task in the “repeat” condition but virtually none in the “switch” condition. Together, the results suggest a role of PPC in multiple aspects of selective perception and selective perception-to-action coupling.

**Acknowledgment:** Supported by NSF and NINDS

**SA130**

**Regions of extrastriate cortex mediating visual neglect: reversible deactivation of 15 loci in the cat**  
William H Barnes1 (swbarnes@hotmail.com), Sheeta Mulloth1, Bertram R Payne2, Stephen G Lomber3,1; 1Behavioral and Brain Sciences, University of Texas at Dallas, USA, 2Anatomy and Neurobiology, Boston University School of Medicine, USA — In humans, damage of posterior parietal and frontal cortices often induces a neglect of the contralateral visual field. In cats, unilateral deactivation of the posterior middle suprasylvian (pMS) sulcus in the posterior inferior parietal region also results in an equally severe contralateral neglect, as assessed by a visual orienting task. Since attention is likely based upon a widespread network, we tested the contributions of the pMS sulcus and 14 other cortical regions to visual orienting in 31 adult cats. Unilateral cooling deactivation of three adjacent regions along the posterior bend of the suprasylvian sulcus (posterior middle suprasylvian sulcus, posterior suprasylvian sulcus, and dorsal posterior ectosylvian gyrus at the confluence of the occipital, parietal and temporal cortices) eliminated visual orienting responses into the contralateral hemifield, while orienting responses into the ipsilateral hemifield remained highly proficient. Additional cortical loci critical for visual orienting include the anterior suprasylvian gyrus (lateral area 5, anterior inferior parietal cortex) and medial area 6. Cooling deactivation of: 1) dorsal or 2) ventral posterior suprasylvian gyrus; 3) ventral posterior ectosylvian gyrus, 4) middle ectosylvian gyrus; 5) anterior or 6) posterior middle suprasylvian gyrus (area 7); 7) anterior middle suprasylvian sulcus; 8) medial area 5; 9) the visual portion of the anterior ectosylvian sulcus (AES); 10) or lateral area 6 were all without impact on orienting Therefore, three adjoining regions at the junction of temporal, parietal and occipital cortices are critical for mediating visual attention into the contralateral visual field. In addition, one anterior inferior parietal and one medial frontal region contribute importantly to visually-guided orienting.

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**SA131**

**Cortico-collicular interactions mediating visual attention**  
Erin M Woller1 (erin0672@yahoo.com), Rachel J Tesla1, Bertram R Payne2, Stephen G Lomber3,1; 1Behavioral and Brain Sciences, University of Texas at Dallas, USA, 2Anatomy and Neurobiology, Boston University School of Medicine, USA — Unilateral deactivation of cat posterior middle suprasylvian (pMS) sulcal cortex or the superior colliculus (SC) results in a contralateral neglect, with
the cats unable to report the position of visual stimuli introduced into the contralateral visual hemifield. To compare the interactive effects of cortical and collicular deactivations on visual attention, we implanted cooling loops bilaterally in the pMS sulcus and over the dorsal surface of the SC in three cats. As expected, unilateral deactivation of either pMS cortex or the SC in the right hemisphere resulted in an elimination of visual orienting responses into the left visual field. This deficit was reversed by additional deactivation of the homotopic site in the left hemisphere. However, deactivation of the heterotopic locus did not yield the same result. During deactivation of right pMS cortex, additional deactivation of the left SC was sufficient to restore some visual orienting responses into the left visual field. The opposite order of deactivations did not yield the same result. During cooling of the right SC, additional deactivation of the left pMS cortex was unable to restore visual orienting responses into the left field. Therefore, while left SC deactivation was capable of restoring orienting responses following right pMS cortex cooling, left pMS sulcus deactivation following right SC deactivation was unable to achieve the same restoration. Simultaneous cooling of pMS cortex and the SC in the same hemisphere also resulted in an orienting deficit in the contralateral hemifield, yet additional deactivation of the opposite pMS cortex was unable to restore orienting responses into the neglect hemifield, whereas deactivation of the opposite SC did result in a partial restoration. Finally, deactivation of all four loci resulted in nearly normal orienting performance throughout the visual field. Therefore, dynamic interactions both between and within the two sides of the brain mediate visual attention.

Acknowledgment: Supported by NSF and NINDS

SA132 Bottlenecks in cortical processing of objects: a category specific phenomenon

Thomas J McKeeff (tmckeeff@princeton.edu),
David A Remus, Frank Tong; Department of Psychology, Princeton University, USA — Object identification is quite rapid and efficient but as the stimulus load increases, bottlenecks in visual performance become evident. These bottlenecks occur when object presentation rates exceed 8-10 items per second and are likely to reflect inherent processing limitations of the human visual system. Here, we investigated whether this bottleneck is a result of insufficient central attentional resources and therefore generalizable across all stimulus types, or due to the limited neural capacity of category-specific visual areas. We measured fMRI activity while participants viewed sequences of faces, houses, or alternating faces and houses. Items were presented serially at rates of 2.3, 4.7, 9.4, 18.8, or 37.5 items per second which allowed us to manipulate the difficulty of discerning individual items. Brain areas concerned with processing faces and houses, the Fusiform Face Area (FFA) and Parahippocampal Place Area (PPA) respectively, showed an inverted U-shape function when presented with their preferred stimuli (i.e., faces only or houses only). The greatest neural activity occurred at the middle presentation rates, and declined at the highest presentation rates. However, when presented with sequences of alternating faces and houses, the peak in fMRI activity for the FFA and PPA occurred at a higher presentation rate than for sequences containing only one stimulus type. This shift in peak activity suggests that the processing limit of each visual area depended on the presentation rate of the preferred stimulus, and not just any stimulus. Neural activity in early visual areas did not show differences between faces, houses, or alternating faces and houses, suggesting that this type of processing limitation occurs beyond striate cortex. The results support the notion that bottlenecks in object perception result from processing limits of category-specific brain areas rather than a general limit in attentional resources.

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SA133 Pattern visual stimulation elicits cortical acetylcholine release with regional specificity in the anesthetized rat

Elvire Vaucher¹ (elvire.vaucher@umontreal.ca), Rémi Quirion², François Laplanche; ¹School of Optometry, Université de Montréal,Canada, ²Douglas Hospital Research Center, McGill University, Canada — The basal forebrain cholinergic system is involved in attentional processes through its projections to the prefrontal cortex (PFC) and the primary visual cortex (V1). It has been suggested that visual-induced cholinergic activation of V1 may exert a permissive and/or restrictive role for the thalamocortical inputs. However, it is not known if visual stimulation may elicit a cholinergic activation of high order brain areas in absence of attentional need. In the present study, we measured the effects of pattern visual stimulation on the release of acetylcholine (ACh) using in vivo microdialysis technique in V1 and PFC in the anesthetized rat. Moreover, we used retrograde track-tracing to determine whether the cholinergic neurons projecting to the V1 or PFC established reciprocal anatomical links.

Eleven male Long Evans rats (300-350g) were anesthetized (urethan, 1g/kg). An horizontal grating (contrast 90%, 0.08c/d, 3.4Hz) was displayed on a computer screen lateral to the animal. The contralateral V1 and the ipsilateral PFC were perfused (2.5 µl/min) with ringer through a microdialysis probe. Intracerebral pressure injection of 2% Diamino Yellow or 2% Fast Blue saline solution were performed within the PFC or V1.

Pattern visual stimulation elicited significant (F(2,20) = 4.08, p<0.04) increase in ACh release in V1 ranging from 20 to 114%. The visual stimulus also produced long-term effect by increasing the basal level of ACh release in V1. Level of ACh release in the PFC cortex were not significantly (F(2,14)=0.4,ns) changed during the stimulation. Cholinergic BF neurons projecting to PFC or V1 established anatomical relationships within the BF. Altogether, these results indicate that only specific BF cholinergic neurons respond to visual stimulation, which suggests a differential involvement of cholinergic projections in the integration of sensory stimuli.

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SA134 Where objects come from: Attention, segmentation, and textons

Ohad Ben-Shahar (ben-shahar@cs.yale.edu), Brian J Scholl, Steven W Zucker; Yale University, USA — It is well established that the units of attention are not merely spatial but closely relate to perceptual objects. While much work in the field of object-based attention (OBA) is aimed at finding these units, their relationship to the basic features (textons) that guide the segmentation of visual stimuli into objects is largely unexplored. Here we bridge this gap for one of the most conspicuous features of early vision, namely orientation. Much work in the segmentation literature suggests that orientation-based texture segmentation (OBTS) is guided by orientation gradients, and our previous work also suggests that it is also significantly mediated by texture flow curvatures. In addition, this work makes the surprising prediction that the flow of attention should *not* depend on the general direction (i.e. the ‘grain’) of the texture — in contradiction to previous findings in the OBA literature (Avrahami, 1999). To address this contradiction and to reveal the relationship between attention, objects, OBTS, and the orientation texton, we employ both the cueing and divided-attention paradigms on various orientation-defined textures (ODTs), both uniform (one ‘object’) and discontinuous (two ‘objects’). Contrary to previous studies, we find that the texture’s ‘main direction’ has no effect: attention flows just as readily with vs. against the ‘grain’ of ODTs. At the same time, texture-defined discontinuities have a major effect: attention flows less readily across texture-defined boundaries which are defined by both orientation and curvature. These effects replicated across multiple paradigms and dependent measures, and also held for jittered ODTs, wherein the effects must be due to the global structure and not local good continuation. We
conclude that uniform ODTs are single objects from an attentional point of view, while discontinuous ODTs are processed as multiple objects. This work reveals how the 'objects' of OBA are formed from simple visual features.

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SA135
Effects of attention and motivation on neuronal activity in parietal cortex  Michael S Bendiksby (bendiksby@neuro.duke.edu), Michael L Platt; Dept. of Neurobiology, Duke Univ. Medical Center – Prior studies have demonstrated that neuronal activity in the lateral intraparietal area (LIP) is correlated with the probability or magnitude of reward that can be expected upon execution of visually-guided saccades as well as by the deployment of visual attention. Reward-related modulations in neuronal activity may thus reflect differential deployment of attention to visual stimuli based on reward size or certainty. The goal of this study was to distinguish motivational from attentional representations in LIP. To accomplish this, rhesus monkeys were trained to perform a peripheral attention task at psychophysical threshold. Subjects were required to indicate the brief flicker of one of two peripheral cues by shifting gaze to a response target positioned in the opposite hemifield. On each trial, one randomly selected peripheral cue was illuminated first, indicating the location of the flicker with 80% validity. The magnitude of reward delivered for correct trials was then varied independently across blocks. Flicker detection was correlated with cue validity, indicating that subjects selectively attended to the early onset location. Blocks of larger reward were associated with shorter reaction times on both valid and invalid trials, indicating a general increase in motivation. Elevated motivation was associated with increases in the signal detection measure d', indicating enhanced visual processing at the attended location. Neuronal activity in LIP was higher for the attended location, and increased reward was associated with enhanced neuronal selectivity. These data suggest that neuronal activity in LIP reflects the differential deployment of attention to visual stimuli, and that motivation sharpens attentional processing.

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Sunday Posters

Authors Present: 1:30 – 3:30 pm

Surfaces, Space Perception, Object Recognition, Natural images, Motion 3: Low-level, Time, Biological, Locomotion, Attention 3, Adaption/Aftereffects

SU1
Two influences of parallelism on the perception of illusory contours

Marc K. Albert (mka@soton.ac.uk); University of Southampton, Southampton, UK – A number of fascinating inhibitory effects of inducer grouping on illusory-contour formation have recently been described by Gillam (1987) and Gillam & Chan (2002). They show that illusory contours are stronger when inducers and potential illusory contours have a ‘random’ relative spatial arrangement, than when they have a more regular arrangement. They suggest that their results are consistent with the ecology of biological vision: An occluder is usually physically independent of the background objects that it partly occludes, and thus the geometry of their contours are likely to be independent. Similarly, contours of individual background objects are likely to be independent. Thus, image regularities among these contours could be taken as evidence against the presence of a camouflaged occluder (the potential illusory figure). However, I show that strong illusory contours can occur in patterns possessing a high degree of regularity among the inducers and the potential illusory contours. I suggest that interactions between nearby, approximately parallel visual contours might help to explain many of the effects described by Gillam and colleagues. Nearby, approximately parallel visual contours tend to group with one another, and also tend to mutually inhibit one another (also see Li, 2001). I propose that these processes affect illusory-contour formation in two ways: 1) When the far ends of line-inducers (the ends not adjacent to the target illusory contour) terminate along a (virtual) contour that is roughly parallel to the target illusory contour, then the target illusory contour is weakened. 2) When inducing lines are roughly parallel to one another they mutually weaken their neural representations, resulting in reduced “end-cutting” responses to the inducing line-endings, and consequently, weaker illusory contours.

SU2
Real surfaces, illusory surfaces, and other perceptually completed regions: direct comparison of boundary sharpness

Damian A Stanley (das@cns.nyu.edu), Vaishnavi Krishnan, Nava Rubin; The Center for Neural Science, New York University, USA – Illusory contours (ICs) are a useful tool to study scene segmentation. In particular, ICs embody two apparently conflicting needs of segmentation: they require integrating information over large distances (‘global’), and concurrently show sensitivity to minute image details like junction structure (‘local’). Understanding this global/local interplay has progressed slowly, partly due to a lack of reliable methods to measure IC completion. We devised a measure of the presence and/or strength of a bounding IC based on performance in a dot localization task. A probe dot was presented briefly near the boundary of a perceptually completed region. Observers reported whether the dot fell inside or outside the region. The slopes of the psychometric functions (fraction ‘out’ responses vs dot position) provide an estimate of the sharpness of the perceived boundary; biases indicate position. We examined four classes of stimuli: (1) Classical kaniza and other illusory figures (IC stimuli), (2) stimuli where the IC inducers had been altered slightly in ways that reduce the subjective impression of ICs, (3) luminance-defined contours (‘Real Contour’, RC), (4) control stimuli to assess performance based on no-contour alignment information. Results show that ICs can support boundary localization almost as well as RCs (thresholds: 9.2 and 6.0 min-arc respectively). Small manipulations to the local features (e.g. rounding the sharp L-junctions) of the IC stimuli significantly reduced performance to that obtained when only alignment information was provided (thresholds: 19.9 and 16.1 min-arc respectively). Our results are consistent with previous data obtained by subjective report (rating methods), but extend them further and, importantly, provide a more sensitive method for assessing the effect of stimulus manipulations on completion processes.

Acknowledgment: Funded by the Sloan Foundation and the NIH (R01 EY14030-01) http://www.cns.nyu.edu/~das/ss32003

SU3
Effects of illumination direction on the perception of shape from shading for photometrically accurate images of randomly shaped surfaces

Baoxia Liu1 (baoxia@uclink.berkeley.edu), James T Todd2; 1School of Optometry, University of California, Berkeley, USA 2Department of Psychology, Ohio State University, USA – There is a common belief among perceptual psychologists that shaded images are inherently ambiguous with respect to the sign of relief, and that this ambiguity is resolved by a bias to perceive surfaces illuminated from above. The research described in the present paper was designed to investigate how observers’ perceptions of smoothly curved surfaces are influenced by various illumination patterns. The images were generated with a photometrically accurate rendering model that simulates the effects of area lights, cast shadows and indirect illuminations. The displays depicted roughly spherical objects with random patterns of ridges and valleys. These objects could be presented with visible smooth occlusion contours, or these contours could be masked by a uniformly convex aperture. The surfaces could be illuminated from four different directions (i.e., above, below, left or right). Observers judged the pattern of ordinal depth on each object by marking local maxima and minima along designated scan lines. They also
judged the apparent magnitudes of relative depth between designated probe points on the surface. There was a high degree of reliability on these tasks both within and between observers. When the different patterns of illumination were compared, the variations in judged depth were remarkably small, and observers’ judgments were highly correlated across each possible pair of illumination conditions. They were also highly correlated with the ground truth – even when the occlusion contours were masked. These findings suggest that perceptual ambiguities obtained with unrealistic rendering models may not generalize to more natural contexts.

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**SU4**

**Spatiotemporal characteristics of illumination on surface material perception**

Tatsuto Takeuchi1 (tatsuto@apollo3.brl.ntt.co.jp), Hiroto Matsuoka2, NTT Communication Science Laboratories, Japan, 2NTT Microsystems Integration Laboratories, Japan – Humans can easily recognize materials, such as metal or plastic, under various illuminations. It has been suggested that the visual system utilizes some statistical properties of natural illumination to recover the surface reflectance. The purpose of this study is to understand which components of illumination determine the appearance of surface material. For this purpose, we examined surface material perception under various illuminations in which their spatiotemporal frequency components are manipulated. It is known that surfaces in computer-graphics images rendered with unrealistic illuminations appear unrealistic. To examine the surface material appearance of real objects in the real world, we made a room that is uniformly illuminated from all directions in 3-D space. The room is large enough (3.5 X 3 X3 m) to serve as realistic environment for observation. To examine the spatiotemporal characteristics of illumination on material perception, we projected various patterns, such as sinusoidal gratings having various spatiotemporal frequencies or band-pass-filtered random dots, on a wall of the room. The angle of the object (boards having different surface materials) was adjusted to make the projected patterns function as illumination. Subjects judged how strongly they were able to perceive the surface material of the object. We found that when the illumination was uniform (zero frequency), metal, plastic, and porcelain completely lost their material impression. Surface material perception of those objects showed low-pass characteristics: low-spatial frequency illumination induced more veridical perception than illumination having high-spatial frequency components. The temporal frequency of illumination also showed low-pass characteristics. These results imply that the visual system can recover surface properties under some artificial illuminations, such as one having a low spatiotemporal frequency component.

http://www.brl.ntt.co.jp/people/takeuchi/seika_3e.htm

**SU5**

**Generality and junctions in motion interpretation**

Josh McDermott (jhm@mit.edu), Edward H Adelson; Dept. of Brain and Cognitive Sciences, Massachusetts Institute of Technology – Spurious motions are commonly produced at points of occlusion by moving objects. The visual system must discount these motions to successfully interpret image motion; this necessitates form information. To help characterize the form analysis affecting the discounting process, we used stimuli based on a cross moving within an occluding aperture. The two bars of the cross cohere or move separately depending on the context; in accord with prior literature, coherence depends in part on whether the bar endpoints appear to be occluded. We explored the dependence of the discounting process on the junctions generated at potential points of occlusion. In some cases, junction categories seemed to have a large effect on whether motion was discounted; in others they made little difference. For instance, coherence depended strongly on whether the junctions formed at the cross intersection were Ls rather than Ts, but was little affected by the category of the junction at the cross endpoints. Further experiments suggested that what matters is not junctions per se, but the relative generality of a display’s various interpretations, which in our stimuli is determined by illusory edges. Changing the junction category seems to matter only when it affects the relative generality of the interpretations of a stimulus. Parsimony thus favors an explanation of these phenomena in terms of the generality of layered surface interpretations, with no explicit reference to junctions.

http://koffka.mit.edu/~kanile/master.html

**SU6**

**Perception of transparency and amodal completion in pigeons**

Yasu Nagasaka (nyasuo@rikkyo.ac.jp), Koji Hori, Yoshihisa Osada; Department of Psychology, Rikkyo University, Japan – Some studies have shown evidence that various animals can recognize partly occluded objects in the same manner as humans. However, there is no positive evidence for amodal completion in pigeons. In this study, we re-investigated the perception of amodal completion together with perceptual transparency in pigeons.

Stimulus was a combination of one horizontal and two vertical rectangles. One of the vertical rectangles was placed in front and the other was placed behind the horizontal rectangle. Four pigeons were separated into two groups (Front and Back group) and trained in 2AFC tasks. The subjects in the Front group were trained to peck a vertical rectangle that was placed in front of the horizontal rectangle, while subjects in the Back group were trained to peck a vertical rectangle lying behind the horizontal one. After subjects reached the training criterion, they proceeded to a test phase. A test session consisted of 80 baseline trials of trained stimuli and 10 trials of probe stimuli randomly inserted in the baseline trials. The probe stimuli differed from the trained stimuli in the luminance of the area where the vertical and horizontal rectangles overlapped, and induced perceptual transparency while maintaining the depth relations among the rectangles.

We analyzed the number of peckings at the probe stimuli. The pecking behavior to trial stimuli was analogous to that to trained stimuli. Subjects in the Front group responded significantly more to the rectangle that was seen transparent in front of the horizontal rectangle. On the other hand, the Back group responded significantly more to the rectangle that was placed behind the horizontal transparent rectangle. The results indicate that the pigeons in Back group didn’t perceive the occluded vertical rectangle as two fragments, but as a unitary rectangle in training sessions. These results suggest that pigeons are capable of perceiving both transparency and amodal completion in the same way as humans.

**SU7**

**The perception and discrimination of local curvature on complex 3-D surfaces**

J. Farley Norman1 (farley.norman@wku.edu), Hideko F Norman1, James T Todd2, Anna M Clayton1, T. Ryan McBride1; 1Western Kentucky University, 2Ohio State University – Past research on the perception of surface curvature from binocular disparity and/or motion has focused primarily upon simple surfaces (e.g. quadric surface patches, see Tittle, Norman, Perotti, & Phillips, 1998; Perotti, Todd, Lappin, & Phillips, 1998). In the present experiments, we required observers to judge differences in the local curvedness of separated regions on complex, globally-convex 3-D objects. The shapes of these computer-generated stimuli resembled those of natural objects (i.e., the objects possessed 10-20 qualitatively distinct regions of positive and negative Gaussian curvature) and were optically defined by binocular disparity, motion, shading, and texture. Discrimination thresholds were obtained for interval tasks requiring observers to judge the magnitude of differences in curvedness between local surface regions and for ordinal tasks requiring observers to judge which of two regions possessed the higher curvedness. We also manipulated whether the regions to be judged on any given trial had the same or different local surface shape. The results showed large effects of these manipulations. Performance was poorest in the interval conditions where observers discriminated the magnitude of differences in surface curvedness (Weber fractions for this task ranged from 50 to almost 100.
percent). In contrast, the observers’ performance for the ordinal conditions was higher (Weber fractions of approx. 30 percent). The highest performance of all (Weber fractions of approx. 20 percent) occurred when the two regions to be compared possessed the same local 3-D shape (both regions were either “bumps”, “saddles”, or “dimples”). Our results demonstrate that human observers do not always possess precise knowledge of local surface curvedness and “good” performance depends critically upon whether metric or ordinal surface structure is judged and upon whether the surface regions to be compared are similar or different in local shape.

SU8
Color-spreading selective for visual surfaces in transparent motion Ryota Kanai1 (r.kanai@fss.uu.nl), Date-An Wu2, Shinuske Shimojo3, 4, 1Utrecht University, The Netherlands, 2California Institute of Technology, U.S.A., 3NTT Communication Science Laboratory, Japan – Filling-in phenomena have been assumed to occur retinotopically based on luminance edge signals (e.g. Cornsweet Illusion, Troxler Fading, etc.). In contrast to this view, we have previously reported that a prolonged fixation at a color gradient interrupted by sharp luminance edges, results in a color-spreading beyond the luminance edges (Shimojo, Wu, & Kanai, 2002, Perception 31, suppl.).

One way to account for this illusion is that color-spreading occurs along perceptual surfaces, rather than retinotopically. Here, we tested this idea using transparent motion in which two surfaces are moving in opposite directions, each having a different color gradient from center to periphery. In a typical stimulus, the color of dots gradually changed from red to green as the eccentricity increased on one surface, and on the other surface, the color of dots gradually shifted from green to red. Thus, at an intermediate eccentricity, there arises a yellow area where the colors of two surfaces are close to each other. The width of this area was varied by changing the steepness of the gradient and the effect of occlusion on this area was tested. Our findings include, 1) The color spreading occurred selectively for each surface, supporting the surface-based account, 2) A shallow gradient did not necessarily result in an immediate color-spreading, as opposed to the classical edge-based filling-in phenomena. Although the final percept of the color for each surface was perceptually similar between the shallow and the steep gradients, two separate effects seem to be involved. First, the color information from the fovea dominates over that of the periphery and spreads in this direction, as in our previous report. Second, when the peripheral colors consist of the colors same as in the fovea, but combined with the opposite motion direction, these colors are actively used to facilitate a percept of homogeneously colored surface via a motion-color misbinding process.

http://www.fss.uu.nl/psn/Kanai/stan.html

SU9
Compression of visual space under steady fixation Holger Außer (hauser@psg.uni-muenster.de), Markus Lappe; Psychological Institut II, Westfälische Wilhelms University Muenster, Germany – Under certain circumstances human perception exhibits a compression of visual space for periscopically flashed objects. Previously, we showed that compression depends on the presence of visual references. Furthermore we demonstrated that also the saccade target itself is mislocalized if its position is not determined by visual references. From these results we hypothesized a relative visual localization process between the saccadic target and the flashed object. In the present work we ask whether periscopically compression relies on the execution of the saccade or whether compression effects may also occur in the absence of a saccade. We chose a paradigm that was identical to the saccade paradigm in which we previously obtained compression. In complete darkness, each trial started with the appearance of a small dot, that observers had to fixate during the whole trial. After a while the dot disappeared and a second dot (which in previous experiments served as the saccadic target and will therefore be named ‘target’) appeared for 50 ms 12.8 to the right of the fixation position. Subsequently a vertical bar was flashed for 8 ms at one of four possible positions. Observers had to localize, in blocked conditions, either the position of the bar or that of the target. Both condition were tested with and without visual references.

When indicating the bar position, observers showed systematic mislocalizations towards the fovea, irrespective of the target and irrespective of visual references. Perceived location of the target, however, was influenced by the position of the bar. If the target position was not indicated by visual references it appeared shifted towards the bar. When we calculated the apparent distance between target and bar we found compression that was similar in strength to that observed in saccade experiments. These results confirm our hypothesis compression of space before saccades results from a visual process of relative localization between the two objects.

Acknowledgment: Supported by HFSP

SU10
The Fröhlich effect is not due to a failure to perceive the beginning portion of motion trajectory Rick H. Cai (rc@wj.harvard.edu); Vision Sciences Laboratory, Dept. of Psychology, Harvard University, USA – In the Fröhlich effect, the onset of a moving bar’s trajectory is perceived to be located further ahead in the direction of motion. One explanation is that the earliest portion of the motion trajectory is not registered in consciousness. It has been suggested that this happens because of metacognitive masking (Kirschfeld & Kamber, 1999), or a lack of attention (Musseler & Acherlesen, 1998). In this study, I explored the alternative possibility that the Fröhlich effect happens because the trajectory’s onset is shifted forward in space. In experiment 1, the first frame of the moving bar was marked by a different color. If the early portion of the trajectory is not registered in consciousness, the marker should not be perceived. Instead, all subjects saw the marker and perceived it as located further ahead in space. In experiment 2, in addition to marking the first frame with a different color, the trajectory’s size was increased or decreased continuously. The color marker appeared not only located forward in space but also as larger or smaller in size. These experiments indicate that the Fröhlich effect is not due to a failure to perceive the beginning portion of motion trajectory. Instead, it is due to a shift of the onset of the motion trajectory. However, such a shift is not simply a forward spatial displacement (experiment 2). I propose that the Fröhlich effect is a special case of the illusory misalignment between the continuous and the sudden changes (Cai & Schlag, 2001).

SU11
Spatial representations obtained through map learning and through navigation in real and virtual environments George SW Chan (changege@mcmaster.ca), Jennifer L Campos, Hong-Jin Sun; McMaster University, Canada – Past studies have shown that learning an environment via a map produces an orientation specific representation, resulting in more accurate directional judgements when tested in the same orientation as that of the originally encoded environment (alignment effect). In contrast, navigating through an environment produces an orientation free representation, resulting in equally accurate performance regardless of orientation. The aim of the current study was to determine whether certain factors, such as the level of interactivity, are involved in developing an orientation free representation. In Experiments 1, subjects either viewed a map of a complex building, navigated within that building, or navigated within a realistic interactive virtual simulation of that building (by pedalling a stationary bicycle while receiving visual feedback). Subjects’ directional judgements of target landmarks demonstrated an alignment effect in the map condition but not in either navigation condition (real or virtual). In Experiment 2, even when the learning condition encouraged the development of an orientation specific representation by only allowing subjects to maintain a single orientation, no alignment effect was observed. In Experiment 3, subjects either actively navigated through a virtual environment or experienced the same visual trajectory by passively...
viewing a visual display. An alignment effect was only observed for the passive viewing condition. In contrast to previous VR studies using keyboard input, these results suggest that sufficiently high quality, multisensory VR setups are capable of producing spatial representations parallel to those developed in the real world. Overall, multiple sources of sensory information as well as active navigation (in a real or a virtual environment) appear to be important factors in establishing an orientation free representation.

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SU12

Time course of apparent midline distortions during stroboscopic induced motion Paul Dassonville (pdr@darkwing.uoregon.edu), Elizabeth L Walter, Jagdeep K Bala; Department of Psychology and Institute of Neuroscience, University of Oregon, USA – In a stroboscopic induced motion display, a large frame that is instantaneously displaced in a horizontal direction will induce an opposing illusory horizontal motion component in a vertically moving target. Bridgeman & Klasson (1983) demonstrated that this illusory motion is best explained by the induced Roelofs effects, with the displaced frames causing a misperception of target locations. Recently, our laboratory has demonstrated that the induced Roelofs effect is itself caused by a distortion of the subject’s apparent midline: a frame, offset from the subject’s true midline, serves to pull the subject’s apparent midline in the same direction (Dassonville & Bala, VSS 2002). Taken together, these findings suggest that a stroboscopic induced motion display can be used to conveniently measure the time course of the apparent midline distortions that underlie the Roelofs effect. Subjects viewed a large frame that was repeatedly displaced left and right, in a square-wave fashion, with a frame duration of 600 ms at each position. Within this moving frame, a short duration (16.6 ms) target was displaced vertically at the same frequency. In separate trials, target onsets were timed to occur after a given delay (0 – 550 ms) from each displacement of the frame. Subjects were required to adjust the horizontal positions of the targets until the induced motion was cancelled (i.e., the targets appeared to be moving in a purely vertical direction). Thus, the true displacement of the targets provided a measure of the magnitude of induced motion, which could be used to subsequently compute the magnitude of the frame-induced distortion of the apparent midline. We found that each displacement of the frame caused a shift in the apparent midline, moving from one extreme to the other in approx. 300 ms. Surprisingly, this distortion of the apparent midline occurred in a predictive fashion, with changes beginning approx. 200 ms before the frame displacement.

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SU13

Dynamic performance of a tracking system used for virtual reality displays Stuart J Gilson1 (stuart.gilson@physiol.ox.ac.uk), Andrew W Fitzgibbon2, Andrew Glennerster1,1 University Laboratory of Physiology, Oxford, UK, 2Department of Engineering, Oxford, UK – Position sensors are widely used in virtual reality and other applications to track the location and orientation of the head or limbs. Measures of accuracy and precision are simple to obtain with a static sensor, or a sensor moving along a controlled path. However, such measures fail to characterize performance under the conditions in which the sensor is typically used, when it is subjected to complex acceleration profiles and moves throughout the working volume of the system. We compared the spatial accuracy of an Intersens IS9000 acoustic/inertial sensor to that of a photogrammetric triangulation system. Two digital cameras streamed images of the sensor as it was moved freely within a 1x1x1m volume. Coordinate frames of the optical tracker and IS9000 were aligned (using least-squares) to minimize point-to-point distances in the IS9000 frame. When the sensor was static, the standard deviation of its reported 3D position was close to the 1.5mm that the device’s specifications describe. On the other hand, when a freely moving sensor’s position was compared with that reported by the optical tracking system, significantly larger deviations were observed. In particular, occasional deviations of up to 5cm were found, which could persist for several seconds before reverting to the reference path. A similar type of deviation occurs in the static state but with a smaller magnitude. The deviations were not consistently related to any particular feature of the motion track such as points of rapid acceleration. Varying the parameters that control the smoothing and prediction filters used by the IS9000 resulted in the expected trade-off between high-frequency noise and smoothing of the output. These changes did not introduce significantly more lag or overshoot into the system, at least within the range of accelerations generated by a sensor carried in a human hand.

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SU14

Navigating without vision: A role for spatial language? Nick Giudice (nickg@umn.edu), Gordon E Legge, Jonathan Z Bakdash; Minnesota Laboratory for Low-Vision Research, University of Minnesota, USA – PURPOSE: We are interested in how well geometric information about the layout of a building can be conveyed by spatial language. Can people explore and learn building layouts nonvisually using verbal descriptions? Does learning strategy or navigation performance differ as a function of the amount of verbal information provided? In this study, we compared performance on environmental learning and route finding ability when the available information about layout geometry was conveyed in three different verbal conditions.

1) Local: verbal information describes the layout geometry at the user’s current position.


3) Global: adds a verbal description about the global geometry of the layout.

METHODS: 8 blindfolded participants trained and tested on all conditions. The participant’s task was to use the verbal descriptions to explore the floor and find 4 target locations, indicated by an auditory cue. At each corridor intersection a description was given and participants chose which direction to walk (guided by the experimenter to avoid obstacles). After a fixed amount of training, participants’ knowledge of the floor plan was tested by finding routes between pairs of targets.

RESULTS: Preliminary results show no significant differences between the verbal conditions. Overall target localization accuracy (M=79%, SE=4.82) was significantly above chance (~2%, defined as 1 over the number of possible target locations), t(71)=15.87, p<.0001. The overall mean for optimal path selection (the shortest possible path between targets over the route taken) was (M=91%, SE=3.01) indicating route efficiency was high for all conditions. Future analysis will address if the amount of verbal information during learning affects exploration strategy.

CONCLUSIONS: The results support the notion that spatial language can be efficiently used to learn and navigate an environment.

Acknowledgment: This research was supported by NIDRR grant H133A011903 and NIH training grant 5T32-EY07133

SU15

Perception of size in a ‘dynamic Ames room’ Andrew Glennerster (ag@physiol.ox.ac.uk), Stuart J Gilson, Lili Techeang, Andrew J Parker; University Laboratory of Physiology, Oxford, UK – In a traditional Ames room, perception of size is distorted by the observer’s assumptions about parallel and perpendicular lines. For the illusion to be convincing, the room must be viewed from one vantage point. Using an immersive virtual reality system, we generated a dynamic version of the Ames room illusion. Subjects were free to move around and yet they experienced gross failures of size constancy. Head position and orientation were tracked to generate binocular views of a virtual scene, presented in a head mounted display.
As the subject walked, the entire scene was scaled (expanded or contracted) about the cyclopean point (midway between the eyes). The instantaneous change in scale was not perceptible. Subjects compared the size of a reference object viewed in one part of the room (where the scale of the entire room was small) with the size of a test object viewed in another part of the room (where the scale was up to 3 times larger). Neither test nor reference object were visible as the subject walked between the two locations (2.5m apart) but the rest of the room could be viewed freely. Using a forced choice procedure, we found that subjects perceived the test and reference objects to be the same size when their sizes actually differed by more than a factor of two. Under normal conditions (when the scale of the room remained constant), subjects were able to make correct size matches. In the dynamic Ames room, the subject’s assumption that the room remains a constant size has a powerful influence on size judgements, overcoming consistent and correct information from binocular disparities and motion parallax.

**Acknowledgment:** Funded by the Wellcome Trust and the Royal Society [http://virtualreality.physiol.ox.ac.uk/vis03.html](http://virtualreality.physiol.ox.ac.uk/vis03.html)

**SU16**

**Perceived size of traffic lights: A failure of size constancy**

Carl E Granrud (carl.granrud@unco.edu), Melissa A Granrud, Julia C Koc, Ryan W Peterson, Shannon M Wright; University of Northern Colorado, USA — McBeath, et. al. (1992) found that observers underestimate the size of traffic lights across a wide range of viewing distances. The present study further investigated this failure of size constancy. Three groups of participants viewed a traffic light from distances of 20, 60, and 120 m, respectively. Each participant estimated the size of the light’s 30.5 cm (diameter) lenses by selecting, from a set of nearby comparison circles, a circle that matched the lenses’ size. A fourth group estimated the size of traffic-light lenses from memory with no traffic light visible. The mean size estimates made by all four groups were approximately 30% smaller (in diameter) than the lenses’ actual size. There were no significant differences between the four groups’ size estimates.

After making their size estimates, participants in the fourth group viewed a traffic light from a distance of less than 2 m, and were asked to rate the light’s size relative to what they expected and to rate their surprise regarding the light’s size. The majority of participants rated the light as “much larger” than expected and reported that they were “very surprised,” giving maximum ratings on ordinal scales for these responses.

The results indicate that perception of traffic-light size is not veridical at viewing distances of 20 meters and greater. The finding that estimated size does not depend on viewing distance or on the presence of a visible traffic light further suggests that observers rely on assumed size when estimating the size of a distant traffic light. For most observers, the light’s assumed size does not match its actual size and size constancy is not achieved. These results are consistent with the hypothesis that size constancy for distant objects is not a feature of perception, and that research participants’ estimates of distant objects’ sizes are based on cognitive strategies in addition to visual information for size.

**SU18**

**Linear vection shows a retinal frame of reference**

Douglas L Morse (doug.morse@vanderbilt.edu), John J Rieser; Vanderbilt University, USA — Three experiments investigated the organization of linear vection (the visually-induced illusion of self motion). Previous studies have shown that optokinetic stimulation of the peripheral visual field in a fashion specifying upward or downward self motion yields shorter vection onset latencies (VOLs) than equivalent visual stimulation for forward or backward self motion (Giannopulu & Lepecq, 1998; Lepecq et al., 1999).

This finding has most often been attributed to differential visual-vestibular conflict, that is, the less sensitive saccules generating less of a conflict signal than the utricles. The major goals of this study were to replicate this finding and to probe its frame of reference by finding out whether the advantage of upward/downward vection is defined relative to the retina or relative to gravity.

A vection chamber was constructed to generate lamellar peripheral optokinetic stimulation specifying either forward, backward, upward, or downward self motion. Participants sat at the open end of the chamber and reported when they first experienced linear vection (i.e., VOLs) and after 30 s reported a subjective rating of peak vection potency (PVPs). Experiment 1 explored the optimal stimulus conditions for inducing linear vection. Experiment 2 replicated the finding of shorter VOLs for upward/ downward vection relative to forward/backward vection and also found an equivalent pattern of results for PVPs. In Experiment 3, participants both looked forward into the chamber while seated and upward into the chamber while supine. Stimulus direction interacted with body position such that images translating vertically on the retina produced stronger vection (i.e., shorter VOLs, higher PVPs) than images translating horizontally on the retina. These results suggest that linear vection has a retinotopic rather than gravitational (environmental) frame of reference.

Results are discussed in terms of congruency and conflict models of visual-vestibular interaction.
point to judge other objects’ positions relative to the head. Objects in the plane of regard are imaged on the horizontal retinal meridia of both eyes, provided the eyes do not rotate about the line of sight. According to Listing’s law eye torsion depends on the fixation direction. Similarly, head-tilt evokes compensatory eye torsion. Does eye torsion cause mislocalisation of the plane of regard?

Subjects judged elevation of flashed probe points relative to their plane of regard, while fixating straight ahead, right upward, or right downward at 30 cm distance. Probe azimuth ranged from –20 to 20 degrees. The fixation point was extinguished prior to the probe’s appearance while subjects maintained fixation in total darkness. If fixation failed, the trial was repeated. Although conjugate eye torsion varies by 8 degrees across these different fixation directions, the perceived elevation of eccentric probes was not biased towards the location of the horizontal retinal meridian. Similarly, the perceived plane of regard tilted by as much as the head tilt, again indicating that subjects did not solely rely on retinal cues for the plane of regard estimation. We conclude that people perceive their plane of regard correctly, which could be useful to represent the position of objects in head centric coordinates.

Acknowledgment: NWO 810.37.006

SU20 Angular declination as an exocentric distance cue: some hints for dissociation between perception and action systems Nilton P. Ribeiro-Filho1 (niltonrp@uol.com.br), Elton H. Matsuhashita2, José A. Da Silva2,1 Institute of Psychology, Federal University of Rio de Janeiro, Brazil, 2 Department of Psychology and Education, University of São Paulo at Ribeirão Preto, Brazil – Several studies in the last ten years were devoted to investigate angular declination as a useful visual cue for spatial perception, as assessed by perceptual and visuomotor tasks. Results were not unequivocal, since some of them pointed out that this cue was independent and effective and some others found dependence on interaction with binocular cues. The present two experiments tried to figure out the role of angular declination for exocentric distance perception as assessed by verbal report and visuomotor (visually directed walking) tasks, the first between-subjects factor. Observers (N=40) were asked to verbally judge exocentric distances in depth or to walk toward endpoints of the same exocentric intervals. In Exp. 1, the exocentric interval was constant (1m) and egocentric distances of this interval varied (1, 2, and 3m). In Exp. 2, the exocentric intervals varied (1, 2, and 3m) and egocentric distance of the interval was constant (1m). The second between-subject factor was angular declination, stimuli were presented either at eye-level (no angular declination), or floor-level. Experimental environment was a dark room and stimuli contained a dim light. Contrarywise to some studies, our data showed strong undershooting for all groups, larger for perceptual performance at eye-level. This may indicate participation of perceptual tendencies, as equidistance tendency. Results also showed that angular declination was not effective as an exocentric distance cue for visuomotor tasks, but was significantly effective for perceptual tasks. Despite the strong deprivation of visual cues of our environment, observers’ performance was tied to physical distance properties, probably due to angular size cue that varied systematically with distance. These differences between tasks can be interpreted as different distance processings for perception and for action, supporting hypothesis of dissociation between these two systems.

Acknowledgment: Supported by Grants from CNPq/CAPES.

SU21 Modelling perceived direction of slant in the presence of surface texture anisotropy Harold Sedgwick1 (h.sedgwick@sunyopt.edu), Barbara Gillan2, Colin Leath3,1 SUNY College of Optometry, USA, 2University of New South Wales, Australia – We have previously reported (ECVP 2002) that errors of up to 40 in perceived direction of slant can be produced by rotation ("spin") of an anisotropic surface texture in the plane of the slanted surface. Here we analyze the geometry of this situation, model our results, and present additional data in support of our model. Our anisotropic surface textures include a preponderance of contours oriented in one direction. When the surface is slanted, this anisotropy produces a projective gradient of convergence and a projective gradient of compression oriented at 90° to each other. The orientations of these gradients relative to the true direction of slant vary with the spin of the texture, but we show that these two gradients, taken together, are sufficient to mathematically specify the correct direction of slant for any spin angle. Observers are not able, however, to make consistent use of this information. Instead, there is a strong tendency to follow one or the other of these gradients rather than combining the information from both of them. We present a measure of the strength of each gradient, based on its rate of convergence or compression, and show analytically that the strengths of the two gradients vary reciprocally as a function of spin. We further show that we can accurately account for the modes of the error distributions, as the spin of the texture varies, with a model that bases judgments of direction of slant on the stronger of the two gradients, ignoring the other gradient. We measured observers’ sensitivity to each of the two gradients as a function of spin and showed that observers were able to detect the direction of each gradient with a high degree of accuracy at all but the smallest spins. Thus our observers’ performance is not due to the weaker gradient being too weak to detect, but is instead due to their failure, as indicated in our model, to incorporate information from the weaker gradient into their judgments of direction of slant.

Acknowledgment: Supported by NSF Award # 0001809

SU22 Systematic distortions of perceptual stability investigated using virtual reality Lili Tcheang (lili.tcheang@physiol.ox.ac.uk), Andrew Glennerster, Stuart J Gilson, Andrew J Parker; University of Oxford, United Kingdom – As observers walk through a 3-D environment with their gaze fixed on a static object, their retinal image of that object changes as if the object itself were rotating. We have investigated how well observers can judge whether an object is rotating when that rotation is linked with the observer's own movement. Subjects wore a head mounted display and fixated a spherical textured object at a distance of approximately 1.5m in an immersive virtual reality environment. Subjects walked from side to side (approximately ±1m). On each trial, the object rotated about a vertical axis with randomly assigned rotational gain factors within a range of ±1: a gain of +1 caused it to always face the observer; a gain of -1 caused an equal and opposite rotation; a gain of zero means the object is static in world coordinates. In a forced-choice paradigm, subjects judged the sign of the rotational gain. We found significant biases in subjects’ judgements when the target object was presented in isolation. These biases varied little with viewing distance, suggesting that they were caused by an underestimation of the distance walked. In a rich visual environment, subjects’ judgements were more precise and biases were reduced. This was also true, in general, when we manipulated proprioceptive information by correlating the lateral translation of the target object with the observer's motion.


SU23 Landmark navigation in a virtual environment: Integrative contributions from global and local landmarks Lori S Thompson1 (lstomps@watarts.uwaterloo.ca), Colin G Ellard1, Kevin R Moule2,1 Department of Psychology, University of Waterloo, Canada, 2Department of Mechanical Engineering, University of Waterloo, Canada – Previous experiments have shown that human beings and other animals can find their way to a familiar location using combinations of both local and global landmarks. Several studies, particularly those using non-humans, have suggested that global landmarks take precedence over local landmarks. Other experiments have suggested that a combination of sources of location information are used, weighted by the exigencies of a particular
trial. In the present experiment, we examined the ability of people to navigate to locations in a virtual environment using combinations of local and global landmarks. The virtual environment was generated using a large screen and look-through stereoscopic glasses with motion tracking. The environment consisted of a 91.4 metre diameter round field containing an array of six simple geometric solids. The background consisted of a panoramic display of a suburban park. On learning trials, participants were required to navigate to the target using a handheld device and to touch the target with a virtual wand. On the immediately following test trial, the display reset, the target was extinguished and participants were displaced to a new location on the field. They were then required to navigate back to the original location of the target and to touch the ground with the wand. On some trials, the local landmarks were displaced by either 30 or 60 degrees before the test trial. Results suggested that although there was a small influence of local landmark shifts, participants relied primarily on global landmarks in this experiment. In addition, there was some tendency for searches on shift trials to take longer and to be more circuitous. In accord with previous research, we found strong trial effects and individual differences, suggesting that no uniform strategy was adopted. In debriefing, participants reported a variety of different search strategies, but there was little or no correlation between these reports and the behavioural evidence.

http://watarts.uwaterloo.ca/~lsthomps/

**SU24**

**Vertical and horizontal references determined by linear perspective and optic flow information**

**Jun Wu**<sup>1</sup>, **Zijiang J He**<sup>1</sup>, **Teng Leng Ooi**<sup>2</sup>; 1University of Louisville, USA, 2Pennsylvania College of Optometry, USA – Judging the height and laterality of an object requires vertical and horizontal references that coincide respectively, with the judged eye level and midline of the body trunk. What visual cues determine these references? We previously found that the focus of expansion (FOE) of the optic flow determines judged eye level (Wu et al, VSS02). Here, we extended the study to the horizontal reference. In a virtual environment, observers judged the midline while viewing optical flow display with its FOE shifted horizontally (±30, ±20 and ±30deg). As predicted, horizontal midline was biased to the FOE [rate=0.20 (left); 0.29 (right)]. Arguably, besides showing the utility of the optic flow, our study also implies that other stable cues, eg linear perspective cue (Sedgwick, 1986), can help determine the references. To test this, observers judged their eye levels in the dark. In condition 1, two fluorescent lines (2.5m long) were placed on the right wall with their relative orientation varied to cause false linear perspective. Compared to baseline (parallel lines/true linear perspective), judged eye level was affected by false linear perspective. For example, with one line parallel to the floor, judged eye level changed with the orientation of the second line. If the two lines converged below the actual eye level, judged eye level shifted down. That the effect was mainly due to false linear perspective was shown by removing the line parallel to the floor; the orientation of the second line produced only about 1/9th of the effect. In condition 2, we placed a fluorescent line on each side of a wall (1.5m apart). While the pair of lines remained parallel at the same height, their orientation relative to the floor varied (0, 5, 10deg). Again, relative to baseline, judged eye level changed at a rate of 0.18 as the orientation of the lines varied, compared to a single tilted line (rate=0.06). These findings highlight the role of environmental constants in space vision.

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**SU25**

**Evidence for a sequential surface integration process hypothesis from judging egocentric distance with restricted view of the ground**

**Bing Wu**<sup>1</sup>, **Zijiang J He**<sup>1</sup>, **Teng Leng Ooi**<sup>2</sup>; 1University of Louisville, USA, 2Pennsylvania College of Optometry, USA – Egocentric distance judgment on a surface spanned by different textures is impaired compared to one on a continuous ground surface, suggesting that an accurate representation of the ground surface is required for the visual system to correctly judge distance (Sinai et al, 1998). Here, extending the ideas of Gibson & Cornsweet (1952) we propose that the visual system uses a sequential surface integration process (SSIP) to represent the ground surface. Integral to the SSIP is that the visual system first relies on near depth cues to represent the near surface, and then integrates it with the farther adjacent patch of surface using texture gradient cue. Step by step, the process continues until the farthest patch of surface is integrated, culminating in a global ground surface representation. Thus, when the ground surface is disrupted by incongruent textures, the inaccuracies in integrating from near to far is compounded, resulting in an erroneous global surface representation. In this study, we tested the notion that surface integration occurs from near to far. Observers judged target distance (4-7m) while wearing a shade to limit the visual field (13-40 deg vertical, 60 deg horizontal), and responded by walking blindly to the perceived target distance. Four viewing conditions were tested: (i) with fixed head position, (ii) by rotating the head downward to scan the ground from far to near, (iii) by rotating the head upward to scan the ground from near to far, (iv) repeatedly rotating the head up and down to scan in both directions. We found that distance judgments were accurate when the vertical visual field was larger than 30 deg, consistent with Loomis & Knapp (in press). With smaller fields, conditions (i) & (ii) led to underestimation, while conditions (iii) & (iv) remained accurate. The resultant difference between conditions (ii) & (iii) underscores the directional dictate of the SSIP (near to far) for forming a veridical ground surface representation.

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SU27
A new “Necker Cube” EEG paradigm reveals low level mechanisms in perceptual disambiguation  Juergen Kornmeier (juergen.kornmeier@uni-freiburg.de), Michael Bach; Dept. of Ophthalmology, University of Freiburg, Germany – Prolonged viewing of ambiguous stimuli (eg. the Necker Cube) causes spontaneous change in perception. Previous studies of electrophysiological correlates used subjects’ response as time reference for averaging, entailing marked latency jitter. We introduced a new paradigm as follows: We attempted to entrain spontaneous reversals to specific time instances by onset/offset presentation and further added a comparison condition with depth-shaded, non-ambiguous stimuli which reversed externally. Finally, in an attempt to involve a larger neuronal population we combined 9 Necker cubes into a “Necker lattice”. Methods. 16 visually normal subjects viewed a “Necker lattice” as ambiguous stimulus for spontaneous reversal (Exp. 2) and a non-ambiguous version for externally induced reversal (Exp. 1). Stimuli were presented for 800 ms followed by a blank interval of 400 ms during which the subjects indicated whether they had perceived a reversal compared to the preceding orientation. We recorded evoked potentials from 11 scalp locations.
Results. (1) Externally induced reversal: 95% of these reversals were correctly detected. In the event related potential (ERP), the difference trace (reversing vs. non-reversing condition) showed a series of 3 components beginning with a negativity at the occiput 200 ms after onset. (2) Spontaneous reversal: Subjects reported reversals only at stimulus onset, never during the presentation interval. Again, 3 ERP components were found. They had the same succession, polarities and scalp locations as those in (1) but appeared about 60 ms later.
Conclusions. Onset/offset presentation successfully entrained reversal, allowing synchronous averaging to an endogenous event. Perceptual disambiguation seems to be accomplished by the same structures that represent objects per se, and to occur early in the visual stream. This suggests that low level mechanisms play a crucial role in resolving perceptual ambiguity.

SU28
Can convexity explain how humans segment objects into parts? Laura L Walker (curlee@alum.mit.edu), Jitendra Malik; UC Berkeley, USA – It is an ecological fact that parts of objects tend to be convex. Hoffman and Richards (1984) used this fact to motivate the breaking of an object boundary according to the minima rule. Since then, more rules have been described to account for human performance, however we still lack a quantitative framework in which to evaluate them. The goal of this study is two-fold. First, we propose a simple convexity cue and segmentation algorithm for parsing objects into parts. Second, we propose a general quantitative framework for evaluating object segmentation algorithms and use it to measure the performance of our convexity cue.
METHODS: Dataset: Object silhouettes were derived from the Snodgrass and Vanderwart (1980) dataset of common objects. Ground-truth segmentations have been collected for 200 subjects (De Winter & Wagemans, VSS 2001).
Convexity Cue: We propose “intervening contour” as a cue for object segmentation. Two points within a shape are connected if no boundary crosses the straight-line path between them, and are disconnected otherwise. This cue implicitly enforces a convexity constraint on the parts.
Segmentation Algorithm: Once a matrix of connections between points is constructed, the best parts can be found by minimizing the normalized cut criterion (Shi & Malik, 2000).
Evaluation: Our segmentations are evaluated against human segmentations within the precision-recall framework. Precision and recall are combined into a weighted harmonic mean called the F-measure. F equals 1 for identical segmentations and decreases as the discrepancy between segmentations increases.
RESULTS: The F values for our algorithm segmentations fall below, but within the error range, of human performance. We conclude that convexity is a very strong cue for parsing object silhouettes into parts and that segmentation schemes can be effectively evaluated using the benchmark data and quantitative measures we have described.
http://www.cs.berkeley.edu/~lwalk/

SU29
Conjunction Benefits with First- and Second-order Features  Lisa R Fournier* (fournier@uwunix.wsu.edu), Brian P Dyre*, Robert Patterson*, Ryan Winters*, Matthew Wiediger*; 1Washington State University, United States, 2University of Idaho, United States – Conjunction benefits refer to the case in which discriminating the presence of multiple features within an object (feature conjunctions) can be faster than discriminating the presence of the less discriminable feature alone (Fournier et al., 1998, 2000). An asynchronous priming model assumes that conjunction benefits result from early partial decision activation by more discriminable features that are combined with activation by less discriminable features to meet a single decision criterion. Conjunction benefits occur if task-relevant dimensions differ in discriminability and are consistently mapped to a response. However, it is unclear whether they occur when feature conjunctions are comprised of first-order and second-order features. This study investigated whether conjunction benefits occur when first-order and second-order features are combined within the same display. Specifically, observers judged whether one or two features were present or absent in a gabor patch. In one condition, observers made judgments of the (first-order) spatial frequency and (first-order) orientation of the carrier grating. In a second condition, observers made judgments of the (first-order) spatial frequency of the carrier grating and the (second-order) orientation of the envelope. Discriminability difficulty between the task-relevant features was varied in each condition. Results showed that conjunction benefits occurred in both conditions. This suggests that decision activation from second-order features can be primed by first-order features, and vice versa. The implications of these results for feature integration models of vision will be discussed.

SU30
Complexity impairs efficiency in the periphery  Mariarita Martelli (mli9@brynmawr.edu), Samba Silla, Najib J Majaj, Denis G Pelli; Psychology and Neural Science, New York University, USA – Pelli et al. (2002) show that efficiency for identifying letters is inversely proportional to their perimeter complexity (perimeter squared over “ink” area). Here we report a much larger effect of complexity in the periphery. Efficiency for simple letters is similar in fovea and periphery, but efficiency for complex letters is a factor of five worse in the periphery (15 deg). The simple letters were either Sloan (a bold sans serif uppercase font, like Helvetica) or “snake” letters made up of colinear gabor patches. The complex letters were either Kuenster (a fancy lacy uppercase decorative display font such as might appear on a wedding invitation) or snake letters made up of gabor patches orthogonal to the letter stroke.
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SU31
Shape transformations and image-plane rotations in object categorization  Markus Graf (markus.graf@tuebingen.mpg.de), Heinrich H. Bülthoff; Max-Planck-Institut für biologische Kybernetik, Tübingen, Germany – Previous research suggested that the shape variability of objects from the same basic level category can be conceptualized by transformations which continuously change object shape (topological transformations). Experiments with line drawings (2D outline shapes) demonstrated that categorization latencies and error rates increase with increasing amount of shape transformation (Graf, 2001). We investigated whether these results generalize to more realistic gray-level images rendered from 3D object models. We also studied the effects of combined shape transformations and image-plane rotations on categorization performance.
New category members were produced by morphing between objects from the same basic level category. Subjects were required to decide whether two sequentially presented objects belonged to the same basic level category or not. In Experiment 1 the amount of shape transformation was varied, while in Experiment 2 topological distance and image-plane orientation were manipulated.

Categorization performance (latencies and accuracy) deteriorated systematically with increased shape transformation, both for upright (Exp. 1) and for rotated (Exp. 2) objects. Furthermore, Exp. 2 showed that categorization latencies increased with increasing amount of orientation change. There was no interaction between shape transformation and object orientation.

The results confirm that categorization performance is systematically related to the amount of shape transformation, both for line drawings and gray-level images, as well as for upright and plane rotated objects. In addition, orientation dependency was corroborated with a basic level categorization task. Finally, categorization processes which compensate for shape changes and plane rotations seem to be independent, confirming previous evidence of independent effects for other combinations of spatial transformations (e.g. Lawson et al., 2000). The results support an image-based model of basic level categorization.

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SU32

Strong category-selectivity is rare in human visual cortex Paul E Downing (p.downing@bangor.ac.uk), Chris M Dodds, Annie W-Y Chan, Oliver Turnbull; School of Psychology, Univ. Wales, Bangor, United Kingdom – A variety of principles have been proposed to describe the organisation of visual representations in the human brain. One simple proposal is that representations are divided by category, with focal cortical areas selectively processing stimuli from a given class. Currently there is fMRI evidence for three strongly category-selective visual areas: the fusiform face area, the parahippocampal place area, and the extrastriate body area. Are these areas exceptional, or are similar focal, selective activations seen for other categories? In order to provide a strong test of selectivity, each category tested must be compared against a wide range of stimuli from other classes. To this end, 12 subjects were scanned in a blocked-design fMRI study (whole-brain, 1.5T) while passively viewing 40 colour photos of stimuli from each of 20 categories: birds, bodies, cars, chairs, clothes, crystals, faces, fish, flowers, fruits & vegetables, insects, musical instruments, mammals, microbes, prepared foods, reptiles, scenes, spiders, tools, and weapons. We performed 3 kinds of contrast in SPM: 1) each category vs all others; 2) category pairs, e.g. mammals vs. tools; 3) sets of categories, e.g. living vs. non-living things. (We will also discuss anatomically-defined regions of interest, and correlation analyses of distributed patterns of category-related activity). Many contrasts revealed activated clusters, but closer examination of the timecourses typically showed that these areas were not strongly selective. For example, in many cases a category not involved in the contrast activated the cluster more strongly than those used to define it. Other clusters responded more strongly to one subset of categories than to the others, but with no apparent organising principle. In general, while there is great variability across the visual system in the response to these stimuli, the majority of categories do not elicit focal, selective activations: strong category-selectivity is rare.

SU33

Cortical Regions Involved in Extracting 3D Shapes from Shading Svetlana S Georgieva1 (svetlana.georgieva@med.kuleuven.ac.be), James T Todd2, Ronald Pieters4, Guy A Orban1; 1Belgium, 2USA – Objective: The present study was designed to determine which cortical areas are involved in the analysis of image shading for the determination of 3D shape. Methods: We investigated cortical activation using functional Magnetic Resonance Imaging (fMRI) with a 1.5 T MR scanner. The whole brains of eight subjects were scanned. Subjects were required to maintain a fixation on the central fixation point throughout the entire experiment. Four experimental conditions (3D Shading, 2D Shading, 2D Uniform gray and Fixation) were presented in a block design.

The 3D stimuli (3D Shading condition) depicted roughly spherical objects with random patterns of ridges and valleys that were shaded with a reflectance model containing both diffuse and specular components. A set of matched control stimuli was created, which appeared perceptually as 2D luminance patterns (2D Shading condition), whose image luminance histogram and amplitude spectra were matched to those of the 3D surfaces. An additional 2D control was also included in which the outlines of the 3D objects were filled with a uniform gray luminance (2D Uniform gray condition). Each stimulus subtended approximately 9 degrees and was presented with a duration of 1.4 sec.

Results and Conclusions: The subtraction of 3D–2D shading patterns revealed significant activation in lateral occipital cortex (LOC), early visual cortex (areas V1/V2), and in intraparietal sulcus (IPS). These areas of activation are similar to those revealed in previous experiments to be involved in the processing of 3D shape from motion [Orban at al., 1999; Peuskens et al., 2002], texture or binocular disparity. These results suggest that there is considerable convergence in the neural processing of different depth cues. In these areas of activation 2D shading stimuli produce stronger activation than 2D uniform gray stimuli, therefore the cortical regions were less activated in the subtraction 3D Shading–2D Shading than 3D Shading–2D Uniform gray.

SU34

Automatic processing of whole objects in a part identification task Chris I Baker1 (chaker@cnbc.cmu.edu), Carl R Olson2, 3Marlene Behrmann3; 1Center for the Neural Basis of Cognition, Pittsburgh, USA, 2University of Pittsburgh, USA, 3Carnegie Mellon University, USA – It is unclear to what extent visual objects are processed as wholes even when some of the object parts are task irrelevant. To address this issue we designed simple objects, ‘batons’, composed of two parts joined by a vertical stem and trained observers to perform a part identification task. In each baton, one of the parts was a ‘target’ and indicated either a left or a right lever response, and the other part was a ‘distractor’. Distractor parts were not predictive of response and observers were told to ignore them. A given target was paired frequently with some distractors (‘frequent baton’ condition) and infrequently with others (‘infrequent baton’ condition). Frequent batons were presented four times as often as infrequent batons. If observers processed the whole baton (the specific combination of parts), it was reasoned, they would respond with shorter reaction times to the frequent than to the infrequent batons. In experiment 1, the targets could appear at either end of the baton. Observers were faster for the frequent than for the infrequent batons which suggested that they were encoding the whole batons. This result persisted even when the stem connecting the different parts was removed (experiment 2). When the targets appeared at only one end of the batons and observers were instructed to attend only to that end (experiment 3), reaction times were still significantly shorter for the frequent than infrequent batons, although this difference was smaller than in the first two experiments. When the targets appeared at only one end of the batons and the bar connecting the parts was removed (experiment 4), the difference in reaction time between frequent and infrequent batons was no longer present. These results indicate that observers automatically encode whole objects under a variety of different conditions even when whole object identity is behaviorally irrelevant.

SU35

Temporal dynamics of negative priming Riku M Lalchandani (rm244@npsu.edu), Fani Loula, Marisa Carrasco; New York University, USA – Negative Priming refers to a slowed response to visual stimuli that is initially ignored and later presented as the target. This decrement in
performance is due to the interference of the irrelevant stimulus on the processing of the relevant stimulus. It is unclear whether this interference in processing is of greater importance during the initial presentation of the irrelevant information in the prime display or during the later presentation of the relevant information in the probe display. In this experiment we used a mask to manipulate the processing time for the target following both the prime and the probe displays.

Observers viewed a series of overlapping novel shapes (green target overlapping a red distractor) presented for 200 ms either to the left or right of fixation and determined whether the target was symmetrical or asymmetrical. Following a negative priming paradigm, in half of the trials (experimental condition) the red overlapping distractor reappeared as the green target (maintaining shape). In the remaining half of the trials (control condition) no shapes were repeated. A 100 ms mask interrupted processing at different time lags (0, 300, 500 ms). Reaction times and accuracy were recorded.

We found that: (a) when the prime was masked either immediately or at 500 ms no negative priming emerged regardless of the time at which the mask followed the probe; (b) when the mask appeared 300 ms after the prime negative priming emerged for the probes that were masked either at 300 or 500 ms. These results suggest that the processing time of the prime is critical for negative priming to occur. When the mask appears immediately after the prime its representation may not be well established and thus need not be inhibited. In contrast, when the mask interrupts processing at 300 ms the representation is well established so that it needs to be inhibited for the probe to be processed efficiently.

SU36
Color-based estimates of stimulus similarity predict perceptual similarity of image pairs to monkeys Sarah R Allred (saralred@u.washington.edu), Jennifer Y Skiver Thompson, Bharathi Jagadeesh; University of Washington, USA—Introduction: Studies of object perception are hampered by the difficulty of mathematically describing the similarity of realistic images. Recently, color based metrics have been developed to search for similar images in large databases of realistic images. Such metrics have been shown to predict human subjects’ similarity rankings of realistic images, because the color of realistic images often depends on their content. Can color similarity metrics also predict perceptual similarity of realistic images to nonhuman primates?

Methods: The color similarity metric used was the Earth Mover Distance (EMD). Y. Rubner, Stanford Vision Lab). We measured performance in a delayed-match-to-sample task using pairs of images. In each trial, the sample was presented for 16-512 ms, followed by a mask. After a delay period, two target images appeared, and the monkey was rewarded for making a saccade to the image that matched the sample. Image pairs were chosen so that the EMD between them spanned the range in our database. For each pair, we estimated the threshold viewing duration as the presentation time required to reach 75% accuracy. If the images are perceptually similar, a longer presentation time should be required to complete the task correctly.

Results & Conclusions: Performance is correlated with EMD. Low EMD pairs have higher threshold duration (take longer to discriminate) than high EMD pairs. In addition, low EMD pairs incurred performance improvements during daily training sessions, while high EMD pairs did not. This finding is consistent with previous findings that experience improves performance in perceptually difficult tasks. A recent study has also shown that EMD can explain some of the response properties of single neurons in IT cortex, an area of the macaque brain critical for object perception (Allred et al, SfN, 2002). Taken together, these results indicate that a color similarity metric (EMD) may predict perceptual similarity of images to nonhuman primates.

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SU37
Does a consistent rotational representation facilitate responding to test probes further along a rotational sequence? Michael D. Anes (Manes@albion.edu), Sarah J. Storbeck; Albion College, Albion, MI, USA—In two experiments, we investigated the processing of rotational motion in a same/different task. In Experiment 1, participants viewed eight 33 ms frames (20º apart) or four 67 ms frames (40º apart) of a rotating (right-to-left and left-to-right) Greeble (courtesy Michael Tarr), followed by a pre- and post-masked, briefly presented (167 ms) test probe. Test probes were presented in differing orientations; in an orientation prior to the first exposed rotation frame, at all four exposed 40º rotations, and in an orientation beyond the exposed rotational sequence. We found that same judgment accuracy of probes beyond the exposed rotational sequence was less accurate than for probes in the final exposed position in the 40º rotation condition [consistent with Vuong and Tarr (Vision Sciences 2002)] but not in the “smoother” 20º rotation condition. In Experiment 2, we varied rotation duration; participants viewed four 67 ms frames (40º apart) or four 133 ms frames (40º apart) of a rotating Greeble followed by a pre- and post-masked, briefly presented (100 ms) test probe. We found that same judgment accuracy decreased for test probes beyond the exposed rotational sequence, and that accuracy was lower at the first exposed position than at later exposed positions in the sequence. A consistent rotational representation facilitates responding to test probes further along in the rotational sequence (Experiment 2), but the effect is quite specific; accuracy for test probes beyond the exposed rotational sequence were not facilitated (Experiments 1 and 2). Further research using test probes at interpolated positions will be discussed.

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SU38
Characterizing object-specific neural correlates of perception Javid Sadr (sadr@mit.edu), Pawan Sinha; Department of Brain and Cognitive Sciences, Massachusetts Institute of Technology, USA—In vision and neuroscience there is great interest in the mechanisms that underlie object perception, and a common approach to their study is the characterization of neural structures that appear more responsive to certain object images than others. However, it may be difficult to dissociate neural activity driven by low-level features of these images from neural activity that drives the higher-level percepts of the objects depicted. We explore an alternative approach, simultaneously measuring changes in perceptual and neural activity as visual stimuli undergo systematic transformations (e.g., as recognizable objects first evolve from, then dissolve into, randomness) while important low-level image properties are held constant. Subjects' object percepts arise quite sharply in such cases and thereafter exhibit a marked hysteresis (i.e., percepts persist at levels of image degradation far worse than those which support their original formation).

These properties, along with the ability to objectively verify subjects' conscious percepts, offer distinct advantages when this technique is used in conjunction with neuroimaging (e.g., magnetoencephalography) to isolate neural activity that corresponds specifically with the object percept -- such activity should demonstrate a similar time course, one with a relatively sharp onset, despite potentially gradual image evolution, and a delayed offset consistent with the perceptual hysteresis. Using this approach, we can indeed distinguish, spatially and temporally, certain MEG signal components that appear to demonstrate such characteristics, whether the visual stimuli depict faces or other objects. Experiments such as these may help further our understanding of the neural mechanisms that underlie a number of important perceptual phenomena, from those associated with the priming and formation of an object percept to those involved in its enhancement and maintenance, as seen, for example, in perceptual learning and hysteresis.

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SU39
The effect of asymmetry and complexity on the sensitivity of inferior temporal neurons to nonaccidental differences
Greet Kayaert1 (greet.kayaert@med.kuleuven.ac.be), Rafin Vogels1, Irving Biederman2
1Dept. of Psychology, Stanford University, Stanford, CA—When tested with simple, symmetric, geon-like stimuli, IT cells are more sensitive to differences in nonaccidental properties (NAPs) than metric properties (MPs). However, the images of objects, or object parts, are not necessarily simple or symmetrical. Would this sensitivity to NAPs be manifested with complex, irregular shapes? 119 neurons (2 monkeys) were tested with 4 groups of stimuli: a) simple, symmetric, geon-like stimuli differing in NAPs; b) complex, irregular curved Fourier-descriptor-based stimuli; c) simple, asymmetric, curved Fourier-descriptor-based stimuli, and; d) stimuli made by connecting the convexities and the concavities of the latter with straight lines. This resulted in c) and d) differing in a NAP, straight vs. curved, while retaining the same general shape. Stimulus differences between pairs within each group and the pairs composed of stimuli from c) and d) were calibrated. Changing a NAP resulted in a large neuronal modulation which was equivalent within group a) and between groups c) vs. d) and significantly greater than the modulation produced by shape changes within b), c), and d). The equivalence in modulation magnitude within a) and between c) and d) suggests that NAP sensitivity does not depend on symmetry. The low modulation within b), c), and d) suggests that IT cells are more sensitive to NAP than to other shape differences. We extended this study by adding stimulus sets that differed in NAPs but were of progressively greater complexity. This was done by increasing the frequency of the Fourier descriptors in c) and d) above. 31 neurons (2 monkeys) showed a significant reduction in NAP sensitivity at higher complexity levels. The more complex shapes approached texture-like masses in appearance (such as the silhouette of a bush), with short and highly variable contours. Overall, the sensitivity of IT neurons to NAP differences is maintained for moderately complex, asymmetrical shapes but is reduced when the complexity of the shape-outlines renders them texture-like.

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SU40
The fusiform face area is significantly correlated with successful detection and identification of faces but not objects
Kalanit Grill-Spector1 (kalanit@psych.stanford.edu), Nicholas A Kohn2, Nancy G Kanwisher3
1Dept. of Psychology, Stanford University, Stanford, CA, 2Department of Brain and Cognitive Sciences, MIT, Cambridge, MA—The fusiform face area (FFA) responds more strongly when people view faces than objects. Here we asked whether the FFA is involved in face-specific processing or subordinate processing of all objects, since it is often assumed that faces are usually identified at the subordinate level (e.g., Tom Cruise) but objects at the basic level (e.g., flower). Subjects were scanned while viewing pictures from one of 6 categories that were presented briefly and then masked. There were 3 types of trials: (1) subordinate target trials (e.g., roses) (2) other objects from the same basic level (e.g., non target flowers) (3) scrambled pictures. Numerous exemplars of each type of target were used in the experiment. Subjects were instructed to respond for each trial whether it was: (1) the subordinate-level target or (2) an object that was not the target or (3) not an object. Trials in which the target subordinate category was presented were sorted according to subjects’ responses (identified, detected but not identified, or not detected). We reasoned that if the FFA is involved in subordinate identification its activation should be higher in trials in which objects were successfully identified compared to trials in which they were not identified. For faces, the FFA response was highest for identified targets, middling for detected but not identified targets and lowest for non-detected targets, implicating this region both in the detection and identification of faces. Activation was not significantly higher for successful identification of electric guitars, roses, barns or jeeps for individual subjects. However, nearby ventral-occipito temporal regions within the FFA was correlated with correct identification, and these data argue against the idea that the FFA is a module for subordinate identification, since FFA activation was correlated with both face detection and identification, and was not strongly correlated with successful identification of other categories.

SU41
Human visual processing of orientation and the slope of the amplitude spectra of natural stimuli
Bruce C Hansen (bchans01@louisville.edu), Edward A Essock; University of Louisville USA—The human visual system has been shown to be optimized to process content with the 1/f slope of the amplitude spectra of natural scenes. However, work on this topic considers processing in the context of the averaged amplitude spectrum (ignoring orientation). Recently, we have shown that visual processing of orientation in 1/f broadband content exhibits an anisotropy quite different from the traditional oblique effect obtained with simple stimuli (instead showing a “horizontal effect”). Here we examine this effect utilizing sets of natural scene imagery possessing a broad range of amplitude spectrum slopes to determine if the horizontal effect is dependent upon the slope of the amplitude spectrum of natural scenes. Sets of images containing approximately equal content (amplitude) at all orientations were gathered and filtered to be isotropic with each set containing images with amplitude spectra slopes within a narrow range. Test stimuli were generated by making an increment in the amplitude of the images at one of four 45deg. bands of orientation (0, 45, 90, or 135deg.). Ability to detect the oriented increments was measured with a single-interval Yes/No task. A control condition was also employed in which the phase spectra of the images were scrambled. Irrespective of image slope, performance for detecting oriented increments was consistently poor at horizontal and best at the obliques. The magnitude of this effect was strongest when the slope of the amplitude spectrum was most similar to that of natural scenes. We have proposed that this horizontal effect evolved to relatively decrease the saliency of horizontal content in natural scenes to emphasize other less-dominant content. The current results show that sensitivity for horizontal was always poor, and that the extent to which sensitivity at the other orientations was ‘emphasized’ depended on the slope of the amplitude spectrum.

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SU42
Seeing the content before the horizon: Visual processing of orientation in natural scenes
Edward A Essock (essock@louisville.edu), Bruce C Hansen; University of Louisville USA—Recently we have shown that sensitivity for detecting oriented content in visual noise or natural scenes is worst at horizontal and best at the obliques (i.e. a “horizontal effect”) and that this effect remains even with natural scene stimuli containing a natural bias in content at a given orientation. We suggested that this effect evolved to discount the dominant horizontal content typically present in natural scenes in order to ‘emphasize’ content at other orientations. Here we investigate this idea with natural scene imagery containing different amounts of horizontal content bias to determine if sensitivity for detecting amplitude increments at off-horizontal orientations depends on the relative predominance of horizontal content in a given image. Sets of natural scene imagery were compiled; each set contained images with a different predominance of horizontal content relative to the other image sets. Additional control sets contained images biased at other orientations. All images were made to have identical isotropic amplitude spectra, differing only in content carried by each image’s phase spectrum. Test stimuli were generated by making increments at one of four orientations (0, 45, 90, or 135deg.). Ability to detect the oriented increments was measured with a single-interval Yes/No task. Consistent with our
previous work, performance for detecting increments was poor for horizonal relative to the other orientations despite the content bias in the image. A significant positive relationship between the amount of horizontal content and sensitivity to increments at the other orientations was observed. The horizontal effect may have evolved in accordance with the typical bias in oriented content in natural scenes, acting to emphasize less-dominant content as the current results show sensitivity for detecting off-horizontal amplitude increments is related to the relative amount of horizontal content present in the natural scene stimuli.

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SU43
Vision and the perception of music have a common denominator
Dale Purves (purves@neuro.duke.edu), Catherine Q. Howe, David A. Schwartz; Dept. of Neurobiology, Duke University Medical Center, Durham NC, USA—All human listeners perceive tones in the presence of regularly repeating patterns of sound pressure fluctuation over a wide range of frequencies. In music, the salient and widely-shared features of this aspect of auditory perception are: 1) an iterated partitioning of the continuous dimension of pitch into octave intervals bounded by tones that are musically similar; 2) the division of each octave into the 12 intervals of the chromatic scale; 3) the preference in musical composition and performance for particular subsets of these 12 intervals (e.g., the intervals of the pentatonic or diatonic scales); and 4) the similar consonance ordering of chromatic scale tone combinations produced by listeners of all ages, places, and periods. Despite intense interest in these perceptual phenomena over several millennia, they have no generally accepted explanation in physical, psychological or biological terms. A rapidly growing body of work in vision has shown that the fundamental qualities that characterize visual percepts (lightness/brightness, color, geometry and motion) accord with the probability distributions of the possible sources of visual stimuli. Since the uncertain provenance of sensory stimuli is general, this empirical solution to the inverse optics problem might be extended to other sensory modalities. We therefore examined the hypothesis that musical percepts also arise from the statistical relationship between sound stimuli and their natural sources. An analysis of recorded speech shows that the probability distribution of amplitude/frequency combinations in human utterances, the principal source of periodic stimuli in the human acoustical environment, predicts octaves, scales and consonance. These observations suggest that the auditory system, like the visual system, generates percepts determined by the probability distributions that link inherently ambiguous stimuli and their sources.

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SU44
The importance of phase information for recognizing natural images
Karl R Gegenfurtner1 (gegenfurtner@uni-giessen.de), Doris I Braun2, Felix A Wichmann3; 1Psychology Dept, Giessen University, Germany, 2Max-Planck-Institute for biological Cybernetics, Tübingen, Germany – Fourier phase plays an important role in determining image structure. For example, when the phase spectrum of an image showing a flower is swapped with the phase spectrum of an image showing a tank, then we will usually perceive a tank in the resulting image, even though the amplitude spectrum is still that of the flower. Also, when the phases of an image are randomly swapped across frequencies, the resulting image becomes impossible to recognize. Our goal was to evaluate the effect of phase manipulations in a more quantitative manner. On each trial subjects viewed two images of natural scenes. The subject had to indicate which of the two images contained an animal. The spectra of the images were manipulated by adding random phase noise at each frequency. The phase noise was uniformly distributed in the interval [-phi,phi], where phi was varied between 0 degree and 180 degrees. Image pairs were displayed for 100 msec. Subjects were remarkably resistant to the addition of phase noise. Even with [-120,120] degree noise, subjects still were at a level of 75% correct. The introduction of phase noise leads to a reduction of image contrast. Subjects were slightly better than a simple prediction based on this contrast reduction. However, when contrast response functions were measured in the same experimental paradigm, we found that performance in the phase noise experiment was significantly lower than that predicted by the corresponding contrast reduction. Therefore, it is not only the effect of phase on local image features, but also phase information per se that determines our percept of natural images.

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SU45
Response of first- and second-order filters to natural images
Aaron P Johnson (aaron.johnson1@mcmill.ca), Curtis L Baker, Jr; McGill Vision Research Unit, Dept. of Ophthalmology, Montreal, Canada – Previous analyses of natural image statistics have mainly dealt with their Fourier power spectra. Here we explore image statistics by examining responses to biologically motivated filters which are spatially localized, and respond to first-order (luminance-defined), and second-order (contrast- or texture-defined) characteristics. We begin by comparing the distribution of natural image responses across filter parameters for first and second order information, and whether the two kinds of response are correlated. First-order filtering was implemented as convolutions with oriented Gabor functions, with gains scaled to give equal amplitude response across spatial frequency for random fractal images (Field & Brady, Vision Res. 37:3367-3383). Second-order operators were a pair of such Gabor’s in a filter-rectify-filter arrangement. Responses were obtained for many combinations of parameters (spatial frequency: 2-64 cycles/image, orientation: 0-180 deg, phase: sine and cosine) in early and late filters. In agreement with previous spectral analyses, the first-order results show approximately equal responses at all spatial frequencies, but a pronounced orientational anisotropy in favor of vertical and horizontal, which was particularly evident at high spatial frequencies. Phase had no significant effect. Second-order responses also exhibited nearly equal responses across spatial frequencies; however, they show only a small bias towards the horizontal orientation, probably due to foreshortening. Magnitudes of first- and second-order responses were usually uncorrelated; however for particular combinations of filter parameters, they were very highly correlated for natural images but not for random fractals. These results indicate that second-order information in natural scenes shows the same self-similarity previously described for first-order statistics, and that the two kinds of information are correlated in a highly structured manner.

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http://ego.psych.mcgill.ca/falls/nov/Aaron/ess03.html

SU46
Visual input statistics of natural time-varying images for different viewers, scenes, spectra and illuminations
Kelly M Stringer (kelly@dove.ccs.fau.edu), Daniel W Dong; Center for Complex Systems and Brain Sciences, Florida Atlantic University, Boca Raton, FL, USA – Purpose: It has been proven that many visual processing characteristics are related to the statistics of natural inputs to the visual systems. But it is not clear if and how such statistics will change due to different eye movement patterns by different viewers for different scenes, for different illuminations and for scenes in color or in black and white.

Methods: We record gaze positions during free-viewing video segments of natural activities in four viewing conditions: low, medium, high illuminations in black and white, and color. We use the recorded eye positions to derive the gaze-centered time-varying images from the original video. The light intensities of the images are calibrated separately for the four conditions. We analyze the statistical properties of the resulting images, in particular, the temporal correlations of the input signals at a given retinal location.
Results: There are significant temporal correlations during fixations and smooth pursuits, but the macro saccades effectively remove the temporal correlation between two signals before and after a saccade. However, the magnitudes of temporal correlations during fixations and smooth pursuits depend on the visual scenes. For different viewers and for sessions of the four viewing conditions, the temporal correlation remains the same for any given scene, although different viewers/sessions have different gaze positions and different saccadic eye movement timings during their natural-viewing of the same scene.

Conclusion: Visual input statistics of natural images are independent of viewers, spectra and illuminations, but dependent on scenes and saccadic timings. This enables a common mechanism across viewers at different viewing conditions to improve the efficiency of visual information coding through temporal decorrelation of the input signal. Such a mechanism can be dynamically changed according to saccadic timing and adapted to different scenes to ensure high coding efficiency.

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http://dove.ccs.fau.edu/abstracts/03VSS-1.html

SU49

Visual analysis of movements generated by biomimetic motor-production criteria and displayed via computer animations and humanoid robots Joshua G Hale1 (halej@dcs.gla.ac.uk), Frank E Pollick2

1Department of Computer Science, University of Glasgow, UK, 2Department of Psychology, University of Glasgow, UK—For even a simple point-to-point movement of the hand there are an infinite number of possible ways the arm can move to obtain the final hand position. One solution used to obtain a unique movement plan is to select the movement which is in some sense optimal. Many optimization criteria have been proposed by computational theorists in human motor control, but the particular form of each criterion remains controversial. We examined this issue from the standpoint of visual perception by producing simulations of 14 different optimization criteria (e.g. minimum torque change, minimum jerk, minimum angular jerk) and presenting these simulations to observers. As an additional control condition we obtained 3D human movement data from the same motions depicted by the simulations. The set of movements were chosen to demonstrate the variety of kinematic features found in natural human movement such as bell-shaped velocity profiles, gently curved paths and corrective submovements. Both the biomimetic simulations and the human movement recordings were displayed as a computer animation on a human form as well as a movie clip of a humanoid robot. In two separate experiments 10 participants either rated the naturalness of the movement or the similarity of a pair of movements. The results of the naturalness judgements revealed complex interactions between the type of movement and the mode of presentation (humanoid robot or human animation). The similarity data was examined with MDS which revealed clusters of different optimization criteria, however natural human movement didn't appear to belong to any of these clusters. These results will be discussed in terms of the kinematic features of natural and synthetic movement that best explain this complex pattern of results.

SU50

The involvement of parietal and prefrontal areas in human imitation revealed by fMRI adaptation Vaia Lestou1 (vaia@psy.gla.ac.uk), Frank E Pollick2, Heinrich H Büllhoff2, Zoe Kourtz2, 2University of Glasgow, Scotland, UK, 3Max-Planck Institute, Tübingen, Germany—The perception and imitation of human movement requires that the brain integrates information about the goal of the movement and the kinematics that define it. Neuroimaging and neurophysiological studies implicate the ventral premotor cortex (BA6/44) in the processing of action goals while the role of the parietal cortex is not entirely clear. The aim of this series of experiments was to disentangle the role of both prefrontal and parietal areas in the imitation of human movement. To this end we used human arm movements presented as point light displays. The movements were manipulated parametrically to produce morphs that differed from each other in their kinematics. Three different action types—throwing, lifting and knocking movements— and their morphs were utilised for this study. We used a rapid event related fMRI adaptation paradigm, in which fMRI responses to two sequentially repeated stimuli are lower than for different stimuli. We begun by functionally localising the brain areas involved in the imitation of human movement. We then looked at the MR signal under the different experimental conditions during the event related scans. In a
first experiment we investigated the basic adaptation effect; identical movements both in their action goals and kinematics were tested against movements that were different in both their goals and kinematics. Preliminary evidence suggests that prefrontal and parietal areas show adaptation under those different experimental conditions. Future experiments will test whether the parietal areas respond to different kinematics even when the goal of the movement is the same, by using the kinematics morphs.

Acknowledgment: This work is supported by the Max-Planck Society, and a GIAR, Sigma-Xi to Vaia Lestou

SU51
The effect of temporal incoherence between mask and point light walker on the detection of biological motion

ERIC HIRIS (ehiris@smcm.edu), DEVON HUMPHREY, ST. MARY’S COLLEGE OF MARYLAND, USA – Purpose: A point light walker can be effectively masked by the motion of spatially randomized dots that have the same motion components as the walker. However, little is known about the temporal fidelity with which the visual system processes biological motion. We sought to address this issue by determining the effect of temporal incoherence between the point light walker and the masking dots. Method: Participants detected point light walkers embedded in spatially randomized masks. The motion of the mask dots was either synchronized with the point light walker or nonsynchronized by varying amounts of the step-cycle. The task was performed for upright and inverted point light walkers. Results: Detectability (as measured by d’) followed an inverted double-U function. Specifically, the most effective masks were those synchronized with the point light walker and those out of synchrony by half of a step-cycle. The least effective masks were those out of synchrony by one-quarter or three-quarters of a step-cycle. Inverted walkers were more difficult to detect, but had the same basic inverted double-U function. Additional experiments showed that masks begin to lose their effectiveness when out of synchrony by more than 1/25 of a step-cycle. This was true for naïve and non-naïve participants and for upright and inverted walkers. Conclusions: Overall, temporal incoherence between mask and point light walker has a large effect on the detectability of a point light walker within a mask. The data suggest the swing of arms and legs are critical in determining the effectiveness of the mask, although the mask and point light walker can be slightly out of synchrony before detectability of the walker increases.

SU52
Obtaining features for the recognition of human movement style

PHILIP MCALER (phil@psy.gla.ac.uk), CALI FIDIOPIASTIS, VIC BRADEN, FRANK E POLLICK; Department of Psychology, University of Glasgow, UK, Institute of Simulation and Training, University of Central Florida, USA, Vic Braden Tennis College, USA – Human movement comes in many different styles and this research investigates features that can explain our ability to distinguish between styles. In particular, we studied how training to recognize the style of one individual can influence the ability to recognize movements performed by another individual. Tennis serves were used since they provide complex whole-body motions with the different styles of flat, slice and topspin. The observers used were not tennis players and pretest confirmed that they performed around chance at the identification before training. The service motions were presented using techniques of computer graphics that transformed 3D motion capture recordings of two professional tennis players into computer animations played on a common body model. Thus, removing all pictorial cues to identity. Two groups of 12 observers were trained on one or the other service’s motions. After performing 6 training blocks on one server, performance at correctly identifying service type increased to approximately 60%. Observers were then required to identify the service style of the other server. What resulted was a consistent pattern of confusions for identification of the previously unseen server’s movements. The pattern being those observers trained on Server A could not recognize the topspin serve of Server B and those trained on Server B could not recognize the slice serve of Server A. We then explored what information in the training phase could have caused this pattern of confusions. These explorations revealed that a linear discriminant classifier based on the first two principal components of the movement set showed a similar pattern of confusions. These data are consistent with the interpretation that a low-dimensional representation of the movement serves as the features used for recognition.

SU53
Does density explain how moving dots mask biological motion? 

ERIC HITTLE (VVHUt10338@aol.com), ERIC HIRIS; St. Mary’s College of Maryland – Purpose: Determining how moving dots mask the motion of a point light walker can elucidate what factors are important in perceiving biological motion. We sought to determine whether absolute or relative mask density is important by varying the size of the point light walker and the relative density of the masking dots. Method: Twenty-four naïve participants (twelve in each experiment) viewed artificially created point light walker sequences with masks for approximately one second. In the first experiment, the number of dots in the mask remained constant, while the size of the point light walker varied (100, 200, or 400%). In the second experiment, the number of dots in the mask varied, such that the density of the dots within the immediate walker area was constant. The same point light walker sizes were used. In both experiments, each participant completed 60 trials for each walker size and the total display area remained constant regardless of the size of the walker. Results: In the first experiment, the walker was more difficult to detect as the size of the walker increased (as measured by d’). In fact, the largest walkers were undetectable by our participants. In the second experiment, the walker still became more difficult to detect as its size increased, but the increase in difficulty was much smaller (the largest walker was detectable). Conclusions: The density of the mask does play a role in masking biological motion, but does not explain all the variability in detectability. The size of the walker also matters, with smaller walkers easier to detect than larger walkers. The important factor may be that the visual system must integrate over large distances between walker dots as the size of the walker increases.

SU54
Discriminating the biological motion of animals

BENJAMIN S THOMPSON (benjamin.thompson@sussex.ac.uk), GEORGE MATHER; UNIVERSITY OF SUSSEX, ENGLAND – Research into biological motion perception has revealed that the human visual system is sensitive to the movement patterns created by both humans and non-human animals when locomoting. In order to further assess the ability of the human visual system to detect the biological motion of animals with different locomotory patterns, observers were required to discriminate between point light displays depicting an animal in motion and point light displays containing dots moving in ways constrained by the properties present in the biological motion displays, but containing no biological motion themselves. Initial results indicated that naïve subjects could accurately discriminate between the displays containing biological motion and those containing motion of a non-biological nature. In order to assess this effect further, a second experiment was carried out to investigate the ability of naïve observers to discriminate between biological and non-biological point light displays as a function of random punctate visual interference density and b) a function of stimulus duration. To allow further investigation into how biological motion information concerning animals might be utilised by the visual system in naturalistic situations, subjects were tested for simple animal phobias in order to assess whether those subjects with a high fear of certain target animals (snakes and spiders, chosen for the sake of general prevalence of fear) would be able to distinguish the target animal from non-biological trials in the presence of a) greater density of noise and b) shorter stimulus duration. Results indicated that noise density had a significant effect on discrimination performance for both groups even at the lowest level.
SU55
Greater immaturity in sensitivity to second-order gratings than to first-order gratings during infancy Terri L. Lewis1 (LewisTL@mcmaster.ca), Vikas C. Bhagirath1, Dave Ellenberg2, Daphne Maurer2; 1Department of Psychology, McMaster University, Hamilton, Canada, 2McGill Vision Research, McGill University, Montreal, Canada – PURPOSE. To study the development of sensitivity to first- and second-order gratings by measuring thresholds for the detection of motion in 3-month-olds, 5-year-olds, and adults. METHODS. Subjects (n = 24/age) saw two 15 x 15 degree vertical 0.5 c/deg sine-wave gratings that were separated horizontally by a 5 gap. The gratings were added to (first-order condition) or multiplied with (second-order condition) binary noise. Randomly, on each trial one of the gratings was stationary and the other moved outward at 6 deg/sec. Amplitude modulation was varied over trials. For babies, we used the method-of-constant stimuli and data from 16 trials per baby to calculate two group thresholds, one for first-order gratings and one for second-order gratings. On each trial, a trained tester who was unaware of the side of motion decided whether the moving grating was on the left or right based on any reliable cues provided by a baby (direction of first look, longest look, etc.). The group thresholds from babies were compared to the mean individual thresholds from 5-year-olds and adults who, on each trial, indicated which side had the moving stripes. RESULTS. Thresholds for infants were far more immature for second-order gratings (2.5 times worse than adults) than for first-order gratings (1.09 times worse than adults). However, by 5 years of age, thresholds were close to adult levels (1.03 and 1.09 times worse than adults for first-order and second-order gratings, respectively) and were no more immature for second-order than for first-order gratings (p > 0.05). CONCLUSIONS. During early infancy, the neural mechanisms that detect second-order gratings are especially immature compared to those that detect first-order gratings. By 5 years of age, at least under the present testing conditions, mechanisms detecting second-order gratings are almost adult-like and are no less mature than those detecting first-order gratings.

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SU56
Interaction between first- and second-order motion signals at the local motion scale Mark Edwards1 (mark.edwards@anu.edu.au), Shin’ya Nishida2, 1School of Psychology, Australian National University, Canberra, Australia, 2NTT Communication Science Laboratories, NTT Corporation, Atsugi, Japan – Motion perception appears to be mediated by, at least, two systems: a first-order and a second-order system. These two systems appear to be independent at the local-motion extraction and global-motion pooling stages. However interaction, in the form of inhibitory links between opponent directions of motion, could exist at the local-motion scale. Such an interaction would account for the failure to perceive coherent motion in a standard global-motion stimulus (random dot pattern in which signal dots move in the same direction and noise dots in random directions) when the signal dots reverse their luminance contrast (go from light to dark) as they move. Second-order motion units would signal motion in the displacement direction of the signal dots and the first-order motion units would signal motion in the opposite direction (reverse-phi motion). If the first- and second-order motion responses for each signal dot were of equal strength, then opponent inhibition would result in no net motion response to the signal dots. The possibility of opponent inhibition at the local-motion scale was investigated by manipulating the contrast-reversing global-motion stimulus to reduce the second-order response relative to the first-order. This was achieved by: decreasing dot contrast; increasing stimulus eccentricity; and increasing dot speed. These manipulations resulted in an increase in the perception of (first-order mediated) reverse-phi motion. We conclude that opponent inhibition exists between first-order and second-order units at the local-motion scale.

SU57
Discriminating the direction of randomly positioned contrast-defined motion Harriet A Allen1 (harriet.allen@mcgill.ca), Robert F Hess2, Tim Ledgeway3; 1McGill Vision Research, Canada, 2University of Nottingham, UK – We investigated whether positional uncertainty affected observers’ ability to discriminate the direction of luminance-defined and contrast-defined motion. If the mechanisms that detect contrast-defined motion can’t be simultaneously monitored, not knowing the position of contrast-defined motion will severely affect performance.

Random dot kinematograms were presented on a circular field (radius10 deg) of low contrast 2D binary noise. Dots were either brighter (luminance-defined) or higher contrast (contrast-defined) than the noise and moved at 3 deg/sec. In a circular target area (radius 1deg) the dots moved either up or down. The remaining dots, surrounding the target area, moved randomly. The target area was centered 2 deg from fixation and there were no dot-density cues to its location. Observers discriminated the direction of motion in the target area (2AFC method) when they knew its position and when it was randomly in 1 of 4 positions. Experiment 1 measured the modulation depth (contrast-defined patterns) or contrast (luminance-defined patterns) required to discriminate motion direction. Experiment 2 measured the number of coherently moving dots required to perform the same task. Both experiments were carried out with stimulus durations of 250ms and 100ms

Thresholds for the motion in randomly positioned areas ranged from 1.1 to 3.4 times the thresholds for the motion in the known position. In experiment 1 the increase in threshold was slightly larger at the shorter duration. For each condition and observer the size of the effect was almost identical for luminance-defined and contrast-defined motion. Mechanisms for contrast-defined motion are not differentially affected in their ability to process motion signals of uncertain position compared with those for luminance-defined motion. Previous findings showing poor performance with multiple patches of contrast-defined motion must reflect some other deficiency in the mechanisms for contrast-defined motion.

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SU58
Effects of jitter and displacement size on performance in random dot kinematograms Nadeemullah Syed (syed_1999@hotmail.com), Srinant P Tripathy; Dept of Optometry, University of Bradford, Richmond Rd., Bradford, UK – Aim: Correspondence noise is a major factor limiting threshold coherence for detecting motion in Random-dot Kinematograms (RDKs) (Barlow and Tripathy, 1997, Journal of Neuroscience, 17, 7954-66). Computer modelling suggests that correspondence noise could also limit Dmax (Tripathy & Barlow, 2001, Perception (Suppl.), 30, p.32). This model assumes that the radii of the catchment area of the Reichardt-type local detectors scale directly with the displacement that the detectors are tuned to detect. We directly test this assumption psychophysically: if detectors tuned to larger displacements are associated with larger catchment areas, then they should be less susceptible to positional jitter of the dots.

Methods: We generated 2-frame RDKs (15 x10, 3000 dots) with different levels of coherence and with positional jitter. On each trial the stimulus moved either right or left and the observer reported the direction of motion. For the different dot-displacements used (10-50 arcmin), the coherence levels were adjusted to equate performance without saturation (80-90% correct responses) for the unjittered stimuli. To generate jitter, each dot was displaced to lie on the circumference of an imaginary circle centred on the dot’s unjittered position with radius proportional to the amount of jitter. Within a block the average dot-displacement was kept fixed and the ratio: r =radius of jitter / average displacement size was varied to obtain a complete psychophysical function (r=0-1.5). Across blocks the average dot-displacement was varied.

Results: Consistent with our predictions, the different psychometric functions were similar, suggesting that catchment regions of local detectors scale with the size of the displacement they are tuned to detect.
and that correspondence noise could indeed limit threshold coherence and \( \Delta_{\text{max}} \).

**SU69**

The perception of apparent motion between two element locations depends on the multiplicative combination of background-relative luminance changes \( \text{Howard S Hock}^1 \) (hockhs@fau.edu), \( \text{Lee A Gilroy}^2 \); \( \text{1Department of Psychology, Florida Atlantic University, USA, 2Psychology Department, Vanderbilt University, USA} \) – Hock, Gilroy & Harnett (2002) have shown that counter-changing luminance provides the informational basis for the perception of luminance defined, single-element apparent motion (AM). That is, irrespective of the presence of Fourier-based, 1st-order motion energy, AM is perceived only when the luminance at one element location changes toward the luminance of the background and the luminance at a second element location changes away from the luminance of its background. The purpose of the experiments reported here was to determine whether the effects of the oppositional luminance changes at each element location are combined multiplicatively, as in various forms of Reichardt’s correlational model, or additively, as in Adelson & Bergen’s motion energy model. The experiments are based on the generalized version of back-and-forth AM between two locations; elements are simultaneously visible at both locations and their luminance values change in opposite background-relative directions. Whether or not motion is perceived depends on the magnitude of the background-relative luminance change (BRLC) (Hock, Kogan & Espinosa, 1997). In this study, the BRLC value at each element location was varied independently; e.g., it might be larger for one element than the other during some trials, similar in magnitude for both elements during other trials, and so on. The likelihood of motion being perceived was best predicted by the product of the BRLC values, much less so by their sum. This evidence for perception of AM depending on the multiplicative combination of activation changes at nearby element locations is consistent with the Reichardt correlational formulation, but the perception of motion when luminance simultaneously changes at both locations (in opposite background-relative directions) is inconsistent with the "delay-and-multiply" principle that defines standard- and elaborated-Reichardt models.

**SU60**

Contrast interactions in two-frame motion discrimination imply a binocular site of contrast gain control for motion \( \text{Avesh Raghu nandan (aran ghu nadan@uh.edu), Frank E Visco, Scott B Stevenson; University Of Houston, College Of Optometry, USA} \) – Background: Previous studies have shown that two-frame motion detection thresholds are elevated if one frame’s contrast is raised, despite the increase in average contrast. This "contrast paradox" phenomenon implies the existence of a gain control mechanism that operates in conjunction with the detection of motion. In this study, we used dichoptic presentation to investigate whether the gain control mechanism in motion detection is essentially monococular or binocular.

Methods: Stimuli were vertical 1 cpd Gabor patches presented as a two-frame movie. Thresholds for left-right motion discrimination were measured with a single interval, forced choice, method of constant stimuli. Each Gabor had a contrast of either 0.1 or 0.4, producing two matched contrast motion sequences (low-to-low and high-to-high) and two mixed contrast sequences (low-to-high and high-to-low). The mixed stimuli were presented in two ways. In the "binocular" condition, both eyes saw the same sequence (low-to-high or high-to-low). In the "dichoptic" condition, each eye saw the opposite order. Thus, if the left eye saw low-to-high, the right eye saw high-to-low, and vice versa.

Results: Matched contrast sequences showed an overall threshold improvement from 0.1 to 0.4 contrast. In agreement with previous reports, mixed contrast sequences were dramatically elevated in the "binocular" condition, where both eyes saw the same mixed sequence. In the "dichoptic" condition, however, thresholds were consistent with the average contrast of the two frames. The "contrast paradox" did not occur. Conclusions: The lack of a contrast paradox in the "dichoptic" condition indicates that the gain control accompanying motion energy extraction includes signals from both eyes. That is, it is at or beyond the site of binocular combination. Preliminary results from interocular motion experiments suggest that an independent, binocular gain control mechanism operates as well.

**Acknowledgment:** EY12886 TO SB STEVENSON

**SU61**

Do motion onsets affect motion adaptation? \( \text{Sven P Heinrich (sven.heinrich@uni-freiburg.de), Anja M Schilling, Michael Bach; University of Freiburg, Dept. of Ophthalmology, Freiburg, Germany} \) – Visual motion processing is strongly susceptible to adaptation. Adaptation strength increases with duration, while little is known about the adapting effect of motion onsets. Animal studies have shown that a number of MT cells produce a transient response to onsets rather than a sustained response [1] and that onset and offset latencies can differ [2]. Using visual evoked potentials (VEPs) and psychophysical measures, we compared 3 different onset rates to assess the effect of motion onsets on motion adaptation in humans. Methods: Intermittent motion was used for adaptation. The duty-cycle (= motion duration vs. total duration) was kept constant at 33% while the rate of motion onsets was either 1.4, 2.8, or 5.6 per second. Stationary stimuli and continuous motion were used as reference conditions. The motion aftereffect was measured psychophysically in 11 subjects with a nulling technique based on motion coherence. VEPs were recorded from 7 subjects. Results: For intermittent adaptation, on average 26% coherent motion was required to cancel the motion aftereffect in the psychophysical experiment. There was no appreciable dependence on the motion onset rate. 7% (indicating a direction bias) and 29% coherence were required for stationary stimuli and continuous motion, respectively. VEP amplitudes were on average reduced by 70% after intermittent adaptation, relative to stationary adaptation. No sizable difference was found between the three motion onset rates. Adaptation with continuous motion resulted in a 95% decrease in VEP amplitude. Conclusion: Both VEPs and psychophysical results suggest that motion adaptation is independent of the number of motion onsets.


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**SU62**

Phantom and concrete motion aftereffects have different temporal tuning \( \text{Nicholas S Price (nprice@rsbs.anu.edu.au), Michael R Ibbotson; Visual Sciences, RSBS, Australian National University, Australia} \) – Using motion aftereffects (MAE), we quantified the adaptation produced by an expanding concentric ring stimulus. The rings had sinusoidal luminance modulations and were presented in a 5 -diameter aperture against a mean grey background. Two adapting stimuli were used: a concrete stimulus (complete circle) and a phantom stimulus (complete circle minus two horizontal grey 40 -arc sectors either side of the mid-line). After adaptation, subjects indicated if test gratings presented for 0.4s in 30 -arc horizontal sectors were expanding (+) or contracting (-). The subjects adapted for 30s, then indicated the motion direction in 32 tests interleaved with 5s top-up adaptation periods. Adapting temporal and spatial frequencies (TF, SF) were 0-24Hz and 1.5-6cpd. Test TFs were from –1 to 1Hz.

Results were obtained for 8 subjects. MAE strength was measured as the test TF perceived as being stationary (i.e. the point of subjective equality (PSE) at which half the tests appear expanding). Concrete and phantom adaptation gave PSEs of 0.1-0.4Hz and -0.1-0.2Hz, respectively. The maximum PSE shifts were at TFs of 8-16Hz (concrete) and 2-4Hz (phantom). Since it is probable that adaptation of local and global motion detectors generates the concrete MAE but only adaptation of global motion detectors generates the phantom MAE, the results suggest that
global detectors in the central field are tuned to lower TFS than local
detectors. Two further findings were: Stationary control stimuli
persistently contracted (PSE 0 to –0.1Hz), possibly due to adaptation
during prior locomotion; and (2) phantom adaptation with TFS of 16-24Hz
reversed the normal MAE direction, so that slow contraction was
perceived as expansion.

The different tuning of the concrete and phantom MAEs suggests that
local and global motion detectors in the central visual field have different
spatiotemporal preferences.

SU63
A "hard threshold" in detection, summation, and direction
discrimination? William A Simpson1 (william.simpson@drdc-rddc.gc.ca),
Helle K Falkenberg2; Velitchko Manahilov2; SMART-Defense R & D Canada
Toronto, Canada, 2Department of Vision Sciences, Glasgow Caledonian
University, UK – According to the old idea of the “hard threshold”, if the
stimulus is too weak, it has no effect on the nervous system. Many
experiments motivated by signal detection theory in the 1960s cast serious
doubt on the hard threshold concept. However we have collected data
from human observers that seem consistent with the presence of a hard
threshold in the detection of a drifting grating, in detecting the sum of two
oppositely drifting gratings, and in discriminating the direction of drifting
gratings. The observers viewed 2 c/deg drifting or flickering patterns
embedded in dynamic Gaussian white noise. The contrast was varied and
d’ was measured. For an ideal observer in each task, the psychometric
function should be a line through the origin. The same is true for a
nonideal observer with suboptimal efficiency and internal noise. In fact,
for all tasks the psychometric function was linear but with a substantial
rightward shift away from the origin. Thus once the contrast declined
below some hard threshold, d’ was 0. The shape of the functions was not
consistent with observer uncertainty. When the temporal frequency was
varied, the psychometric functions did not change slope but shifted
sideways. Thus a major factor determining the shape of the temporal
contrast sensitivity function is the position of the hard threshold rather
then internal noise or sampling efficiency as conventionally defined.

SU64
Equivalent noise in relative- and absolute-motion detection for
pattern translation with artificial jitter Ikuya Murakami (ikuya@
apollo3.brl.ntt.co.jp); Human and Information Science Lab., NTT
Communication Science Labs., Japan – Small eye movements produce
coherent and random image motions. As they are normally kept totally
unnoticed, it is unclear to what degree they might limit motion perception.
I measured motion detection threshold in the presence of artificial jitter
simulating small eye movements, to estimate the equivalent noise (i.e., the
artificial jitter that deteriorates performance just the way the visual
system’s internal noise would), and to compare its value to actual eye-
movement statistics. On a gray background, two dense random-dot fields
were presented concentrically for 853 ms. The disk pattern was moving
coherently, whereas the annulus pattern was stationary. The annulus was
shown constantly (condition R), invisibly constantly (condition A), or
flickered coherently at 9.4 Hz (condition F). The disk motion was the linear
sum of Brownian random jitter and translation in one of eight directions.
The observer was asked to identify the translation direction. For each
condition, the translation speed at motion detection threshold was
determined at several levels of jitter amplitudes, and the resulting
threshold-versus-jitter function was fitted with the noisy linear amplifier
model (e.g., Pelli & Farell, 1999, JOSA A). The estimated equivalent noise
for condition R, where relative motion existed, was almost negligible.
In contrast, that for condition A was significantly greater and was correlated
with variability of small eye movements. Moreover, in condition F, which
would evoke illusory jitter in the central disk even if it were static
(Murakami, 2002, VSS), an even greater equivalent noise was found. These
results suggest: (1) relative motion is a strong cue to reduce the visual
system’s internal noise; (2) small eye movements are the major source of it
when no relative-motion cue is available; (3) the flickering annulus does
not so much reduce noise as create a wrong relative-motion cue to eye-
movement-originated image jitter, degrading performance of the current
task.

SU65
Motion perception and localization during smooth pursuit eye
movements Jan L. Souman (j.l.souman@fss.uu.nl), Alexander H. Wertheim,
Ignace T.C. Hooge; Utrecht University, Psychonomics Division, The
Netherlands – When a vertically moving dot is perceived during ocular
pursuit of a horizontally moving pursuit target, it appears to move in a
slanted instead of a vertical direction, which is thought to reflect
incomplete compensation for the eye movement (Becklen, Wallach, &
Nitzberg, 1984). We investigated the influence of three factors on this
misperception: stimulus duration, pursuit velocity and the moment during
pursuit at which the stimulus was presented.

While following a horizontally moving pursuit target with their eyes,
participants were presented with a vertically moving dot (the stimulus),
crossing the pursuit path. The task of the participants was to indicate
either the perceived motion direction, or the (horizontal) position where
the stimulus appeared or disappeared. Stimulus presentation duration
varied from 200 ms to 1400 ms and the stimulus was presented half-way
the pursuit, or shortly before or after this. In a second experiment, pursuit
target velocity was varied from 6 /s to 14 /s.

Decreasing the stimulus presentation duration increased the perceived
slant and reduced the horizontal distance between perceived begin and
end points of the stimulus path. Perceived slant could be predicted fairly
well from this horizontal distance, except for the shortest presentation
durations. Increasing the pursuit velocity also caused the perceived slant
to increase. The moment of stimulus presentation, however, did not have
an effect on perceived slant.

An additional finding was that the whole slanted stimulus path was
mislocated in the direction of the pursuit. This mislocalization did not
depend on stimulus presentation duration or pursuit velocity, but it was
larger when the stimulus presentation occurred earlier in the pursuit path.
Our results show that the perceived path of a vertically moving dot
presented during horizontal ocular pursuit is not only slanted, but also
placed. This might have implications for theories of motion perception
during ocular pursuit.

SU66
Effect of contrast on the active control of a moving line Li Li
(llil@mail.arc.nasa.gov), Barbara T Sweet, Leland S Stone; Human Information
Processing Research Branch, NASA Ames Research Center, Moffett Field, CA,
USA – In passive speed-matching tasks, perceived speed is contrast-
dependent with little evidence of saturation at high contrast (e.g. Stone &
Thompson, 1992), while simple 1D direction discrimination saturates at
near threshold contrasts (e.g. Watson & Robson, 1981). To explore the use
of speed information in a manual control task, we examined observers’
performance as they actively controlled a moving luminance-defined line
for a range of contrasts (2, 3, 4, 8, 16% around 22 cd/m2) and for two
different controller dynamics. The stimulus consisted of a Gaussian-
blurred (SD = 1) horizontal line. Four observers (three naive) were asked
to use a joystick to keep a horizontal line centered on a 34 x 26 display as
its vertical position was perturbed by the sum of 10 harmonically-
related (0.02 to 2.18 Hz) sinusoids. Two control paradigms were tested
in blocked conditions: joystick displacement generated a command
proportional either to the rate of change of line position or to the rate
of change of line velocity. Four-minute time series of line position and
joystick displacement were Fourier analyzed and averaged across 6
sessions. For all four observers, the RMS error decreased quasi-linearly
with increasing log contrast across the tested range (mean slope: -8.0 &
- 7.7% per log2 contrast unit, averaged across observers, for the two control
paradigms, respectively). Bode plots (frequency response plots) showed a
systematic increase in sensitivity (mean slope: 1.61 & 1.52 dB per log2
contrast unit, respectively) and decrease in phase lag at high frequencies,
which can be accounted for by a decrease in response delay (mean slope: -31 & -26 ms per log2 contrast unit, respectively). The finding that performance continues to improve even for relatively high contrasts suggests that speed information is used in the manual control of a moving object under both control paradigms.

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**SU67**

The flash-lag effect during voluntary and involuntary limb movements Roni Nijhawan (romin@cogs.susx.ac.uk), Beena Khurana; Department of Psychology, University of Sussex, United Kingdom — The flash-lag effect results from displays in which a flashed object is physically colocalized with a moving object. Despite the alignment of the two objects, the observer perceives the flashed object as lagging behind the moving object. It is not known if analogous effects occur with respect to a moving body part, such as the observer’s hand. Here we show that a flash presented in alignment with an invisible rod that the observer voluntarily moves, also appears to lag behind the felt position of the rod. Four observers moved a 220 gm rod in the dark while an LED was flashed at various positions relative to the rod. Observers reported whether they perceived the position of the flash as “ahead”, “behind” or “centered” in relation to the rod. On average, a flash presented 125 ms in advance of the rod position was judged by observers as centered on the rod. In a second preliminary experiment, two new observers grasped a manipulandum. Glue on the manipulandum fixed the observer’s hand in position without requiring the observer to exert any force. The invisible manipulandum (and the observer’s hand) was then carried by a linear drive, while the flash was presented in various positions. In this “passive movement” condition, observers similarly judged the position of a flashed LED relative to the manipulandum. Once again a significant flash-lag effect was observed. These experiments show that a flash-lag effect occurs relative to the felt position of a limb, both when the limb is moved passively and actively. This suggests that compensation for neural delays in the registration of limb position occurs both when motor and sensory information for limb position is simultaneously available (active movement case), as well as when only sensory information is available (passive movement case).

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**SU68**

Catching ground balls: Optical control heuristics used by humans and robots support a unified fielder theory Michael K McBeath1; (m.m@asu.edu), Thomas G Sugar2, Michael J Thompson3, Keshav Mundhra4; 1Department of Psychology, Arizona State University, Tempe AZ, USA, 2Dept. of Mechanical and Aerospace Engineering, Arizona State University, USA — In past studies we examined optical control heuristics used by fielders and robots for interception of fly balls. Our findings support use of the heuristics of maintaining optical speed constancy and a linear optical trajectory (LOT) for balls projected above the horizon. In the current study we explore behavior of robots and fielders intercepting ground balls projected below the horizon. In robotic simulations, we confirmed that the same control heuristics demonstrated for fly balls are viable ones for intercepting ground balls. In the human experiment, we measured optical position of the ball with three skilled fielders using a head cam, and measured actual ball and fielder location using stationary external cameras. Our findings support that, for most easily caught grounders, fielders select a slow running pace and maintain the same optical control heuristics that they do for fly balls. This also results in an energy-efficient, near constant-speed running path. On a number of the more difficult trials, where fielders needed to run a long distance, the optical trajectory was much better accounted for as two phase: an initial constant-speed linear trajectory at a severe lateral angle, followed by a second constant-speed linear trajectory at a new diminished lateral angle. On these trials it appears fielders overshoot the first LOT and establish a second one with a more workable approach angle. The findings also support that fielders tend to establish a running path with a fairly constant velocity that remains roughly within a vertical plane perpendicular to their initial lineup with the ball. Overall, the findings are consistent with a unified fielder theory in which the same optical control heuristics are used by both fielders and robots to navigate to the interception destination for both fly balls headed above the horizon and grounders below it. Use of these heuristics holds promise in the creation of navigating mobile robots designed to achieve or avoid collisions.

**Acknowledgment:** (passive movement case).

**SU69**

Effects of grouping and attention on the perception of causality Hoon Choi (h.choi@yale.edu), Brian J Scholl; Yale University, USA — Beyond perceiving patterns of motion in simple dynamic displays, we can also perceive higher level properties such as “causality”, as when we see one object “collide” with another object. Though causality is a seemingly high-level property, its perception – like the perception of faces or speech – often appears to be automatic, irresistible, and driven by highly constrained and stimulus-driven rules. Our goal, following Michotte, is to discover these rules. Consider a disc (A) which moves toward a stationary disc (B) until they are adjacent, at which point A stops and B starts moving along the same path. We perceive this event as a ‘launch’: A smashes into B, causing its motion. When A and B fully overlap before B starts moving, however, the display is ambiguous: in addition to launching, observers often perceive a ‘pass’ wherein a single moving object simply passes over another stationary object. In a series of experiments, we demonstrate that perceptual grouping and attention can heavily influence whether such ambiguous events are perceived as causal. When a single additional disc (C) is added to the display, its motion can determine the percept. When C always stays aligned with B, subjects reliably perceive A & B as causal launching; when C always remains stationary (even after B moves), subjects reliably perceive A & B as noncausal passing. In this and many related experiments which we will demonstrate, we thus show that grouping induced by either connectedness or common motion can influence causal perception. We further suggest that such grouping effects are mediated by attention and in other experiments we directly demonstrate that attention can both promote and attenuate causal perception. Like Michotte, we find that the perception of causality is mediated by strict visual ‘rules’. Beyond Michotte, we find that these rules operate not only over the objects involved in an event, but over additional objects, constrained by the allocation of attention.

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**SU70**

Neuronal activity in parietal cortex during active control of a moving stimulus Gaby Mainon (gmainon@fas.harvard.edu), John A Assad; Harvard Medical School, Department of Neurobiology, Boston, MA, USA — Motion in the visual world is often caused by the organism itself. Consider a primate’s arm moving across his field of view, or the optic flow generated while an animal locomotes. As compared to other forms of naturally occurring motion, self-generated motion is inherently more predictable to the organism, and it is also more directly coupled with ongoing motor behavior. Perhaps it is processed differently by the brain. We have been recording from direction-selective cells in the parietal lobe of an awake, behaving macaque monkey. While the monkey fixates he views a peripheral stimulus – a dot moving back and forth between two parallel bars, 22 apart. The bars are situated such that the dot reverses direction within the cell’s receptive field, along the preferred-null axis. The monkey does three different tasks in separate but interleaved blocks of trials. In the ACTIVE block the monkey himself induces the dot’s motion reversals by pressing a lever. He is allowed to turn the dot only when it is within a few degrees of the bar. In the ACTIVE-DELAY block the monkey experiences a 200 msec delay between the time he presses the lever and time the dot turns. In the REACTION block the monkey no
motion environments

The effects of visual information on postural stability in dynamic locomotion toward the stimuli. Conclusions: Walking error varies systematically with walking direction; walking after a 90 deg right turn (mean errors: +30 vs. +16 cm); errors after walking forward tended to produce larger responses than to walk farther when they walked toward the stimuli versus parallel to them (mean error: +41 vs. +17 cm).

Method. Observers saw 2 short vertical rods resting on the ground and separated by .5 to 3.5 m; they then indicated the rod separation by nonvisual walking. Exp. 1: The rods were aligned in either a fronto parallel or a sagittal plane. When responding, participants walked directly forward, or after turning 45 or 90 deg to the right. Exp. 2: The rods were aligned in a fronto parallel plane. Walking was executed along an axis PARALLEL to this plane, or along an orthogonal axis pointing to the nearest rod. Some trials required a 90 deg body rotation prior to walking while others did not. Sometimes this entailed viewing the rods over the left shoulder while straddling the PARALLEL axis; this could be followed by a leftward body turn to walk along the ORTHOGONAL axis or by no turn (walking straight along the PARALLEL axis). Observers walked without vision while facing the direction of walking.

Results: Exp. 1: Response errors varied systematically with walking direction; walking forward tended to produce larger responses than walking after a 90 deg right turn (mean errors: +30 vs. +16 cm); errors after a 45 deg turn were intermediate (+24 cm). Exp. 2: Regardless of whether or not a body rotation was required prior to responding, participants tended to walk farther when they walked toward the stimuli versus parallel to them (mean error: +41 vs. +17 cm).

Conclusions: Walking error varies systematically with walking direction when observers attempt to reproduce exocentric spatial extents by nonvisual walking, observer accuracy is biased by the direction walked relative to the initial viewing direction (Philbeck, VSS ‘02). Here, we set out to confirm this and test whether body rotations imposed before walking are responsible.

SU72
The effects of visual information on postural stability in dynamic motion environments Moira B. Flanagan¹ (MFlanagan@UNO.EDU), James G. May², Thomas G. Dobie²; ¹Psychology Dept. University of New Orleans, Lakefront, New Orleans, LA, USA, ²National Biodynamics Laboratory, University of New Orleans, Lakefront, New Orleans, LA, USA — It is apparent that visual information is used in maintaining stable posture in a stationary world. Considerable previous research has indicated that significant perturbations of posture can be induced with a shift in the entire visual scene. When standing or walking on moving platforms, it is assumed that posture and ambulatory ability are controlled more by vestibulo-spinal reflexes, but the role of visual reference has not been extensively studied. In the present study, we measured force plate recordings while subjects stood on a moving platform and derived the frequencies of motion-induced interruptions (MIIs) under two conditions. In the first condition a view of the stationary world within which the motion occurred was provided. In the second it was not. Subjects were tested on a motion platform driven by simulated ship-motion profile. In condition 1, subjects were allowed to see the walls and ceiling of the stationary test cubicule that housed the motion platform. In condition 2, curtains attached to the motion platform precluded this view. Significantly more MIIs (defined by differences in force plate recordings for the left and right feet) were found under the condition involving curtains. These results suggest that the visual input to postural stability in motion environments is more important than previously assumed. This suggests that manipulations (e.g. artificial horizons) that provide stable visual representations of the static environment within which the motion occurs may provide important health and safety measures for individuals working in enclosed environments on modern vehicular conveyances.

SU74
On-road measures of the visibility of pedestrians at night Richard A. Tyrrell¹ (tyrrell@cllemson.edu), Joanne M. Wood², Trent P. Carberry², Tabitha Faulks², Kevin Jones²; ¹Clemson Univ., USA, ²Clemson Univ., USA, — Most collisions between vehicles and pedestrians occur at night. This experiment quantified the ability of drivers to detect pedestrians at night. Ten younger (M=27.8 yrs) and ten older (M=67.9 yrs) participants drove an instrumented car ten laps around an unilluminated 1.1 mile test track. Drivers pressed a dash-mounted touchpad when they recognized the presence of a pedestrian. A computer-based system measured recognition distances by interpreting the parallax provided by two synchronized digital video cameras mounted on the car’s roof. Two pedestrians walked in place at different positions on the far shoulder. One pedestrian was in darkness and one was positioned just beyond a stationary pair of headlights that was a source of glare for the approaching driver. Across laps, drivers used both low and high beams and pedestrians wore four different clothing configurations. The effects of age, glare, clothing, and beam all significantly influenced both pedestrian identification (all p < .01) and recognition distance (all p < .001). With and without glare, older drivers identified only 48% and 59% of the
pedestrians, respectively. Younger drivers identified significantly more pedestrians (75% with glare, 94% without glare). Recognition was worst for pedestrians wearing black (34% identified). Only 5% of drivers identified the black-clad pedestrian when the driver used low beams and faced glare. Recognition was best (94% identified) for pedestrians wearing retroreflective markings configured to depict biological motion. Analysis of the recognition distances revealed that when identification occurs it is often at a distance insufficient to allow a successful avoidance maneuver. Taken together, these data confirm that even alerted drivers can have great difficulty recognizing the presence of pedestrians at night. The problem is greatest for older drivers, when drivers rely on low beams, when pedestrians wear low reflectance clothing, and when glare is present.

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SU75
Human shortcut performance in a structured maze environment Patrick S Foo (Patrick_Foo@brown.edu), William H Warren Jr., Michael J Tarr; Brown University, USA – The layout of an environment must be learned from experience with particular routes. One possibility is that the process of path integration links environmental locations into a metric "cognitive map," which would enable novel shortcuts. We have demonstrated that humans are unable to use path integration alone to perform novel shortcuts. Instead they rely on local landmarks over metric knowledge (whether they appear at the beginning, middle, or end of a novel path; Psychonomics, 2002). These previous studies were performed in open environments with small clusters of visible landmarks, which may have increased subject's dependence on landmarks. Therefore we now pursue this question for complex multi-leg routes in a closed, structured environment with restricted views, a virtual hedge maze (Harrison et al., VSS 2001). Participants walked in an immersive virtual environment (12 m x 12 m) while wearing a head mounted display (60 x 40 deg, 50 ms latency). The hedge maze contained eleven places (stair, bird bath, etc.). During training, participants learned the layout of places with a free exploration period, followed by structured practice along specific routes. During testing, the hedges were removed, and subjects were asked to walk the overland shortcuts between learned places. We compare equidistant shortcuts that are linked by more or less circuitous routes. If spatial knowledge is truly metric, then performance should be equal. Implications for theories of human metric navigation will be discussed.

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SU76
The stages of steering Richard M Wilkie (r.m.wilkie@rdc.ac.uk), John P Wann; University of Reading, UK – We routinely locomote through the world successfully, even at high speeds. At VSS2001 Wilkie & Wann presented evidence supporting the contribution of Retinal Flow (RF) and Visual Direction (VD) to the control of steering. When steering curved paths towards a target we observed that both RF and VD information could be used to perform the task successfully. It was still unclear whether there was any switching between information sources when there was a shift in their relative strengths. We investigated this in two ways:

i) We reduced the illumination of the scene to degrade RF information, and found that participants did rely more on VD information.

ii) We examined steering behaviour over the time-course of individual trials to see if there were temporal shifts in information use. We split the trials into early (2-4s) and late (4-6s) steering and compared conditions with contrasting amount of RF and VD information. During early stages it was clear that both RF and VD could influencing steering, even when other veridical sources of information were present. By comparing the observed data with modelled data (using the model in Wilkie & Wann, 2002) it became apparent that there was a shift in weight from RF to VD between the early and late steering periods.

We conclude that the weighting of an information source is linked to its strength, and so reliance upon a source can be modified by degrading/enhancing the quality of that information. This shift seems to occur naturally over the time course of an approach to a steering target.

Acknowledgment: Supported by EPSRC UK


SU77
Perception of heading without optic flow Kristen L Macuga (macuga@psych.uchicago.edu), Jack M Loomis, Andrew C Beall; University of California, Santa Barbara, USA – Observers can perceive heading over a ground plane with an accuracy of 1.2° using radial patterns of optic flow (Warren et al., 1988). Can observers successfully use information other than optic flow to extract heading? An alternative idea is that the perceived flow of visible elements can be used even when optic flow is absent. To investigate this question, we determined the accuracy of heading perception using two stimuli: a luminance defined dioptric stimulus containing smooth optic flow and a scintillating random dot cinematogram (SRDC) stimulus (Julesz, 1971), devoid of any optic flow relating to the task. The SRDC stimulus consists of a sequence of random-dot stereograms with single-frame lifetimes, which to each eye appears as a scintillating display of uniform dot density. Thus, there is no relevant optic flow signal in the SRDC stimulus. We then employed a discrimination task to assess translational heading thresholds for each condition using the method of constant stimuli. Subjects viewed simulated self-motion parallel to a ground plane covered with randomly placed objects through a head mounted display. In the last frame of each trial, motion ceased and a vertical target line appeared at the horizon, remaining visible until a response was made. Observers were required to judge whether they were moving to the left or to the right of the target. Bearing angle between the heading direction and the target varied randomly between 20° and 60°. Environmental features were approximately matched for visibility in the two conditions. Data were collapsed across heading direction and positive-negative bearing angles. Mean thresholds of 75% correct for 4 observers were less than ~1° for the dioptric condition and less than ~2° for the SRDC condition. Thus, observers can perceive heading only slightly less accurately using the SRDC stimuli than using a stimulus with optic flow.

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SU78
Learning and Unlearning Spatial Relationships during Navigation Ranxiao F Wang (francesw@s.psych.uiuc.edu); University of Illinois at Urbana-Champaign – How do people learn the spatial relationship between places that share no common landmarks (e.g., a windowless interior room & the outside world)? A potential solution is navigation between these environments. For example, if one can keep track of the orientation of one environment while walking toward another environment, then she can establish the spatial relationship between these environments when she arrives at the second environment. Two experiments investigated how people learn the directional relationship between environments through navigation. Participants walked from a windowless interior room to a testing position outside the building, along a path with six 90 deg turns, and then returned to the room along the same path. People failed to learn the directional relationship between the room and the outside world, because they lost track of the room orientation when they walked outside, and lost track of the orientation of the outside world when they returned to the room. When participants were forced to report the orientation of the room after each turn along the path (i.e., forced to "update" the room orientation), they successfully kept track of the room orientation after they walked outside, and thus reported the geographical orientation of the room in correct relationship to the outside world. However, when they returned to the room, again reporting the room orientation along the way, they failed to report the orientation of the outside world in correct relationship to the room. These results suggest that spatial learning through navigation requires updating of the proper
target (i.e., the environment one just left), which does not occur automatically in everyday navigation, and updating of the wrong target can override spatial relationships already learned.

SU79
Meaning influences the perception of apparent human motion
Arieta Chouchourelou (areti@psychology.rutgers.edu), Fani Loula, Maggie Shiffrar, Rutgers University, USA – When and why does the visual analysis of human movement differ from the visual analysis of other types of motion? Previous research suggests that the visual analysis of human motion does not always differ from the visual analysis of non-human animal motion (Chouchourelou et al., 2002). Instead, unusual human movements and common animal movements appear to be similarly analyzed. In this experiment, we examined some of the factors that might perceptually differentiate categories of human movement. Social relevance may ultimately differentiate human action from other motions (e.g., Brothers, 1997). Using assessments of apparent motion quality as a window into the temporal aspects of visual motion analyses, we compared the perception of apparent human motions across systematic variations in social context. Two-frame apparent motion sequences were created from digital videos of two human actors interacting with each other. In the "interaction" condition, both actors were visible but only one moved. In the "isolated" condition, the stationary actor was removed. Thus, identical displacements were shown in both conditions. Naïve observers saw either interactive or isolated picture pairs in a between-subjects design and were asked to make qualitative assessments of the smoothness of the apparent motion they experienced at each of seven interstimulus intervals (ISI). Across trials, stimulus duration was fixed at 100ms and ISI randomly varied between 0 and 600ms. Qualitative assessments were rendered with a 7-point scale in which 1 represented no apparent motion and 7 indicated perfectly smooth motion. Identical displays of human displacement produced significantly different percepts of apparent motion quality as a function of the social context of the displacement. Control studies with non-interactive and inconsistently interactive contexts support the idea that social interactions might actually shape the visual analysis of human action.

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SU80
Speed information and the visual control of braking to avoid a collision
Brett R Fajen (fajen@rpi.edu), Rom S David; Rensselaer Polytechnic Institute, USA – Using closed-loop computer generated displays in which observers adjusted a hand brake to stop at an object in the path of motion, Yilmaz and Warren (1995) provided evidence to support Lee’s (1976) hypothesis that people use the first derivative of the optical variable tau (“tau-dot”) to control braking. In addition, they found only minor differences when speed and distance cues were removed, suggesting that successful braking can be achieved on the basis of tau-dot alone. More recently, Andersen, Cisneros, Atchley, and Saidpour (1999) reported that passive judgments of upcoming collisions during constant deceleration approaches to an object were also influenced by information about speed of self-motion provided by edge rate. The purpose of this study was to further explore the role of speed information in actively controlled braking. Participants sat in front of a large projection screen and viewed computer generated displays simulating approaches to a stop sign. They used a force-feedback joystick as a hand-operated brake to stop as closely as possible to the object. Initial distance and time-to-contact were varied, and information about speed was manipulated by adjusting the simulated eye height above a textured ground surface, which alters the relation between speed of self-motion and rate of optic flow. To ensure that participants were unaware that eye height varied, the ground texture was rescaled with eye height so that texture density was the same on every trial. The results indicate that braking is influenced by the rate of optic flow. When eye height was lower than normal, observers overshot the required deceleration and stopped short of the target. When eye height was above normal, observers undershot the required deceleration and often collided with the object. Braking profiles from each individual trial were analyzed to determine the influence of rate of optic flow on both the direction and magnitude of brake adjustments.

SU81
The role of gaze fixation in locomotor control
John P Wann (J.P.Wann@reading.ac.uk), Richard M Wilkie; School of Psychology, Univ of Reading, UK – At VSS 2001 & 2002 we presented data on the use of retinal flow & visual direction information in controlling steering (in press JEP:HPP & Current Biology), and also on gaze fixation patterns during heading and steering tasks. Here we link the two into a theory of path planning and locomotor control based on active gaze. In this scheme the performer fashions their future trajectory through a series of path fixations. The locomotor control system then acts as an attractor to the point of fixation by nulling the rotation components of retinal flow (rather than optic flow) and non-visual (gaze-angle) information. This system differs from that of Fajen & Warren (VSS 2001 & 2002) in that it does not require any estimate of target of obstacle distance and is robust to errors in the estimation of heading, visual angle or rotation rates. It also provides a clear mechanism for skill learning and refinement whereby the advanced performer learns WHERE to look and WHEN to yield a "racing line" or specific safety margin.

Acknowledgment: Supported by the UK EPSRC http://www.rdg.ac.uk/arl/conferences/VSS2003/VSS_2003.htm

SU82
More recalibration of the perception of linear self-motion
Laura F Fox (lfox2@swarthmore.edu), Frank H Durgin; Swarthmore College, USA – It has been demonstrated, using a treadmill, that adaptation to a mismatch between locomotor activity and visual feedback (optic flow) produces an aftereffect on the task of walking, without vision, to a previewed target (Rieser et al., JEP:HPP, 1995). We (Durgin, Fox, et al., Psychonomics, 2002) have recently demonstrated that a more powerful version of this aftereffect can be obtained from normal walking in a wide-area virtual reality (VR) with altered visual gain (relative optic flow rate). We attribute the greater effect to concomitant recalibration of vestibular signals. There were no changes in perceived distance, as assessed verbally. Hypothesizing that the aftereffect therefore entailed a recalibration of locomotor estimates of the rate of self-motion, we investigated whether subjects would also show changes in their drift rate when running in place without visual feedback (see Anstis, EBR, 1995; Durgin & Pelah, EBR, 1999), after adapting to the same VR experience. Subjects’ drift (rate of inadvertent forward advance while attempting to run in place with eyes closed) was assessed before and after adaptation. Adaptation consisted of exposing subjects to 5 minutes walking at a normal pace (~ 4 kph) back and forth in a hallway in which the visual gain (in VR provided via an HMD) was either too high or too low by a factor of two. Subjects who were adapted to low visual gain demonstrated increased posttest drift, and those adapted to high visual gain tended to show reduced posttest drift. Asymmetries in the effects of high and low gain were quantitatively similar to those found for target-walking tasks in our previous study. The results provide a unique demonstration of altered drift rate modulated by the relative rate of optic flow during normal walking. They also strongly support the conjecture that the two aftereffects (altered drift rate and altered locomotor gain in walking without vision) have a common source (Durgin, Pelah, et al., ARVO, 1998).

Acknowledgment: HHMI

SU83
Egocentric representation affected by target context and head/eye positions more so for women than for men
Kathleen A Turano, Jane M Eisinger, Hau Lei, Siddhartha Chaudhury; Wilmer Eye Institute, Johns Hopkins University, Balt., MD, USA – Purpose: Goal-directed walking requires an estimation of the goal’s location in space relative to one’s body. Information for this estimation could come from various sources, e.g. visual, efferent, vestibular, and somatosensory signals. In this study we
determined whether there is a gender difference in the effect of visual and non-visual information on action-task performance—walking to a briefly exposed target. Methods: Subjects were 10 men and 10 women. An immersive virtual environment was used to present a scene of a room with a ball in a doorway. The ball was positioned at −3, 0, or 3 relative to the subject's midline, and the doorway was either centered on the subject's midline or offset 5°. The scene was displayed for 1 sec, replaced with a uniform field, and the subjects were to walk to the ball (4 m). In Exp. 2, subjects began walking at display onset. In Exp. 3, the positions of the subject's head and/or eyes were rotated relative to straight-ahead as they viewed the scene. Results: Doorway offsets affected the women's paths significantly more than the men's, t(18) = 2.3, p < .05. Nine of 10 women had errors of 2.8–22.7°. The majority of the men (7/10) had errors of 0.1–1.4°. With rotated head and/or eyes (Exp. 3), the women had significantly larger path errors than the men. With visual feedback (Exp. 2), the magnitude of the women's errors decreased to the range of the men's. Conclusions: Women are more affected than men by the context of a target and by the positions of their head and eyes in determining the spatial position of a target to self.

Acknowledgment: Supported by NIH grant EY07839

SU84 Does preknowledge of target depth affect visual processing? Monika Puhakka1 (Monika.Puhakka@Nokia.com), Jukka Häkkinnen1, Jari Laarni2; 1Visual Communications Laboratory, Nokia Research Center, Finland, 2CKRI, Helsinki School of Economics and business Administration, Finland—Several studies have suggested that it is possible to direct attention in 3-D space (e.g., Nakayama & Silverman, 1986). If attention is directed similarly in depth as in 2-D space, it is possible that preknowledge of a target's depth plane not only help to direct spatial attention to a relevant location in space, but it also enhances the sensory quality of the stimulus representations. Previously we have shown that attention in 3-D does not enhance the sensory quality of stimuli, and thus is different from attention in 2-D (Puhakka, Häkkinen & Laarni 2002).

To further explore these questions, three search experiments were carried out in which observers searched for a digit target among letter distractors. Probability of the target location in a particular depth plane was varied between blocks. In Experiment 1 and 3 half the characters were at one depth plane and the other half at the other depth plane; in Experiment 2 only one character was at a different depth plane. In the first two experiments the exposure duration was set to 200 ms, which is considered to be too short for vergence eye movements. In the third experiment display remained visible until a response was made.

Probability manipulations had no effect on performance when the exposure duration of the search display was 200 ms. Even when only one character was at a different depth plane, observers were still not able to use the preknowledge of target location in searching for the target. Preknowledge had a clear effect on performance only when the vergence eye shifts were possible.

Results suggest that when display remains visible long enough and there is time to allocate attention to multiple items, the performance improves. It is not clear whether attending to a depth plane enhances the sensory quality of items located at that depth plane or whether these items are only prioritized (see Moore & Egeth, 1998).

SU85 Transient blindness to disparity defined depth Arash Sahraie1 (a.sahraie@abdn.ac.uk), Maarten Milders3, Michael Niedeggen2; 1Vision Research Laboratories, Dept. of Psychology, Univ. of Aberdeen, Scotland, 2Institute of Experimental Psychology, Heinrich-Heine-University, Duesseldorf, Germany—Background: We have devised a paradigm to modulate selective attention in temporal domain using two synchronised rapid serial visual presentation (RSVP) streams (features: colour and motion). A switch between the streams evoked a transient deficit in visual motion perception (Sahraie et al, 2001, Vis Res. 41, 1613-7). Purpose: We have investigated whether disparity defined depth can also be modulated by attention using a similar paradigm. Methods: Subjects viewed two synchronised RSVP streams. A local stream was defined by a fixation point changing colour every 100 ms, and provided a ‘cue’ with the onset of a unique red fixation. A global stream consisted of a static black/white random noise with and an annulus surrounding the fixation that appeared in a different depth plane (baseline plane) with respect to the background. The disparity of annulus could be temporally modulated every 100 ms but transient disparity changes preceding the onset of the colour cue (distractors) were to be ignored. Following the cue onset, subjects’ task was the detection of a transient disparity defined change in depth of the annulus (target) appearing in a plane either in front or behind the baseline plane. Stimulus onset asynchrony (SOA) of cue and target was varied between 0, 100, 300 or 500 ms. In the control condition, subjects were asked to ignore the fixation colour changes and report the last transient change in depth plane. Results: At 0 ms SOA, subjects were at chance level in detecting a transient change in disparity defined depth. Performance improved at longer SOAs (>80% at 500 ms SOA). Subjects were not impaired in detecting the depth target if its onset was not preceded by distractors, or in the control condition. Conclusions: Similar to motion detection, a change in disparity defined depth is also modulated by attentional demands. The ‘distractor effect’ obtained for both features probably reflects a top-down regulation which parallels recent neurophysiological findings.

Acknowledgment: Supported by a project grant from the VolkswagenStiftung (VW 2277)

SU86 The spatio-temporal constraints of object-based priming Doug J. Barrett1 (D.Barrett@sic.ac.uk), David Rose2; 1Department of Psychology, University of Southampton, Southampton, UK, 2Department of Psychology, University of Surrey, Guildford, UK—Purpose. Priming has been shown to produce facilitation and inhibition in at least two frames of reference (e.g. Tipper & Weaver, 1998). Location-based priming is associated with the location to which attention is oriented while object-based attention is associated with moving objects independently of the location they were primed. Usually these separate effects are attributed to differences in the underlying representations activated by visual attention. Alternatively, object-based priming may reflect a spatial process that dynamically updates the successive locations occupied by the activated object. We investigate this distinction by measuring object-based priming for objects moving at different velocities. Method. Participants (N=8) responded to a pair of moving targets that were validly or invalidly primed by their features (colour and shape). Four object velocities were used and location and object-based effects were disambiguated using four prime conditions: (i) features valid, location valid, (ii) features valid, location invalid, (iii) features invalid, location valid and (iv), features invalid, location invalid.

Results. The results demonstrate a distinction between priming associated with the cued location and that associated with the moving object. Location-based priming persists despite changes in target velocity while object-based priming declines linearly as the target’s velocity increases. Conclusion. The data support a process that dynamically updates the successive locations of a moving object that has been primed by non-spatial features. Priming associated with slow moving objects is equivalent to that associated with the location at which the object was primed. As velocity increases and the spatio-temporal coherence of the selected object is disrupted, priming reduces as the allocation of attention to successive locations becomes more difficult.

SU87 The spatial footprint of the perceptual template Barbara Dosher1 (bdosher@uci.edu), Shu-Hua Liu1, Nathaniel Blair1, Zhong-Lin Lu2; 1University of California, Irvine USA, 2University of Southern California USA—Visual stimulus discrimination or identification requires input from and weighting of information presented in spatial regions incorporating the signal stimulus. In this study, we evaluate the spatial “footprint” of
The role of memory in static and dynamic visual search  

Adrian von Muhlenen  

von Muhlenen (adrian@psych.ubc.ca); University of British Columbia, Canada—  

Adrian The role of memory in visual search has lately become a controversial  

issue. Horowitz and Wolfe (H&W, 1998) asked participants to search  

displays for a letter “T” among letters “L” in two experimental conditions:  

In the static condition, the displays remained unchanged, whereas in the  
dynamic condition, all letters were randomly re-located every 111 ms.  

If search involves a memory-based mechanism that keeps track of the  
previously examined locations, observers would be expected to have great  
difficulties searching the dynamic display. Surprisingly, the target-present  
search rates in the dynamic did not differ from those in the static  
condition. Because a memory-based mechanism would be of no use in the  
dynamic condition, H&W concluded that memory is likewise not involved  
in the static condition.  

One alternative explanation for the results of H&W is that participants  
adopted a sit-and-wait strategy, which consists of attending to a region of  
the display and waiting for the target to appear there. Although H&W  
tried to rule out such an alternative explanation, this study argues that  
their participants have opted for a more sophisticated sit-and-wait  
strategy, one that allows the attentional focus to encompass several  
stimulus locations, and where the attentional focus can be shifted to other  
areas after some time has elapsed.  

This hypothesis is supported by experimental data showing that  
performance in H&W’s dynamic condition does not differ from another  
dynamic condition (aperture condition), in which observers are forced to  
adopt a sit-and-wait strategy by being presented with a limited region of  
the display only. These results seriously question H&W’s assumption that  
the dynamic condition provides an “analytical” counterpart to the static  
condition, which would allow us to infer how search is performed with  
normal, static displays. This paves the way for other theories emphasizing  
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SU89  
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Adrian von Muhlenen (adrian@psych.ubc.ca); University of British Columbia, Canada—  

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SU90  
An auditory secondary task modulates attention capture in visual search  

James R. Brockmole (jbrockmole@psych.uiuc.edu), Walter R. Boot, Daniel J. Simons; University of Illinois, USA—  

Most studies of attention capture consider the effects of an anti-predictive or irrelevant stimulus on visual search performance. If the attentional prioritization revealed in such tasks is entirely stimulus-driven, it should be immune to variations in the attentional resources available for search. However, if prioritization depends on the availability of attentional resources and is not entirely stimulus-driven, then capture should be influenced by the division of attention.  

We used two capture paradigms to measure the effects of a secondary task on attentional prioritization. In one task, the critical item was a color singleton and was never the target of search. Capture is revealed by slowed search in its presence. In the other task, the critical item was a statistically irrelevant abrupt onset—it was just as likely to be the target of the search as any of the other items. Capture is revealed by a reduced influence of distractors on search speed when the critical item happens to be the target of search. Subjects performed these tasks while listening to an auditory stream of digits and counting repetitions.  

When subjects ignored the auditory stream and only performed the search task, both anti-predictive color singletons and irrelevant onsets captured attention. However, when performing the secondary task, attention capture by an anti-predictive color singleton increased, but capture by the irrelevant onset was eliminated.  

When an anti-predictive critical feature is present during search, attentional resources are needed to ignore it. Consequently, a dual task leads to increased attention capture. When a critical feature provides no information about target location, the dual task reduces the salience of that feature and thereby reduces capture. In both cases, capture is modulated by the attentional resources available during search, suggesting that attentional prioritization is not automatic and that the two tasks measure different aspects of prioritization.  

SU91  
The influence of target position and response hand on efficient feature search  

Julie Palix1 (julie.palix@hcuge.ch), Vincente Ibañez1, Claude-Alain Hauert2, Ute Leonards1; 1Department of Psychiatry, University Hospital of Geneva, Switzerland; 2Faculty of Psychology, University of Geneva, Switzerland –  

In event-related potential recordings (ERPs), the N2pc component, an enhanced negativity over parietal electrodes contralateral to the target hemifield about 270ms after stimulus onset has been earlier suggested as neurophysiological correlate for spatial shifts of visual attention (e.g. Woodman & Luck, 1999, Nature 400:867-869). The presence of this component in efficient feature search (FS) thus indicated that at
least one attentional shift is involved in this type of search. Here we asked whether possible attentional processes involved in efficient feature search are purely search-driven, or are modulated by motor response and target position. We measured in 17 subjects the influence of responding hand (left versus right) and target location (left versus right hemifield) on reaction times (RT) and on ERPs during FS. For RTs, a 2 (hands) X 2 (hemifields) ANOVA revealed a significant effect of the hemifield (left < right), and significant interactions between hand and hemifield, provoked by longer RTs for targets in the right hemifield during left hand responses. Taking the N2pc component and its ipsilateral counterpart (N2pi) into account, ERP peak latency analysis allowed us to isolate influences on cortical search dynamics of both responding hand and of target location, respectively. We show that ERP latencies for both N2pc and N2pi are shorter over electrode sites contralateral to the responding hand, thus independently of the target hemifield. Moreover, a target located in the left visual hemifield evokes faster N2pc and N2pi potentials than a target in the right hemifield, irrespective of the responding hand. We conclude that, in efficient search, both speed of target detection and cortical dynamics of the suggested neurophysiological correlate of attention depend on executive processes of the motor response, and the target hemifield.

**SU92**

Selective substitution: Attentional set modulates object substitution masking

Steven B Most (steven.most@vanderbilt.edu), Marvin M Chun, David M Widders; Vanderbilt University, USA – The act of seeing might be a temporally extended one where visual information that is not sufficiently attended can be overwritten by new or remaining information. Behavioral support for this view of perception comes from work on object substitution masking (OSM), which can occur when a target in a search array is surrounded by a mere 4 dots. If the dots linger in the display after the target disappears, perception of the target suffers relative to when the dots offset simultaneously with the target (Di Lollo, Enns, & Rensink, 2000). But can any lingering stimulus override a developing target representation regardless of its similarity to the target, or is OSM instead modulated by a subject’s top-down attentional set? Jiang and Chun (2001) found that bottom-up featural similarity between the mask and target did not affect OSM, yet work on inattentional blindness has shown that attentional set heavily influences subjective perception (Most et al., 2001). Here, we investigate OSM under conditions in which subjects are forced to adopt an attentional set to distinguish a target from distractors. In one study, one black ‘C’ and one white ‘C’ (each randomly facing forwards or backwards) appeared among other black and white distractors on each trial, and subjects reported the orientation of either the black or white ‘C’ for the duration of the experiment. Thus, they were required to establish an attentional set for luminance. Across trials, the luminance of the 4-dot masks either matched or did not match the luminance that subject were attending to. When the luminance of the mask matched that of the target set, OSM was substantially more pronounced than when the luminances of the mask and target did not match. Additional experiments suggest that this modulation of OSM emerges as an effect of attentional set, rather than simply the featural similarity between the mask and target.

**SU93**

The breakdown of efficient search when either of two colour targets can appear

Tammy Menneer (t.menneer@soton.ac.uk), Doug J Barrett, Luke Phillips, Nick Donnelly, Kyle R Cave; Department of Psychology, University of Southampton, Southampton, England – Purpose. In visual search tasks, single target searches are most efficient when the target can be discriminated from other items in the display by differences within a single feature dimension. We investigate whether this efficiency is maintained when either of two targets specified by differences within a single feature dimension can appear. Method. Participants responded to the presence or absence of a specified color target in displays of eight heterogeneous color patches. Three separate searches were carried out, with participants searching for (i) color A, (ii) color B, or (iii) color A or B. The order of presentation was counterbalanced, and exposure thresholds for 71% correct performance were determined using a two up one down staircase procedure for single and multiple target searches (N=37). Results. Exposure thresholds in the A or B condition significantly exceeded the exposure thresholds for A and B. Identical search conditions using complex shapes, however, produced a different pattern of results with exposure thresholds for the A or B condition being statistically equivalent to the summed thresholds for conditions A and B. Conclusion. Searching simultaneously for either of two color-targets is very inefficient compared to searching for a single color-target. This suggests that guided search is possible for a single color-target but not for a single complex shape target, or for multiple color-targets when these are not linearly separable in color space from other items in the display.

**SU94**

Investigating the spatial modulation transfer function of attention – distinguishing between effects of false target crowding and spatial frequency

Joetta Gobell (joetta@uci.edu), Chia-huei Tseng, George Springer; University of California at Irvine, CA, USA – We wish to study observers’ ability to divide attention more and more finely in a search task, i.e., to study the spatial modulation transfer function of attention. Prior to viewing a black-and-white test stimulus, subjects are shown a map of the search regions (defined by a red-green grating) where attended stripes–within which a target (T) can occur–are green, and nontarget areas are red (or vice versa for other observers). Observers tend to ignore the fine structure required by the map unless false targets (FTs) are placed in unattended areas to force confinement of attention to the to-be-attended stripes. As the stripes become thinner [spatial frequency (SF) of the attend/nonattend grating increases] search performance deteriorates (ARVO, 2001; VSS, 2002). Unfortunately, there is a confounding effect of FT-crowding: at high SFs, FTs are closer to Ts than at lower SFs. We discriminate the effects of attention and FT-crowding by, unbeknownst to the observers, embedding occasional one-FT trials (stimuli with only one FT) in a series of stimuli with many FTs.

Results: For identical one-FT stimuli (obviously with the same FT-T distance), search performance still consistently decreases with an increase in the to-be-attended SF. Attempting to divide attention finely has a cost (which is why observers don’t do it unless forced to by FTs). However, crowding also has a big effect–more and/or closer FTs impair T detection. Discriminating the effects of FT-crowding from spatial frequency fall-off enables a more accurate model of the malleability of visual spatial attention, per se.

**SU95**

A biased competition computational model of spatial and object-based attention mediating active visual search

Linda J Lanyon (lanyon@plymouth.ac.uk), Susan L Denham; Centre for Neural & Adaptive Systems and Institute of Neuroscience, University of Plymouth, UK – Monkey feature conjunction search data [1] indicate that colour is more important than form in driving the scan path. Target object-based attentional effects appear to develop over a time course beginning later than spatial attention in area V4 [2,3] and target-coloured features are enhanced in parallel across the visual scene in this area [4]. Parietal area LIP encodes colour information where this is behaviourally relevant [6] and may act as a saliency map [7] that determines positions of potential targets during visual search. This computational model shows that object-based attention in V4 is able to provide featural information to LIP necessary for it to become an integrator of information used to guide the scan path towards behaviourally relevant features. The model suggests that spatial inhibition of return in the scan path may be implemented within parietal cortex [8] partly as a result of a scene-based “novelty” bias, possibly supplied by frontal regions [9]. Resultant active vision scan paths detect target-coloured stimuli across the scene, as found in [1]. Also, the area within which object-based attention develops and a target can be identified [10] may be constrained by the initial spatial focus of attention.
SU96

Searching for stimulus-driven shifts of attention

Steven L Franconeri1 (franconer@wjh.harvard.edu), Daniel J Simons2; 1Harvard University, USA, 2University of Illinois, Urbana-Champaign, USA – Demonstrating that a stimulus-driven attention shift is a thorny problem. In the attention capture literature, stimulus-driven attentional shifts are inferred when the task provides no incentive to attend to the critical feature. Using this definition, most studies suggest that when the critical feature is unpredictable of target location in a visual search task, dynamic events (e.g. onset, looming) capture attention but static singletons (e.g. unique colors or shapes) do not.

In practice, even if a feature is unrelated to the target, subjects might attend to it voluntarily. For example, because observers must anticipate the appearance of the search display itself, this top-down goal bias subjects to attend to any dynamic event. Without this bias, dynamic events might not capture attention (Gibson & Kelsey, 1998). We rule out this explanation with a search task in which all display changes (except the critical dynamic event) are made during saccades. Even when the task does not require a top-down bias toward display changes, the abrupt onset of a new item still garners attentional priority.


Acknowledgment: Grant support from NEI, NIMH, AFOSR

SU98

Are the singleton-processing brain activities contingent on attentional set? Toshihide Imamura (imamura@pv.crl.go.jp), Satoru Miyachi: Brain information Group, Kansai Advanced Research Center, Communications Research Laboratory, Japan – A salient object such as a feature singleton captures visual attention only when it matches the observer’s attentional set. Here we study whether the neural activities for processing of feature singletons are also contingent on the observers’ attentional set. We conducted an event-related fMRI study in which observers were required to perform two types of detection task (singleton detection and luminance-change detection task) using the identical stimulus set. The stimulus comprised four drifting sinusoidal gratings surrounded by gray rings. In the three quarters of the trials, one of the four gratings was differentiated in one feature dimension (color, shape, or drifting speed). In one tenth of the trials, luminance of the gray rings were decreased for 16.7 ms. The feature singletons would match to observers’ attentional set in the singleton detection task but would not match in the luminance-change detection task. Although the activated brain areas were variable across the feature dimensions and the subjects, a fixed effect analysis from six subjects revealed the following results. Firstly, in the singleton detection task, the singleton stimuli induced brain activities in the bilateral intraparietal areas and in the bilateral extrastriate cortices. In contrast, the control stimuli, which did not contain any feature singleton, did not induce the bilateral intraparietal activation. This result suggests that the bilateral intraparietal areas participate in the processing of the feature singletons. Secondly, in the luminance-change detection task, as in the singleton detection task, the bilateral parietal areas were activated only by the singleton stimulus though the singletons would not match to observers’ attentional set. This result suggests that the intraparietal activities induced by the feature singletons were not contingent on the observers’ attentional set.

SU99

Prioritization by visual transients in search: Evidence against the visual marking account of the preview benefit

Artem V Belopolsky1 (belopolski@uiuc.edu), Ian Theeuwes, Arthur F Kramer1; 1Beckman Institute, University of Illinois, Urbana-Champaign, USA, 2Department of Cognitive Psychology, Vrije Universiteit, Amsterdam, Netherlands – There is an ongoing debate as to whether prioritizing new elements over old elements in visual search (the so-called preview benefit) is the result of top-down inhibition of old objects (i.e., visual marking; Watson & Humphreys, 1997, 1998, 2000; Kunar, Humphreys and Smith, in press) or attentional capture by new elements (Donk & Theeuwes, 2001). The present experiment shows a preview benefit when there are no old elements and there is nothing to inhibit. Participants viewed multi-element displays while a subset of elements was briefly flashed. Participants prioritized flashed elements over non-flashed elements, showing results similar to visual marking. Our results provide evidence...
that the preview benefit in visual search is the result of attentional capture by luminance transients.

SU100
Size and shape of the attentional spotlight affect efficiency of processing
Cesar Galera1 (agalera@usp.br), Michael W. von Grünau2; 1FFCLRP, DPE, University of São Paulo, Brazil, 2Department of Psychology, Concordia University, Montreal, Québec, Canada—Purpose: In this study, we examined the effect of cueing for the size and for the shape of a spatial area containing relevant items for a visual search task. Methods: For the size study, the cue could be a small (5.5deg) or a large (13.5deg) circle, presented at the center of the monitor screen, followed by the relevant stimuli presented always in the same place, around the fixation point. For the shape study, the cue could be a vertical or a horizontal rectangle (4deg x 12deg) and the stimuli were also presented around the fixation point. Results: Cueing for area size is effective, with valid cues decreasing and invalid cues increasing search times, with respect to non-informative cues. With the valid cue, there is a significant cue size effect, with performance being better when the stimuli are presented inside a small shape than inside a large shape. With the invalid cue, the reaction time increases when the stimuli are presented inside a shape larger than the cued one, but not when the stimuli are presented in a shape smaller than the cued one. The cueing for the size of the area is also effective, with valid cues decreasing and invalid cues increasing search times, with respect to non-informative cues. In general, the vertical cue produced faster responses than the horizontal one. Conclusions: The effectiveness of cueing is evidence that shape and size of the attentional spotlight can be adjusted by experimental manipulations.

Acknowledgment: CNPq (CG), NSERC, FCAR (MvG)

SU101
Face-gender discrimination is possible in the near-absence of attention
Leila Reddy (Ireddy@kalb.caltech.edu), Patrick C Wilken, Christof Koch; California Institute of Technology, Pasadena, CA, USA—Several studies have shown that simple visual tasks, such as color or orientaton discrimination, can be performed in the near-absence of attention. In contrast, participants are unable to perform slightly more complex tasks, such as discrimination between the arbitrarily rotated letters “T” and “L” or between two spatial arrangements of colors when attention is engaged elsewhere. Recently, Li and colleagues (2001,2002) showed on the basis of a dual-task paradigm that natural scenes (e.g., animal vs. non-animal) can be categorized in the near-absence of attention. In this study we investigate whether subjects are able to perform a sub-ordinate level categorization task in the near-absence of attention. Participants performed a face-gender discrimination task (database of colored faces obtained from MPI, Germany) either alone (single-task), or concurrently (dual-task), with a known attentional demanding task (5-letter T/L discrimination). Overall performance on face-gender discrimination suffered remarkably little impairment in the dual-task condition compared to the single-task condition. Similar results were obtained in a set of experiments which controlled for possible training effects or low-level representations that were accessable outside the focus of attention. Results: We thank Heinrich Bueltloph for access to the face database.

Acknowledgment: We thank Heinrich Bueltloph for access to the face database.

SU102
Object-token individuation protects targets from object substitution masking
Cathleen M. Moore1 (cmn150@psu.edu), Alejandro Lleras2; 1Pennsylvania State University, USA, 2University of British Columbia, Canada—Object Substitution Masking (OSM) occurs when a very sparse mask, such as a group of four single-pixel dots, is presented simultaneously with the target, such as a circle with a small gap that must be localized (Di Lollo, Enns, & Rensink, 2000). Despite the minimal opportunity for contour interference afforded by the sparse masks, when a mask lingers following target offset, severe masking can occur. Phenomenologically, it can appear as though the target is “sucked” out of the array by the mask. Using apparent motion, we showed that OSM can occur even when no mask appears at the target location, as long as a stimulus is perceived as the same object token as the target lingers elsewhere in the display (Lleras & Moore, 2003). These findings suggest that at least a component of OSM occurs at object-level representations of the scene. In the present study we examined the effect of cueing for the size and for the shape of a spatial area containing relevant items for a visual search task. Methods: For the size study, the cue could be a small (5.5deg) or a large (13.5deg) circle, presented at the center of the monitor screen, followed by the relevant stimuli presented always in the same place, around the fixation point. For the shape study, the cue could be a vertical or a horizontal rectangle (4deg x 12deg) and the stimuli were also presented around the fixation point. Results: Cueing for area size is effective, with valid cues decreasing and invalid cues increasing search times, with respect to non-informative cues. With the valid cue, there is a significant cue size effect, with performance being better when the stimuli are presented inside a small shape than inside a large shape. With the invalid cue, the reaction time increases when the stimuli are presented inside a shape larger than the cued one, but not when the stimuli are presented in a shape smaller than the cued one. The cueing for the size of the area is also effective, with valid cues decreasing and invalid cues increasing search times, with respect to non-informative cues. In general, the vertical cue produced faster responses than the horizontal one. Conclusions: The effectiveness of cueing is evidence that shape and size of the attentional spotlight can be adjusted by experimental manipulations.

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SU103
Object Substitution Masking Does Not Spread within a Perceptual Group
Do-Joon Yi (dojoon.yi@vanderbilt.edu), Marvin M Chun, Geoffrey Woodman; Vanderbilt University, USA—When a briefly flashed target object is surrounded by four dots that all disappear at the same time, the target object can be easily discriminated. However, if the four dots remain visible after the target object disappears, discrimination is severely impaired. The object-substitution masking (OSM) account proposes that the representation of the target object is replaced by the representation of the four-dot mask (Di Lollo et al., 2000). Jiang and Chun (2001) have shown that a four-dot mask need not surround a target object to impair its discrimination but that OSM occurs even when the four-dot mask is displaced away from the target. The present study extends past work by testing whether the four-dot stimulus may mask targets in an object-based manner such that neighboring objects that are perceptually grouped with a target may suffer from greater OSM. This hypothesis predicts that the four-dot masks will not only replace the target they surrounded but also neighboring objects that are grouped with it via connectedness or color. However, across a series of experiments using color and connectedness as grouping cues the flanking objects that were grouped with the masked object were always discriminated more accurately than flanking items that were not grouped with the masked item. These findings indicate that attention spreads to grouped flankers but not ungroupped flankers prior to OSM, making the grouped object less vulnerable to OSM. However, the substitution masking of a target stimulus does not spread in an object-based manner.

SU104
Neural signature of consciously-perceived visual events
Russell Epstein1 (epstein@psych.upenn.edu), Nicholas Hon1, John Duncan2; 1University of Pennsylvania, USA, 2MRC Cognition & Brain Sciences Unit, UK—Which brain regions are necessary for the conscious perception of a visual stimulus? We examined this question by scanning subjects with fMRI while they viewed an array of four photographs which flickered on and off several times a second. Every few seconds, one of the four photographs was replaced by a new photograph. Subjects were required to attend to two of the four array locations whilst ignoring the other two. We compared the event-related fMRI response to the appearance of new stimuli in the attended locations to response to stimuli in the unattended locations. The presence of a constant stream of visual transients ensured that subjects rarely noticed the appearance of a new photograph in the unattended locations. A surprise memory test given at the completion of the scan verified that stimuli in the unattended locations were rarely...
encoded into memory. Greater response to attended events was observed in ventral stream visual areas such as fusiform gyrus, but not in frontal-parietal regions that have previously been implicated in conscious perception. We suggest that occipitotemporal regions are involved in conscious perception, while frontal-parietal regions may be involved in redirecting attention towards novel stimuli, storing them in working memory, and arranging responses to them.

SU105
Can visual objects be accessed in rapid counting without their positions being encoded? John L Dennis (dennis@ruccs.rutgers.edu), Vidal Arnan; Rutgers University Center for Cognitive Science, USA – Previous research has shown that “subitizing”, i.e., the process of enumeration when there are fewer than 4 items, is accurate and relatively rapid (70 ms/item) whereas “counting”, i.e., the process of enumeration when there are more than 4 items, is slow (300 ms/item), and error-prone. Trick & Pylyshyn (1994) have hypothesized that subitizing requires preattentive individuation and access by a visual index, as assumed to be provided by the FINST indexing mechanism (Pylyshyn 1989). Their assumption is that subitizing relies on a process of enumerating indexes without the need to encode object locations. Slower counting, on the other hand, relies on scanning attention to each of the objects in the display, and thus may result in the encoding of the objects’ locations. To explore this proposal we presented observers a total of 10 objects (small rectangles). A subset of 3, 4, or 5 of these (the “targets”) were a different color from the rest of the objects (they were either red or green), and all objects were present for 300 ms before they changed to a neutral gray. Subjects were instructed to count the number of objects of the specified color as fast as possible. After indicating how many targets there were (by pressing keys marked 3, 4 or 5), observers selected the targets by clicking on the objects that had been the target color. If the rapid counting involved in this procedure (135 – 300 items/sec) does not require accessing the objects by scanning the display, then observers may be able to enumerate objects without the opportunity to encode their locations. Hence they may be able to count objects without correctly locating them or to locate objects without having counted them. Errors in counting need not be accompanied by errors in locating objects. We found that when subjects made counting errors there was only a 0.19 probability that they would also make a location error. The large difference between expected and observed errors will be discussed.

SU106
Can flashing objects grab visual indexes in multiple object tracking? Alex Kashmier (akash@eden.rutgers.edu), Zenon W Pylyshyn; Rutgers Center for Cognitive Science – Visual Indexing Theory (Pylyshyn, 1989, 2001) assumes that events such as flashes cause indexes to be automatically assigned, or “grabbed,” by the flashed objects. It also assumes that once assigned, indexes stay assigned to the same individual objects as these objects move around in the visual field, and even when they briefly disappear, thus accounting for the high performance observed in multiple object tracking (MOT) studies. In the present study we ask whether already assigned indexes can be draw away by flashing nontargets during tracking. Method: Observers tracked 4 targets among a total of 8 identical randomly-moving objects. Approximately midway through the 6 s tracking trial, 4 objects flashed on and off for 300 ms: two of these were targets being tracked and the other two were nontargets. We examined only those trials (37% of the total trials in our case) in which exactly one target was lost and replaced by one nontarget, since in those cases it was unambiguous which target had been lost and which nontarget erroneously selected as its replacement. For these trials we asked: (1) was the dropped target more often one that had flashed than one that had not? and (2) was the erroneously substituted nontarget more often one of the distractor objects that had flashed than one that had not. Results: The results showed that (1) the target object that was lost was no more likely to be one that had flashed than one that had not flashed, and (2) the nontarget that was erroneously selected was significantly more often one that had flashed. We interpreted these results to suggest that once objects were indexed for tracking, flashing them did not tend to cause the index to be dropped, but flashing nontargets tended to draw indexes away from tracked targets.

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SU107
Measuring the attentional demand of multiple object tracking (MOT) Carly Leonardi (carlly@ruccs.rutgers.edu), Zenon W Pylyshyn; Rutgers Center for Cognitive Science – Recently we reported an attempt to measure the attentional demand of the Multiple Object Tracking (MOT) task, which many people have claimed requires considerable attentional resources. The experiment we reported appeared to support this contention since tracking performance was worse when carried out simultaneously with a color-change monitoring task. However the monitoring task we used required an immediate response, so it is possible that this decrement in tracking was not due to the attentional requirement of visual monitoring, but to the requirement of responding while tracking. Method: In the present studies we compared performance on MOT while monitoring for a brief change in the color of targets, nontargets or an area-matched fixation point. We also measured baseline tracking performance without monitoring, or on trials when a monitored event failed to occur. We examined dual task performance under both an immediate-response (forced choice) condition and a delayed response condition, in which the observer had to indicate whether a color change had taken place only after completing the tracking trial. Results: We found that tracking performance was worse when monitoring than in the baseline control, but only when the response was made immediately, during tracking. When the response to the monitoring task was made at the end of each trial no decrement in tracking performance was observed and all monitored locations led to the same tracking performance. This finding is compatible with other findings (e.g., Alvarez, Horowitz & Wolfe, 2000) showing that observers can track without decrement while engaged in a secondary task such as search. It is also compatible with the view (Pylyshyn, 2001) that tracking involves a preconceputational mechanism. These findings suggest that apparent attentional tasks such as MOT may not draw on the same resource as other apparent attentional tasks such as monitoring or search.

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SU108
Does tracking disappearing objects in MOT involve predicting the locus of reappearance? Brian P Keane (positivity@usa.com), Zenon Pylyshyn; Rutgers University Center for Cognitive Science – Purpose. In Multiple Object Tracking (MOT), subjects follow a flashed subset of identical visual objects that move independently about a display. It is known that under some conditions it is possible to track objects even when they completely disappear from view (e.g. Scholl and Pylyshyn (1998)). Our primary aim in this study is to examine whether tracking mechanisms are predictive, and, in particular, whether subjects track better when objects reappear at a location predicted by their trajectories rather than at some other location, such as at the location at which they disappeared. A secondary aim is to see for how long objects can disappear without significantly interfering with tracking. Methods. Four of eight objects momentarily flash, and subjects are asked to track the flashed objects for 5 seconds. Midway into each trial, all objects on the screen disappear and reappear either a) at point of disappearance (“non-move” condition); or b) at a position consistent with trajectory (“move” condition). Three disappearance intervals were used: 150ms, 300ms, and 450ms. Results. Subjects tracked better in the non-move condition than in the move condition for all disappearance durations. For the move condition subjects tracked best in the shortest disappearance interval and worst in the longest. There was no significant difference between performance at the different disappearance durations for the non-move condition. Conclusion. The main conclusion suggested by this experiment is that
objects are not tracked predictively for disappearance durations we have examined (up to 450 ms). Subjects appear to only keep track of where objects disappear and not where they are likely to reappear.

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SU109
Items in MOT are easily lost when they chase each other
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— Based on a multiple object tracking (MOT) paradigm, Scholl, Pylyshyn, & Feldman (2001) reported that when the pairs of items were “merged”, participants ability to track them were significantly disrupted. This disruption also occurred when the items were merged for a short time (Scholl & Feldman, 2002), or in a three-dimensional display (Suganuma & Yokosawa, 2002). Scholl et al. (2001) argued that in an item merging display, visual objecthood was mediated by the whole (i.e. two items plus a merging line), but not by each item. However, in previous studies concerning this item-merging effect, the items were always visually connected with the merging line. Therefore, both factors of visual connectedness and of perceptual grouping are confounded. Our aim was to isolate both factors on MOT display. To solve this problem, we tested an item-merging display without merging lines. In our experiments, four target and four distractor items were presented. During the movement sequence for 14 seconds, the target and the distractor items were made in a pair, and the target ‘chased’ the distractor (or vice versa). Participants’ performance for the chasing condition was significantly lower than that for the control condition (ordinary MOT), and was worse when the items made a chasing movement in a close distance to each other. Thus, we have observed a similar result to the item merging effect even without visually presented merging lines. These results indicate that the visual objecthood which each item possessed was disrupted by perceptual grouping (caused by the factor of uniform destiny or proximity). This shows that both perceptual grouping and visual connectedness affects MOT. However, the error rate of chasing condition was higher than that of the line or rubber band conditions of Scholl et al. (2001). This indicates that visual connectedness plays an important role than perceptual grouping (or than Gestalt laws) on the item merging effect.

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SU110
Inhibition of nontargets during multiple object tracking (MOT)
Zenon W Pylyshyn (zenon@ruccs.rutgers.edu), Carly Leonard; Rutgers Center for Cognitive Science – In Multiple Object Tracking (MOT), observers keep track of a set of (about 4) targets which move randomly and independently among a set of identical nontargets. Earlier we reported that keeping track of the identity of targets (as measured by recall of their previously assigned labels) tended to be poorer that keeping track of their status as targets, and that ID errors tended to increase more rapidly with trial length. We provided evidence that this was likely due to the fact that targets tended to be more frequently confused with other targets than with nontargets.

A possible reason for this asymmetry is that nontargets might be actively inhibited in MOT, thus resulting in their being less readily confused with targets. In the present study we investigated this hypothesis using the dot-probe method first adopted by (Watson & Humphreys, 1997). Observers viewed an MOT display during which they had to detect the brief appearance of a small spot that occurred on 50% of the trials at one of 3 location types: on a target, a nontarget, or somewhere in between. At the end of each trial, observers selected the targets using a mouse, and then indicated whether or not there had been a probe during that trial.

We found that accuracy for detecting a probe was significantly worse when the probe was on a nontarget. No other pairwise contrast was statistically reliable. Tracking performance also appeared to be the same for all probe locations as well as for the no-probe condition. These results are consistent with the hypothesis that nontargets are inhibited during MOT, thus accounting for the asymmetry between target-nontarget and target-target confusions. They are also consistent with the hypothesis that MOT does not consume the same visual-attention resources as monitoring a visual event. These results are discussed in relation to the FINST Visual Indexing Hypothesis.

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SU111
Attentive tracking of objects vs. substances
Kristy vanMarle (Kristy.vanMarle@yale.edu), Brian J Scholl; Yale University – Recent research in vision science, infant cognition, and word-learning all suggest a special role for the processing of individual discrete objects. But what counts as an object? Answers to this question often depend on contrasting object-based processing with the processing of spatial areas, or unbound visual features. In infant cognition and word-learning, though, another salient contrast has been between rigid cohesive objects and nonsolid substances. Whereas objects may move from one location to another, a nonsolid substance must “pour” from one location to another. Here we explore whether attentive tracking processes are sensitive to dynamic information of this type. We employ the multiple-object tracking task, wherein observers are presented with an array of identical items, a subset are briefly highlighted as targets, and observers must use attention to keep track of the targets as all of the items move randomly about the display — so that they can indicate the targets at the end of a 20-second tracking period. We find that observers can easily track 4 in 8 identical unpredictably-moving items which move as discrete objects from one location to another, but cannot track similar entities which noncohesively ‘pour’ from one location to another -- even when the items in both conditions follow the same trajectories at the same speeds. Other conditions reveal that the inability to track multiple ‘substances’ stems not from the violations of rigidity or cohesiveness per se, since subjects are able to track multiple non-cohesive collections and multiple non-rigid deforming objects. Rather, the impairment is due to the dynamic extension and contraction during the ‘substance-like’ motion, which render the ‘the’ location of the entity ambiguous. We will demonstrate these and other effects, which suggest a convergence between processes of mid-level adult vision and infant cognition, and in general help to clarify what can count as a persisting dynamic ‘object’ of attention.

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arrays was equivalent and above chance in both conditions, even for arrays prior to change detection trials, and was not correlated with change detection. These results have implications for current theories of change blindness and visual memory. Theories proposing that visual details are not retained in memory can not easily account for these results, nor can theories positing similar retrieval mechanisms for on-line change detection and long-term recognition.

**SU113**

Are there event-related potential (ERP) correlates of implicit change detection? A miscuing paradigm  

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Glasgow Caledonian University, UK—Is conscious change detection produced by the implicit registering of a sensory mismatch drawing attention to the change? Electrophysiological correlates for early, implicit stages in this process have been claimed in the auditory domain (Nätänen, 1992), but evidence is mixed in vision. The strongest evidence for early implicit detection would be significant event-related potentials (ERPs) indicating a sensory mismatch representation when psychophysical performance on conscious change detection is close to chance. In the present experiment subjects had to detect an orientation shift in one of six heterogeneously oriented D6 pattern elements. To maximise sensory mismatch, while keeping subject performance poor, a 90° increment miscued condition was included. For such large element changes, performance, even in an uncued (‘change blindness’) condition was substantially above threshold (83%) but for the miscued condition; performance remained close to chance (56%). ERPs were recorded from 20 electrodes from 9 subjects in a miscuing paradigm (60% correctly cued, 20% uncued, 20% miscued trials). In the uncued condition, there was a larger posterior negativity (ca. 200-300ms, N2, p<0.001) and a larger positivity (ca. 350-600ms, the P3, p<0.02) to increments, but when miscued these differences were absent. There was also no evidence of the putative sensory mismatch component (Tales et al, 1999) which should be evident in the miscued condition. Hence, in a paradigm designed to optimize the detection of implicit components we do not find evidence of implicit change detection. This is consistent with a recent psychophysical study (Mitroff et al, 2002).

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**SU114**

Failure to detect brief disruptions to visual events  

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Kent State University USA—Previous research on inattention blindness has demonstrated that when people focus their attention on one object they do not detect the appearance of another object. In the current experiments, we demonstrate that inattention blindness can occur even when subjects are not required to attend to a distracter object. Subjects viewed brief videos of simple real-world events such as a collision between two people, or a person sitting down and reading a newspaper. Each event included a moment in which an object moved from one side of the screen to another. For example, during the newspaper video, the actor turned the page. Within these movements, we placed a disruption consisting of very low spatial frequency motion field that was either consistent or inconsistent with the direction of on-screen object motion. In our initial experiments, most subjects failed to detect 200 ms disruptions, whether or not they were consistent with their object-motion context, but were more successful in detecting disruptions that did not occur during on-screen movements. In a second experiment, we lengthened the disruptions and found no increase in detection of 400 ms and 600 ms disruptions. In addition, we tested whether a static stimulus would be detected, and found that even a 600 ms series of blank frames was not detected by a large proportion of subjects. We suggest that visual attention in an ecological context is strongly shaped by well-structured events such that samples from the visual world may not reach awareness once sufficient information has been obtained to specify the nature of an event.

**SU115**

Spatial cueing with and without distractor on contrast thresholds for face recognition  

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Institute of Occupational Health, Helsinki, Finland—Purpose: We investigated the effect of spatial attention on contrast sensitivity for face recognition using Posner spatial cueing method. The aims were to explore whether an attention effect occurs for a recognition task of face images, and in a further experiment, to investigate the effect of a ‘distracter face’ on the complex task. Methods: Contrast thresholds at which a face was correctly recognised were measured in a 4AFC procedure. Subjects were extensively pre-trained in recognising the four synthetic face images. The stimulus image was presented on either the left side or the right side of the fixation point. Contrast sensitivity was measured for 79% correct responses. Posner cueing was used to direct spatial attention. An arrow cue pointing left or right preceded the stimulus for 100ms. The signal display was presented for 60 ms. The cue validity was either 100% (always pointed at the upcoming stimulus location) or 50% (pointed randomly on the same or different side as the stimulus). In the first experiment, only the ‘face image’ was presented. In the second experiment, subjects were required to ignore a ‘distracter face’ in the location not occupied by the stimulus. The set size for the divided attention task was limited to two because of the high memory load. Results: In the first experiment, contrast sensitivity for face recognition increased in the range of 5% to 8% with accurate cueing of spatial location. In the presence of the distractor face, contrast sensitivity increased significantly in the range of 32% to 67% when the location was accurately cued. Discussion: Results revealed that valid cueing of the spatial location of the stimulus increased contrast sensitivity for face recognition. The benefits for spatial cueing increased significantly in the presence of a distracter face. Data are discussed in terms of existing data with simpler stimuli and to existing models of attention.


**SU116**

A neural framework for visual attention  

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California Institute of Technology, USA—We present a theory of visual attention motivated by recent, seemingly contradictory psychophysical findings. We previously observed that natural scenes and objects could be categorized while attention was engaged by a concurrent task, suggesting that not only simple features can be processed "preattentively". Yet the same natural scenes or objects were not necessarily categorized in parallel during visual search experiments, implying that the two paradigms (dual-task and visual search) might in fact reveal distinct attentional resources. We proposed that the ability to discriminate stimuli preattentively (in dual-task) is dependent upon the existence of selective neuronal populations at any level of the visual cortical hierarchy, while parallel visual search (which is expected to occur for such stimuli) can sometimes be prevented by competition within the large receptive fields (RFs) of neurons in high-level visual areas. Indeed, we found that in such cases, increasing inter-stimulus distance could facilitate visual search. We organize these and other findings into a unified framework by proposing that (i) the preattentive visual system can be equated with feed-forward cortical selectivities, and (ii) under the common label 'attention' are grouped at least two collections of feedback processes. The first one corresponds to "feature binding" mechanisms, allowing to process objects for which no selective neuronal population exists. The other corresponds to "biased competition" mechanisms, with the role of combating RF clutter. This framework thus reconciles two "classical" theories of attention. By relying on common properties of neuronal systems, such as cortical selectivities, hierarchical organization, feed-forward and feedback circuitry, and RF sizes, this theory explains the apparent discrepancy between the remarkable efficiency of our visual systems on the one hand, and its
dramatic failures observed in situations such as change blindness, on the other hand.

**SU117** Semantic repetition blindness: Picture versus word effects  
Heather Buttle (h.m.buttle@bangor.ac.uk), Carys K Ball, Jing Zhang, Jane E Raymond; University of Wales, Bangor United Kingdom — Repetition blindness (RB) refers to a failure to detect two occurrences of the same item when presented in a rapid serial visual presentation (RSVP). Similarly, semantic repetition blindness (SRB) is a failure to detect two conceptually related items. SRB has been found for pictures of associated items (Kanwisher, Yin, & Wojulik, 1999) and for a word and picture describing the same thing (Bavelier, 1994). However, there are conflicting findings as to whether SRB can occur for two semantically related words (McKay & Miller, 1994; Kanwisher, et al., 1999). Using a conventional RSVP paradigm, we investigated SRB using images of everyday branded products because these stimuli combine picture and word information and provide a wide range of easily recognized objects that can have different names but be closely associated semantically (e.g., Brand X cola and Brand Y cola are both colas). Using brand names as items, we used RSVP streams containing exact brand name repetitions (RB condition: e.g., Brand X cola, Brand X cola), repetitions of the same product category but using different brand names (SRB condition: e.g., Brand X cola, Brand Y cola), and no repetition (different product categories, different brand names; e.g., Brand X cola, Brand Z ketchup). We also tested these conditions using intact product images of the same products. Although robust RB was found when either word or picture stimuli were exact repetitions, SRB was only found with intact product images. These findings confirm that SRB reflects attentional processes special to semantic categorisation of visual image processing.

**SU118** Visuo-perceptual abilities in patients with atypical Alzheimer's Disease  
Diego Fernandez-Duque (diego@rothen-baycrest.on.ca), Sandra E Black; University of Toronto, Canada — We tested the spatial attention and visuo-perceptual abilities of two patients with atypical Alzheimer's disease. Neuroimaging revealed hypoperfusion in parietal, posterior temporal, and lateral occipital cortex. In patient R.D, who exhibited neglect and extinction, hypoperfusion was lateralized to the right hemisphere. In patient M.M., who had no spatial neglect, hypoperfusion was left lateralized. Both patients were impaired in the copying and matching of simple shapes, but recognition of more complex figures was relatively preserved. A 2-AFC task assessed the patients' ability to perceive two objects at the same time. In this task, two concentric figures (e.g., a circle and a square) were briefly displayed. When the figures were displayed sequentially, patients correctly reported whether the shapes were the same (e.g., two circles), or not (e.g., a circle and a square). In contrast, performance was close to chance when the figures were displayed simultaneously. This simultanagnosia may stem from a deficit in spatial attention. To explore this possibility, in a follow-up study two concentric figures were displayed, and patients had to report the shape of one of them (i.e., the target). In separate blocks, the feature that defined the target was either spatial (e.g., the 'large' figure) or non-spatial (e.g., the 'black' figure). Spatial cues led to more accurate performance than non-spatial cues. This result is consistent with an attentional account of simultanagnosia, by which patients can attend to a selected stimulus, but have difficulties disengaging from it.

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**SU119** Explaining why the perceived brightness of a flash is modified by temporal relationships with its neighbors: the commitment, adaptation, and comparison model  
John E Jacobson (jacobson@salk.edu), David M Eagleman, Terrence J Sejnowski; The Salk Institute, CA, USA — We have previously reported that the perceived brightness of a brief flash depends on its temporal relationships with its neighbors (the Temporal Neighborhood Illusion [Eagleman et al, VSS 2002]). In our experiment, two flashes, identical in luminance, appear on the screen: one lasts for 56 ms ('brief'), the other for 278 ms ('long'). When the flashes have simultaneous onset, subjects report that the brief flash looks dimmer than the long flash (the Broca-Sulzer effect). Surprisingly, however, when the flashes have simultaneous offset, the brief flash appears conspicuously (~30%) brighter (and much brighter than it appears in isolation). Our new experiments suggest that the brightness enhancement of the offset-aligned flash results from a comparison with the long flash. In our model, the offset-aligned flash appears brighter because the visual system commits to a brightness value for the long flash (say, labeling it a '10') -- but the associated neural activity fatigues (adapts) through time. When the new (brief) flash subsequently appears, its attendant neural activity, unfatigued, is greater. When the system compares the ratio of activities, it is forced by its previous commitments to label the new flash brighter, say as a '13'. This commitment-adaptation-and-comparison model suggests that two independent representations contribute to brightness perception: one based on neural activity (probably firing rate in V1), and another system that labels the object's brightness, irrespective of the neural fatigue that inevitably follows. This second system, which maintains adaptation-blindness and provides computational savings, is here unmasked by the Temporal Neighborhood Illusion.

http://www.cnl.salk.edu/~eagleman/TNE

**SU120** Pre-adaptation effects in multistable binocular rivalry  
Satoru Suzuki (satoru@northwestern.edu), Marcia Grabowecky; Department of Psychology, Northwestern University, Evanston, IL 60208 USA — We recently reported path dependence and on-line adaptation in multistable binocular rivalry (Suzuki & Grabowecky, 2002, Neuron, 36, 143-157). Perceptual transitions between a pair of related shapes (e.g., opponent convex and concave shapes) were elevated, termed "perceptual trapping." During such trapping, on-line adaptation to perceived shapes increased the probability to break from trapping and to shift to an unrelated shape. Here we examined effects of pre-adaptation in multistable binocular rivalry. As before, rivalry displays were quadra-stable, generating 2 pairs of opponent shapes (e.g., diamond and hourglass [convexity opponent] and right- and left-pointed chevrons [curvature opponent]). Observers pre-adapted to one of the 4 shapes. Adaptors were binocular, low contrast (compared to the rivalry stimuli), and contrast-polarity reversed (1.9 Hz) to prevent afterimages. In each trial, an adaptor (30 s) was followed by a rivalry inspection period (20 s) during which observers continuously reported dominant shapes. Transition probabilities to and dominance durations of adapted shapes were reduced relative to no-adaptation control conditions. Interestingly, adaptation to a shape also boosted its opponent shape in some cases (both in transition probability and dominance duration). These results cannot be explained solely in terms of low-level contour adaptation because similar effects occurred (though reduced in magnitude) with small adaptors (25% in area relative to rivalry stimuli). Further, we found evidence that perceptual transitions can be primed. For example, when diamond and hourglass shapes were alternated (0.6 Hz) during adaptation, the transitions between them were increased during rivalry. Thus, in multistable binocular rivalry, pre-adaptation weakens adapted shapes, can strengthen opponent shapes, and can prime specific perceptual transitions.

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**SU121** Parameters that affect adaptation in the human visual system  
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1Neurosciences Department, Stanford University, Palo Alto, CA, USA,  
2Psychology Department, Stanford University, Palo Alto, CA, USA — When a subject repeatedly views the same stimulus, the visual system exhibits a decreased response. This decrease in activity has been variously referred
to as "adaptation," "repetition suppression" and "priming," and has been observed using numerous techniques including single-cell recordings in primates and fMRI in humans. Previous studies examining adaptation in humans have simultaneously varied several parameters which may exert diverging effects. Here we examined the separate role of three parameters on adaptation and behavioral priming using an event-related fMRI design. The parameters that were manipulated were: the number of stimulus repetitions (n=1-8), the time between repetitions (ISI=0-16 or more sec), and the number of intervening stimuli between repetitions (i=0-8 or more). Subjects were instructed to classify animal images. Reaction time and accuracy were recorded during the fMR scans. Regions of interest involved in object recognition consistently exhibited repetition suppression. The dependence on n was graduated, adapting steadily with the first 4-5 repetitions of an image. Adaptation was significant for all values of i and ISI and maximal when there were no intervening stimuli. Surprisingly, increasing the number of intervening stimuli did not much change the amount of adaptation. Subject reaction-time data exhibited a similar but not identical dependence on these parameters. These results indicate that adaptation in the visual system is not a short-term phenomenon, but can persist with little reduction over many intervening images and long periods. Ongoing work is aimed at further elucidating the relationship between behavioral priming and fMR adaptation.

Acknowledgment: Supported by a National Institutes of Health training grant.

SU122
Weak motion aftereffect from a square wave test Fang Fang (fang0057@tc.umn.edu), Sheng He; Department of Psychology, University of Minnesota—In a complete linear system, the behavior of a square wave pattern can be predicted by its sinusoidal components. However, we observed a complete breakdown of the linear system prediction in the perception of motion aftereffect (MAE). The duration of the MAE was measured following a one-minute adaptation to a rotating radial grating. Four different luminance patterns were used for both the adapt and test stimulus: 1. sine wave, 2. square wave, 3. complex grating composed of the 1f, 3f, 5f and 7f harmonic components of the square wave grating, and 4. complex grating with the same components as 3, but with randomized phases. The sine wave stimulus generated the highest magnitude MAE, followed by the random-phase complex grating, then the square-wave-like complex grating, and lastly the square wave grating. To test whether the square wave grating is a weak adapter or a weak test for the MAE, we performed a cross adaptation experiment in which the sine wave and square wave gratings were paired in all four possible ways. Results show that both sine and square wave adaptation generated a strong MAE for the sine wave test, but neither induced nearly as strong of a MAE when tested with a static square wave grating. Further experiments ruled out the possibility that differential MAEs between these conditions are due to different peak contrasts in these patterns.

Linear system theory cannot predict the magnitude of the MAE in complex gratings. The spatial features of a test stimulus such as position reliability or luminance uniformity strongly influence the magnitude of the MAE. Sharp edges and local luminance uniformity can greatly reduce the MAE.

Acknowledgment: This research is supported in part by the James S. McDonnell Foundation

SU123
Multiplicative and suppressive effect of sustained and transient edge adaptation in peripheral target detection Farshad Moradi1 (farshadnr@caltech.edu), Shinski Shimojo1,2, 1Computation and Neural Systems Program, California Institute of Technology, Pasadena, CA, USA; 2NTT Communication Science laboratories, Atsugi, Kanagawa, Japan – Filling-in can be induced by high-contrast edge adaptation (Shimojo & Kamitani VSS’01), or after prolonged adaptation to a peripheral low-contrast object (Troxler 1904). Adaptation to sustained low-contrast vs. adaptation to transient high-contrast suggests synergy between contrast and edge adaptation, but the possible interactions are not well understood. We observed that presenting a low-contrast edge for 5-10 seconds and then flashing a high-contrast edge over it elicited the perceptual disappearance of a subsequent low-contrast edge at the same location. Neither adaptation to the low-contrast edge nor flashing the high-contrast edge alone had any significant effect. We investigated this effect using Gabor signals (2 cpd, 5 deg eccentric, sd=1, mean lum. 50cd/m2, background 50cd/m2). Target (contrast=4%) followed either a) a sustained (8 sec) low (4%) contrast stationary or drifting Gabor signal (adaptation only), b) a brief (20ms) high (~100%) contrast Gabor signal (flash only), or c) adaptation followed by flash (combined condition). A random-dot mask followed the target after 1 second. The task was to identify whether the target was present or not. Subjects (n=5) failed in less than 5% of the trials in adaptation only or flash only conditions, but more than 30% in the combined condition (p<0.0001). For combined condition trials, failure of detection was more pronounced after adaptation to a drifting Gabor than a stationary one (p<0.05). There was no significant difference between same or opposite contrast polarity (phase insensitivity). In other experiments we found: a) suppression is selective for orientation, and b) disappearance could be transferred to other locations. Results suggest 1) Contrast gain adjustment to transient change is processed separately from adaptation to sustained stimuli; 2) the two mechanisms interact non-linearly. Findings are compatible with non-local orientation selective cortical mechanisms presumably at the level of V1 to V4.

Acknowledgment: Supported by Caltech

SU124
Interactions of afterimages for orientation and color: New results force model revisions Gregory Francis (gfrancis@psych.purdue.edu), Wade Schoonveld; Purdue University—We describe experimental and modeling work related to a recently discovered orientation afterimage (Vidyasagar, et al, 1999). In this afterimage, sequential viewing of two orthogonally related patterns produces an afterimage of the first pattern. In recent work (Francis & Rothmayer, in press), we reported experimental measurements of this afterimage and modeled the effects with Grossberg's BCS-FCS theory. We now report new experimental results that both validate the basic explanation provided by the BCS-FCS theory and suggest that new mechanisms are required for the theory to remain consistent with the data. In particular, the experimental results suggest that the filling-in process in the FCS cannot be isotropic diffusion. We show how an alternative neural mechanism can account for our new results and continue to act much like diffusive filling-in for other contexts.

SU125
Attention dependent illusory line-tilt aftereffect Leila Montaser Kouhsari (montaser@ipm.ir), Reza Rajimehr; Cognitive Neuroscience Department, School of Intelligent Systems (SIS), Institute for studies in Theoretical Physics and Mathematics (IPM), Niavaran, Tehran, Iran – Selective visual attention modulates neuronal activation in different cortical areas. This type of neuronal modulation could be happened even in the early stages of visual processing where specific attributes of visual stimuli are processed. It has been psychophysically showed that visual aftereffects such as figural aftereffect (Shulman, 1992), motion aftereffect (Rees, Frith & Lavie, 1997) and tilt aftereffect (TAE) (Spivey, 2000) are modulated by attention. In this study we investigated the effect of visual attention on the tilt aftereffect of illusory lines. The stimuli contained a tilted illusory line (15 degree clockwise or counterclockwise from vertical or horizontal) induced by two colorful line gratings abutting each other with a phase shift. In the adaptation phase two transparent stimuli were presented for 30 sec and subjects were asked to selectively attend to one of the tilted illusory lines. The attended illusory line was announced to subjects before each trial by the color of its line gratings. Following adaptation, TAE was measured by presenting a vertical or horizontal illusory line in the same location. The TAE for the attended illusory line was significantly greater than non-attended illusory line (P < 0.05). The results showed that the
illusions of line-TAE depends on the presence of attention. Since visual area V2 seems to be the first stage in the processing of illusory lines, we could conclude that selective attention modulates the activation of V2 neurons.

**SU126**

Phase-specific interactions in the perceived blur of edges

Aaron C Bilson (bilson@unr.nevada.edu), Michael F Fry, Sarah L Moore, Michael A Webster; University of Nevada, Reno, US – The perceived blur of an image can be strongly affected by prior adaptation to a blurred or sharpened image or by induction from a blurred or sharpened surround (Webster et al., Nature Neuroscience 2002). We examined some of the stimulus properties controlling these interactions by comparing the adaptation and induction effects in simple edges with different luminance profiles but equivalent amplitude spectra. Stimuli were vertical edges, with amplitude spectra filtered over a range of slopes relative to 1/f. Different edge profiles were formed by shifting the phase of the component frequencies by fixed increments of π/4. A staircase procedure was used to adjust the spectral slope until the edge appeared properly focused. For phases other than 0 and π, the 1/f edges appeared blurred and therefore had to be physically sharpened. These perceptually blurry 1/f edges might therefore be expected to induce sharpness in a squarewave test, yet adaptation to them instead caused the test to appear blurrier, suggesting a dissociation between perceived focus and the effective focus for the adaptation. The magnitude of the adaptation and induction was also selective for the relative phase relations of the components and strongly selective for the contrast polarity of the edges. These results suggest that the perceived blur and blur interactions in local edges cannot be accounted for by the relative amplitude of the different frequency components and may instead depend on (potentially different) properties of the spatial luminance gradients of the edges.

**Acknowledgment:** Supported by EY10834

**SU127**

Afterimages and pursuit: refining Helmholtz’s theory of visual motion perception

Herbert C Goltz (hgoltz@imaging.robarts.ca), Douglas B Tweed, Ravi S Menon, Tutis Vilis; CHHR Group on Action & Perception, University of Western Ontario, London, Ontario, Canada – Why does the world appear stable during gaze shifts, yet retinally-fixed afterimages appear displaced with movements of the eyes? Helmholtz proposed these phenomena could be explained by linear summation of retinal and extraretinal motion signals. We studied the interaction between extraretinal information and the spatial patterns of afterimages during perceived afterimage motion. Six observers pursued a target which oscillated horizontally in the presence of 3 different afterimages created by fixation of large (~50°) high contrast patterns: 1) parallel line elements oriented at -45°, 2) the same line elements oriented at +45° and 3) a grid composed of both -45° and +45° components. Subjects reported the angle of perceived afterimage motion while pursuing horizontally. When the afterimage was of oblique parallel lines, its mean perceived motion angle was determined by line orientation: -34° ± 3° SE for lines at -45° and 31° ± 4° SE for lines at 45°. In both cases the percept swings slightly toward the horizontal motion angle of the eye. When the afterimage was a grid the mean motion vector was determined by the eye movement angle: 1° ± 1° SE. In all 3 instances, Helmholtz’s model predicts a perceived motion orientation of 0° since the eyes only move horizontally. Our results, however suggest that linear summation of retinal and extraretinal signals is not adequate for explaining perceived afterimage motion. Rather eye velocity must interact multiplicatively with the spatial gradient of illumination (or its afterimage). This approach predicts human perception and cortical activity correctly.

**Acknowledgment:** Supported by Canadian Institutes of Health Research & Human Frontiers Scientific Program

**SU128**

Simultaneous monocular and binocular motion aftereffects for radial flowfield stimuli

Michael W von Grunau (vgrunau@vw2.concordia.ca), Landrew MacKinnon; Concordia University, Montreal, Que., Canada – Purpose. The motion aftereffect (MAE) and interocular transfer (IOT) can be used to probe the human visual system for characteristics and location of motion mechanisms. We used these techniques to measure direct and transfer MAEs with static and dynamic test stimuli. Methods. Adaptation stimuli were random dot expanding radial flowfields with acceleration, 100% coherence and infinite lifetime, viewed by one eye. Testing was either with the same eye (direct MAE) or with both eyes (binocular MAE) followed by viewing with the adapting eye (monocular MAE). The duration of the direct, binocular and monocular MAEs was measured for static and dynamic test stimuli. Results. For both static and dynamic testing, the binocular MAE was much shorter than the direct MAE. It was also shorter than the monocular MAE, which was measured immediately after the binocular MAE had disappeared. On average, the direct and monocular MAEs were about equal. These effects were more pronounced for dynamic testing. Dynamic MAEs were longer than static MAEs. Conclusions. The results indicate the existence of a monocular and a binocular MAE, which are fairly independent and occur simultaneously. Binocular testing can preserve the monocular (direct) MAE, which then appears delayed, but in full strength.

**Acknowledgment:** Supported by NSERC and FCAR (MvG).

**SU129**

Visual motion adaptation can impair decision making in driving

Rob Gray1 (rogray@asu.edu), David M Regan2; 1Arizona State University East, USA, 2York University, Canada – Drivers are often faced with decisions, which have potentially life-threatening consequences. Accident reports indicate that errors in decision-making during driving (e.g., deciding whether or not to pull out in front of another vehicle) are the probable cause of the majority of accidents on our roadways. One possible source of these errors of judgment is that in some situations the information provided by the human visual system is inaccurate. We have previously shown that staring straight ahead during simulated driving on a straight open road can give the driver the illusion that the time to collision with other vehicles is longer than it really is. This effect occurs because the neural mechanisms in the human visual system sensitive to time to collision with an approaching vehicle become adapted to closing speed. Here we show that this closing speed aftereffect can impair the ability of a driver to decide whether there is sufficient time to (i) overtake another vehicle on the highway and (ii) execute a left-turn in front of oncoming traffic. Closing speed adaptation resulted in decisions that were delayed, of higher risk, and more variable.

**SU130**

Color-contingent orientation adaptation for unresolvable Gabor patches

Reza Rajinehr (rajinehr@ipm.ir); Department of Cognitive Neuroscience, School of Intelligent Systems (SIS), Institute for Studies in Theoretical Physics and Mathematics (IPM), Niavaran, Tehran, Iran – McCollough effect is an orientation-contingent color aftereffect in which adapting to differently colored gratings of different orientations produces negative color aftereffects contingent on bar orientation. In this study a ‘modified McCollough effect’ (color-contingent orientation adaptation) was introduced in order to evaluate the interactions between orientation and color in unresolvable patterns. At first orientation selective adaptation was examined for unresolvable Gabor patches. Adapting stimulus was a peripheral Gabor patch whose spatial frequency was beyond the perceptual resolution limit. Test stimulus was a low contrast thin line with either the same (‘same adapt-test’) or different (‘different adapt-test’) orientation with respect to the adapting Gabor patch. Results showed that although subjects were unable to discriminate the adapting orientation (the performance was at chance level), they discriminated the orientation of ‘different adapt-test’ more accurately than the orientation of ‘same
adapt-test’. In the second experiment adaptation to colored (green or red) unresolvable Gabor patches was tested using low contrast colored resolvable Gabor patches as test stimuli. Results revealed that orientation selective adaptation existed only when the colors of adapting and test stimuli were identical (‘color-contingent orientation adaptation’). According to these results the interaction between orientation and color occurs during the ‘modified McCollough effect’ in probably V1 or higher cortical areas when subjects have no conscious access to the orientation of adapting stimulus.

Acknowledgment: The author wishes to thank Patrick Cavanagh and Leila Montaser Kouhsari for helpful comments on the manuscript.

SU131
Further investigations of the distractor color preview effect (DCPE) Brian A Goolsby (b-goolsby@northwestern.edu), Marcia Grabovecky, Satoru Suzuki; Department of Psychology, Northwestern University, Evanston, IL, USA — In a color-singleton search task, Os located an odd-colored target among uniform-colored distractors. Results revealed that orientation selective attention existed only when the colors of adapting and test stimuli were identical (‘color-contingent orientation adaptation’). According to these results the interaction between orientation and color occurs during the ‘modified McCollough effect’ in probably V1 or higher cortical areas when subjects have no conscious access to the orientation of adapting stimulus.

Acknowledgment: Supported by NSF SBR-9817643

SU132
Cyclopean Motion Processing Does Not Depend Exclusively Upon Selective Attention Cheryl Becker (csbecker@mail.wsu.edu), Lisa R Fournier, Greg Varvken, Ivan Bickler, Matthew Wiediger, Robert Patterson; Washington State University, United States — This study investigated the degree to which the visual processing of cyclopean motion (motion of binocular disparity information) depends upon selective attention by employing a motion aftereffect paradigm. Cyclopean motion aftereffects were induced under conditions of low, high, and no attentional load. For comparison, luminance motion aftereffects were induced under the same conditions. Specifically, observers adapted to a moving cyclopean or luminance grating (spatial frequency = 0.5 c/deg; temporal frequency = 2 Hz) while performing a rapid serial visual presentation (RSVP) task that was superimposed over the central portion of the motion display. Observers attended to the RSVP task and ignored the motion display. For the low attentional-load RSVP task, observers determined whether words presented were upper or lower case; for the high attentional-load RSVP task, observers determined whether the words contained one or two syllables. For the no attentional-load condition, observers adapted to the moving grating without performing any RSVP task. Results showed that the duration of the motion aftereffect declined with increasing attentional load, but there was no reliable difference in the rate of decline between cyclopean and luminance motion (under high attentional load, the duration of the cyclopean motion aftereffect was 61% of that obtained under no attentional load). This equivalence between the two types of motion suggests that selective attention is mechanism invariant. These findings challenge the validity of the three-systems model of motion perception as proposed by Lu and Sperling (1995, 2001), which postulates that the processing of cyclopean motion, not luminance motion, depends exclusively upon selective attention.

SU133
Contrast decruitment is reduced in matching procedure Benjamin R. Stephens1 (bstephe@clemson.edu), James L Dannemiller2, Jessica Diehl1; 1Clemson University USA, 2University Wisconsin-Madison, USA — To investigate contrast decruitment of compared to noise grating whose contrast increased or decreased logarithmically over a 45 sec sweep. Estimates for the low contrast probes were two-fold lower in the decreasing sweep conditions. Since magnitude estimation procedures may be sensitive to subtle methodological variables, we examined contrast decruitment using a contrast matching procedure. Stimuli were stationary squarewave gratings. In each trial, the grating’s contrast was constant, increased, or decreased logarithmically over a 45 sec sweep, with start or end points of 0.2 and 0.006 contrast. A probe contrast (0.1, 0.07, 0.01, or 0.007) was cued by a tone during each sweep. Observers (n=17) adjusted the contrast of a comparison grating to match the perceived contrast of the probe contrast after each sweep. For all probe contrasts, match estimates were lower in the decreasing sweep conditions.

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MO1

Separating signal from noise in visual discrimination  
Mikhail Katkov (katkov@wicc.weizmann.ac.il), Misha Tsodyks, Dov Sagi; The Weizmann Institute of Science, Neurobiology/Brain Research, Rehovot, Israel—Psychophysical contrast discrimination is believed to be mediated by internal responses, each characterized by contrast-dependent mean value and noise amplitude. The standard measure of contrast discrimination, TvC (threshold versus contrast) curve does not allow unambiguous characterization of these two components of the internal response, since many possible combinations could account for the same TvC curve. Here we propose a novel approach that is based on performing a larger number of pair wise contrast discriminations. The performance, measured as percent correct discrimination, is compared with the predicted one based on a model that assumes normally distributed responses. The two response components are then determined by matching the model predictions to the experimental results. This procedure requires a minimal number of stimulus pairs in order to derive a complete or over-complete system of equations for mean and noise response amplitudes. The method can also be used for other stimuli configurations, such as local stimuli surrounded by flankers, allowing to study the lateral interactions. We applied the method to a set of 6 isolated Gabor patches (9.2 cpd, sigma=0.11 deg) with different contrasts (randomly mixed) and 10 pair wise discriminations (temporal 2AFC) that resulted in the complete system of model equations. The preliminary experimental results (2 observers, ~600 trials each) indicate that the shape of the TvC curve is determined by a nonlinear transducer function and a non-trivial contrast-dependence of the noise amplitudes. However we find that calculated noise amplitudes are more sensitive to experimental measurement errors. It is possible that we will be able to reduce this uncertainty by considering additional contrast discriminations that will result in an over-complete system of equations for response amplitudes.

Acknowledgment: Supported by BRF/ISF  
http://www.weizmann.ac.il/~masagi/vss03

MO2

Local and global coherence in two and three dimensional textures  
Flip Phillips1 (flip@skidmore.edu), James T Todd2; 1Skidmore College, 2Ohio State University—Purpose—What can the perception of scale and coherence of texture features tell us about the nature of our visual representation of shape? A trivial gedankenexperiment shows that the scale of features in 2- & 3-D textures has a direct effect on the ability of an observer to make ‘same/different’ judgments. Fields of uniformly distributed, high spatial frequency features are more difficult to match than their lower frequency cousins. However, in cases where the distribution of point features is not uniform, ‘meta-features’ may cohere in the form of clusters or linear structures that alter the scale at which matching is possible.

What is the nature of this scale/structure relationship?

Methods—In a series of experiments, fields of uniformly distributed noise were presented in a same/different matching task. Spatial frequency of the noise varied in concert with different structuring and de-structuring operations. These included introduction of linear and area structures through filtering and the modification of phase information.

Results—Spatial frequency thresholds for the noise-only discrimination tasks were on the range of 1.5-2.5 degrees of visual angle. Linear structuring of the noise yielded performance consistent with the scale of the introduced structuring. Disturbing the phase in the structured noise again degraded performance consistent with the unstructured conditions.

Conclusions—Our results show that structuring the point features of uniform noise creates emergent features that are more readily used as ‘landmarks’ for a matching task. At least part of the structuring takes place in the texture’s phase-space because disturbing phase degrades performance back to unstructured levels.

http://ebv.skidmore.edu

MO3

The effects of visual angle on the perception of 3D curvature from texture  
James T Todd (todd.44@osu.edu), Lore Thaler, Tjeerd Dijkstra; Ohio State University, USA – At the 2002 VSS meeting there was conflicting evidence presented about whether it is possible to perceive the direction of surface slant or the sign of surface curvature from perspective gradients of isotropic textures. In the present paper a theoretical analysis will be presented that quantifies the available information from texture gradients for a wide range of geometric conditions. An important implication of this analysis is that the discrimination of concave and convex surface regions may require integration over relatively large visual angles. A series of psychophysical experiments will also be reported that examined the effects of visual angle on observers’ judgments of surface curvature from texture. Images of singly curved surfaces with polka dot or plaid textures were presented in a same/different matching task. Spatial frequency of the introduced noise yielded performance consistent with the scale of the introduced structuring. Disturbing the phase in the structured noise again degraded performance consistent with the unstructured conditions.

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Authors Present: 2:30 – 4:30 pm

Texture, Synesthesia, Search, Scene Perception, Perceptual Organization, Perceptual Learning, Memory, Eye Movement Cognitive, Color, Attention 4
from 60-20 degrees. Reductions in visual angle also lowered the perceived magnitude of curvature. These results provide strong evidence that the perception of shape from texture can involve pooling of information over large regions of visual space, and that other reported results obtained with small visual angles may have led to erroneous conclusions about observers' perceptual capabilities.

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MO4
Shape categorization from texture 
Victoria L Interrante (interran@cs.umn.edu), Sanghee Kim, Haleh Hagh-Shenas; Computer Science and Engineering, University of Minnesota, USA — As computer science researchers, we are interested in gaining a better understanding of how to more effectively use texture to facilitate shape perception. To study these questions we have been using a novel texture synthesis algorithm to apply arbitrary patterns over arbitrary doubly curved surfaces in a way that avoids both seams and stretching yet allows fine control over the local texture orientation. Previously we found that judgments of shape from anisotropic textures are most accurate when the direction(s) of anisotropy are aligned with one or both of the principal directions over the surface. However many questions remain: why is it easier to accurately perceive the surface shape when the texture follows the principal directions? What information are we inferring from the texture orientation and how are we using it? How important is it that the pattern be capable of conveying the extent of texture compression along the principal directions in addition to or in lieu of directly indicating what these directions are? In our current experiments we are working with a disparate collection of 23 texture swatches, primarily drawn from the Brodatz album. We have applied these textures to families of quadric surface patches related by variations in curvature. We are showing subjects local views of the surfaces, in which no contour edges are visible. We have been struck by the strength of the influence of aperture shape cues on shape perception from texture at the second-order compared to first-order mechanisms

David Ellenberg (dave.ellenberg@staff.mcgill.ca), Harriet A Allen, Robert F Hess; McGill Vision Research Unit, McGill University, Canada — We compared the spatial extent of lateral masking for first- versus second-order images and investigated spatial interactions between these two types of images. To do so we measured the apparent contrast of a target Gabor at fixation, in the presence versus the absence of horizontally flanking Gabors. The Gabors' grating was vertical, had a peak spatial frequency of 3 cpd, and was either added to (first-order) or multiplied with (second-order) binary 2-D noise. Apparent 'contrast' (i.e., the perceived difference between the high and low luminance regions of the first-order stimulus, or between the high and low contrast regions of the second-order stimulus) was measured with a contrast-matching paradigm. Using a temporal 2 AFC and the method of constant stimuli, subjects indicated in which interval the central Gabor had the higher 'contrast'. For each subject, the first- and second-order Gabors were equated for apparent contrast without the flankers. Two of the authors and two naive observers participated in this study. When first-order flankers abutted a first-order target the apparent contrast of the target was reduced by 29%, and remained reduced up to an element separation of 6 wavelengths. When second-order flankers abutted a second-order target the apparent contrast of the target was reduced by 23%, and remained reduced up to an element separation of 3 wavelengths. The spatial frequency and orientation tuning of the suppression effect was broader for second- than first-order stimuli. Second-order flankers did not reduce the apparent contrast of the first-order target; however, in three subjects, first-order flankers reduced the apparent contrast of the second-order target. This effect was tuned for spatial frequency.

Therefore, we find that lateral interactions operate over shorter distances for second- than for first-order information, and that these two types of information interact in an asymmetrical fashion.

Acknowledgment: Supported by NSERC grant OGP0046528 to R. F. Hess

MO6
Energy-frequency analysis reveals orientation-opponent channels in human vision
Isamu Motoyoshi (imotoy@po-box.mcgill.ca), Frederick A A Kingdom; McGill Vision Research Unit, Canada — It has been suggested that the representation of global form and texture is subserved by visual mechanisms that integrate the outputs of first-order orientation-selective filters. We here directly characterized the input-orientation characteristics of such mechanisms using linear-system analysis. The stimulus was band-pass noise whose Fourier-energy was sinusoidally modulated across orientation (i.e., not across space). Sensitivity for detecting Fourier-energy modulation was measured for various orientation frequencies (1-20 cycle/pi), stimulus sizes (2.3-18.6 deg), and carrier spatial frequencies (0.9-6.9 cpd). An inverse Fourier transform of the sensitivity data revealed a strong centre-surround antagonism across orientation (excitatory centre within 6-9 deg and inhibitory lobes at 15-20 deg), that increased with stimulus size far beyond the size of orientation-selective filters (more than 64 times the spatial wavelength of the noise carrier). These results demonstrate the existence of 2nd-order mechanisms that integrate and differentiate 1st-order orientation signals over a wide area of the visual field when processing texture. We term these mechanisms 'orientation-opponent' channels, analogous to the colour-opponent channels in colour vision. We applied a similar analysis to the spatial-frequency domain, using fractal (1/2) noise whose Fourier energy was modulated across spatial frequency (1.5 cycle/octave). However, we failed to obtain clear evidence for 'frequency-opponent' channels.

Acknowledgment: Supported by a JSPS fellowship (IM) and by NSERC grant ref: OGP 01217130 (FK).

MO7
Exploring the opponent structure of complex (second-order) channels
S Sabina Wolfson (sabina@psych.columbia.edu), Norma V Graham; Dept of Psychology, Columbia University, USA — To investigate the opponent structure of complex (second-order) channels we ran texture segregation experiments. A complex channel is assumed to have a linear-nonlinear-linear form: linear first-stage receptive fields followed by pointwise nonlinearity followed by linear second-stage receptive fields. We consider three structures: (i) SIGN-but-not-orientation-opponent, (ii) ORIENTATION-but-not-sign-opponent, and (iii) BOTH-orientation-and-sign-opponent.

“Orientation-opponent” means that the small first-stage receptive fields of the complex channel are orthogonal to the large second-stage receptive fields. (“Not-orientation-opponent” means that the receptive fields are of the same orientation.) “Sign-opponent” means that the centers of the second-stage receptive fields are of the opposite sign from the surrounds. (“Not-sign-opponent” means that the sign is the same.)

Our experiments used a forced-choice region-segregation task with element-arrangement patterns composed of vertical and horizontal Gabor patches arranged in checkerboarded or striped patterns. The results are best fit by the SIGN-but-not-orientation-opponent structure.

Acknowledgment: Supported by NIH grant EY08459
MO8

The critical factor for performance improvement in multi-frame orientation texture segregation Masamitsu Harasawa (harasawa@be.to), Takao Sato, Dept. of Psychology, Univ. of Tokyo, Japan—Sequential presentation of multiple frames with the same texture characteristics improves texture segregation. In this study, we evaluated contributions of three potential factors for this improvement (border-signal enhancement, internal-noise reduction, and narrowed tuning for border detection) by using internal noise estimation method based on perceptual template model. Methods. Stimuli were dynamic texture consisting of 8 x 8 Gabor patterns. The whole field was divided into two areas of homogenous texture characteristics by either a horizontal or vertical border. Subjects' task was to identify the orientation of border (2AFC). Within each texture region divided by the border, orientations of Gabors were varied randomly following a normal distribution. The mean orientation for each region was randomized between frames while keeping the difference between regional means constant. Each texture frame was presented for 100ms without ISI. Number of presented texture frames was from 1 to 5. The thresholds for difference of mean orientations (signal) were measured for each value of standard deviation of intra-region orientation distribution (external noise) using a QUEST method. Results. The threshold decreased as external noise was decreased and as the number of presented frames was increased. Discussion. The results of analysis indicated that the performance improvement can be attributed to both enhancement of textural border signal and noise reduction by multiple sampling. The contribution of signal enhancement suggested that an intermediate representation of textural border is pooled over frames. The effect of internal noise reduction seems to be accounted for by the effect of probability summation by multiple sampling. These results indicate that border-signal enhancement and internal-noise reduction may contribute together for the improvement, but the effect of narrowed tuning is minimal.

Acknowledgment: JSPS, HFSP

MO9

Texture thresholds inaults and infants Francesca Pei (francesca@ski.org), Chuan Hou, Anthony M Norcia; Smith Kettlewell Eye Research Institute, USA—Textures are defined by regularities in spatial scale and orientation. In previous experiments, we have studied brain responses elicited by a sub-class of textures that have a single spatial scale. These textures are made up of Gabor patches that are either randomly arranged or are comprised of a single orientation across the image. In order to discriminate the two stimuli, observers have to be able to compare the relative orientations of multiple patches, a 'global' task. Using these textures, we have identified a texture-specific component in the VEP that is present as early as 8 weeks of age in human infants.

In the present study, we wanted to quantify the relative maturity of this response by measuring the minimum amount of orientation required to elicit the texture-specific component in infants and adults. Thresholds were measured by varying the percentage of patches that were of the same orientation vs. a random orientation (percent coherence). The exchange of random and organized images leads to a texture-specific component at the first harmonic of the exchange rate and thresholds were measured by extrapolating the first harmonic amplitude vs. percent coherence function to zero amplitude. Adult texture-specific responses were robust and their thresholds were around 20%. Infant texture-specific responses were weaker and thresholds were not measurable in most individual infants. However thresholds of around 50% could be estimated from group average data. Infants are capable of detecting the global structure of our textures, but their sensitivity is quite low. Our results are broadly consistent with two previous behavioral studies that have found successful detection of highly coherent line textures in 3-4 month old (Atkinson and Braddock, 1992), but a long developmental period before adult thresholds are reached (Sireteanu and Rieth 1992).

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MO10

Internal noise and sampling efficiency in discrimination of second-order patterns Velitchko Manuilovich (emai@cal.ac.uk), William A Simpson2, Julie Calvert;1 1Glasgow Caledonian University, Department of Vision Sciences, United Kingdom, 2Defence R & D Canada, SMART Section, Toronto, Canada—The visual system is sensitive to both first-order luminance modulations and second-order modulations of carrier contrast. Studies have shown that sensitivity to second-order modulations is lower than the sensitivity to first-order stimuli. We sought to determine the factors which make second-order vision less sensitive than first-order vision. We evaluated internal noise and sampling efficiency of first- and second-order vision employing the phase-discrimination paradigm (Burgess and Ghandeharian, 1984) in conjunction with the equivalent input noise approach (Legge et al. 1987). The observers were presented with a 2-cpd pedestal or the pedestal plus a 2-cpd signal with a fixed phase shift relative to the pedestal. Detectability of the signal at various phase angles was measured in the absence and presence of static 2D Gaussian noise. Given sufficient a priori phase information, the observers performed phase-sensitive discrimination of both first- and second-order stimuli, although imperfectly. We found that the internal noise in phase discrimination of contrast modulations was five times higher than that in phase discrimination of luminance modulations. This finding may be due to the presence of an additional demodulating stage in the analysis of second-order information which adds extra noise. The sampling efficiency in discrimination of second-order signals was half that found for discrimination of first-order signals. This effect did not depend on the phase angle between the pedestal and the signal which suggests that second-order information processing is characterised by imperfect signal demodulation rather than to inefficient sampling strategy.

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MO11

Casting shadows on synesthesia Nathaniel S Witthoft (weththo@mit.edu), Jonathan A Winawer; MIT, USA—Experiments with a color-grapheme synesthete AD have turned up several novel findings regarding the origin of the synesthetic colors and how they interact with normal visual processes.

No systematic organization to the color-grapheme associations has been previously reported either for a particular synesthete or between synesthetes. A number of theories have been put forward to explain the origin of synesthesia but do not address the source of the colors produced. However, in this case, the colors can be traced to a childhood letter set still in AD's possession. Furthermore, AD moved to Russia while a child, and experiences synesthetecolors in response to Cyrillic letters as well as the English alphabet. Where the Cyrillic letters are visually similar to English letters, the color is the same, otherwise, the color of the Cyrillic letter is determined by phonetic similarity to English.

The interaction of AD's photisms with normal visual processing was explored using the Adelson checkershadow illusion in which squares of identical luminance produce different subjective experiences of lightness depending on whether they appear to be in shadow or direct light. Normal controls attempting to match colored letters embedded in the illusion showed effects of context on their matches. AD's photisms were also affected by the illusion. This result suggests that the processes that influence lightness perception in normal vision also operate on synesthetic photisms.

There are also certain conditions under which AD's photisms can be abolished. Of particular interest is the finding that presenting letters in saturated colors in the vicinity of the hue opponent to her synesthetic color prevents AD from seeing her photisms. This novel result points to the involvement of low level mechanisms in AD's synesthesia.
MO12
Synesthetic colors act like real colors and interact with real colors
Chai-Youn Kim (chai-youn.kim@vanderbilt.edu), Randolph Blake, Thomas J. Palmeri, Rene Marois, William Whetzel; Vanderbilt University, USA — People with color-graphemic synesthesia experience vivid colors when viewing achromatic alphanumeric characters. We tested two such individuals on tasks for which color is ordinarily important. Binocular Rivalry: Spatially distributed objects of the same color tend to dominate simultaneously during binocular rivalry. In synesthetic observers WO and LR, rivalry between pairs of achromatic letters was influenced by the relation between their associated synesthetic colors. In addition, a real color paired with a synesthetic color produced grouping comparable in strength to that produced by two real colors. Bistable motion: For non-synesthetic observers, color strongly biases perception of otherwise ambiguous apparent motion. For LR and WO, apparent motion between different pairs of achromatic letters was governed by the “color” of those letters. Similarly, motion between achromatic letters and real colored figures was determined by the similarity between the real and the synesthetic colors. McCollough Effect: Prolonged adaptation to color paired with orientation induces an orientation-contingent color aftereffect. LR and WO were alternately adapted to an achromatic “vertical grating” composed of letters synesthetically appearing green and to an achromatic “horizontal grating” composed of letters synesthetically appearing red. Upon viewing an achromatic test figure organized as horizontal and vertical stripes, LR saw horizontal as faint green and vertical as faint red. WO only saw faint red vertical, not green horizontal; intriguingly, WO also does not see “green” when tested using the standard McCollough effect procedure. Conclusions: These findings expand the range of phenomena influenced by synesthetic colors and reveal interactions between real and synesthetic colors.

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MO13
Cortical cross-activation as the locus of grapheme-color synesthesia
Edward M Hubbard1,2, (edwardhubbard@psi.ucsd.edu), Vilayanur S Ramachandran1, Geoffrey M Boynton2; 1Salk Institute for Biological Studies, La Jolla, CA USA, 2Center for Brain and Cognition, UCSD, La Jolla, CA USA — Subjects with grapheme-color synesthesia report that a given number is always associated with a certain color (e.g., “5” may be green). We have previously shown that synesthetes perform better than controls in various perceptual tasks, presumably due to their induced colors (Ramachandran & Hubbard, 2001). This suggests that synesthesia is a sensory effect, perhaps due to cross-activation between color selective occipital brain areas (V4/V8) and a nearby brain area responsive to graphemes. To test this hypothesis, we conducted behavioral and fMRI experiments with four grapheme-color synesthetes and four non-synesthetic controls. Each subject participated in a perceptual grouping experiment in which a pattern of numbers was detected amongst a background of other numbers (e.g. a triangle of 3’s against a background of 5’s). The foreground and background graphemes were chosen to induce opposing colors in each synesthete. Performance was compared against an unselected pool of 20 non-synesthetes. Behavioral performance was highly variable, with two synesthetes performing significantly better than controls, and two synesthetes performing no better than controls. Next, we identified retinotopically organized visual areas using standard fMRI retinotopic mapping techniques. FMRI responses were then measured while subjects viewed letters or numbers alternating in a block-design with non-linguistic symbols while performing an upright vs. italic discrimination on these symbols. Synesthetes showed significantly greater fMRI responses than control subjects to letters and numbers in color selective areas (V4/V8), but not early visual areas (V1/V2). Activity in retinotopically organized visual areas (V1, V2, V4v, V8), but not grapheme selective areas, was positively correlated with behavioral performance on the pop-out task. These results support the hypothesis that grapheme-color synesthesia may arise from cross-action of color selective areas by visually presented graphemes.

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http://psy.ucsd.edu/~edhubbard/vss2003.ppt

MO14
Saccadic behavior in Rhesus monkeys performing a visual search task
Anna Ipaia (ai2109@columbia.edu), B. Suresh Krishna, James W. Bisley, Jacqueline Gottlieb, Michael Goldberg; Laboratory of Sensorimotor Research, National Eye Institute; and Center for Neurobiology and Behavior, Columbia University, USA — Monkeys performed a visual search task which began with their fixating a central point for 500 ms; after which an array appeared with a target (an upright or inverted T) and 7, 11, or 15 distractors (upright or inverted crosses). The stimuli subtended roughly 2° and were arranged in a symmetric array 10 from the fixation point. All stimuli were black, except in certain blocks in which the target or a distractor was brightly colored and therefore pop out from the remainder of the array. The monkey manually signaled the target orientation. For trials in which the target did not pop out the manual reaction time varied as a function of distractor number and also of the number of saccades. The probability of finding the target on any given fixation varied as a function of popout and distractor number, but not of saccade sequence, suggesting that there was no memory effect in this search paradigm. First saccades were most likely to be drawn to the popout distractor, but also slightly more likely to be drawn to the non-popout target These results suggest that three different factors influence the oculomotor system in this search paradigm: the popout, the target, and the pool of non-popout distractors. In multiple saccade trials (but not 1 saccade trials), the final fixation time (the time from the final saccade to the response) correlated strongly with reaction time. When the eye position just prior to the onset of the final saccade lay within a certain range of the target it strongly determined the time it would take for the monkey to make the discrimination after moving its eye to the target. This suggests that there was a zone within which visual discrimination of the stimulus orientation could take place before the saccade that captured the target. In addition, the properties of this zone varied as function of trial type and distractor number.

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MO15
The eyes can search large displays more effectively than small ones: an oculomotor paradox?
Eugene McSorley1 (eugene.mcisorley@rhul.ac.uk), John M Findlay2; 1Royal Holloway, University of London, England, 2University of Durham, England — We report a set of results showing that increasing the number of distracting elements in a visual search task improves oculomotor search performance. A search target was presented together with distractors and subjects were required to move their eyes to the target. When the target was presented with a single distractor in a neighbouring location, the first saccade was often inaccurate. However increasing the number of distracting elements from 1 to 15 considerably improved the ability to locate the target with the first saccade. We considered two hypotheses to account for this paradoxical finding. Perceptual grouping processes might operate amongst the distractors. However, when we modulated the heterogeneity of distractors in the 15 distractor displays on four dimensions separately, performance did not deteriorate. The second hypothesis arose from the observation that the first saccades in large displays generally showed lowered latency. When we introduced distractors contralateral to the target, this induced a “remote distractor effect” whereby saccade latency increased. Search performance was superior in this condition to that when all distractors were ipsilateral. We suggest that oculomotor search performance is improved with greater distractor number because contralateral onsets increase initial saccade latency and in consequence allow improved perceptual selection.

Acknowledgment: BBSRC grant
MO16
Optimal visual search  Jiri Najemnik (najemnik@mail.cps.utexas.edu), Wilson S Geisler; Center for Perceptual Systems, University of Texas at Austin –
Given the importance of visual search for survival, humans may have evolved sophisticated fixation strategies for finding targets of interest quickly and accurately. We have derived the optimal search strategy for a visual system with variable sensitivity across its retina, where the task is to search for a target embedded in a noise background. The ideal search strategy is as follows: (1) during a fixation, collect all the available information (which is corrupted due to internal noise and sensitivity variation across the retina), (2) compute the (posterior) probabilities that the target is present at each potential location in the visual field, (3) given those posterior probabilities, compute the shortest sequence of subsequent fixations necessary to find the target with a desired level of accuracy. (4) execute the first saccade of this sequence, and (5) repeat steps 1 – 4. We have simulated an approximation to the ideal visual searcher and compared it with other less efficient searchers – making random fixations and fixating on the location with the highest posterior probability. At the time of writing this abstract we have not made detailed comparisons of human and ideal search patterns, but we have discovered some interesting properties of the ideal that are qualitatively similar to those of humans (and different from the less efficient searchers above). Specifically, even without time or energy costs for long saccades, the ideal searcher often (1) makes short- and intermediate-length saccades, (2) tends not to fixate near the edge of the display, and (3) sometimes fixates a central location within a cluster of locations with high posterior probability. The ideal visual searcher promises to serve several important roles: providing the appropriate benchmark for comparison with human performance; providing a starting point for developing real models of visual search; and helping to uncover the specific inefficiencies in human search performance.

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MO18
Environmental cues modulate memory during visual search
Matthew S Peterson1 (mpeterson2@gmu.edu), Walter R Boo1, Arthur F Kramer2; 1George Mason University Dept. of Psychology, USA, 2Beckman Institute & Dept. of Psychology, University of Illinois Urbana-Champaign, USA – In everyday visual search, we are presented with a feature-rich environment that can help guide the search process. For example, Peterson et al. (Psychological Science, 2001) found near-perfect memory when searching a display of 12 items. In contrast, when searching an impoverished environment in which only two possible saccade targets were visible at any one time, memory capacity is reduced to the last 4 items and items at lags 5 and greater are often reexamined as if they had not been previously viewed and rejected (McCarley et al., Psychological Science, in press). A feature-rich environment not only allows for potentially greater spatial localization of examined items through the use of salient landmarks, but also provides knowledge-in-the-world of examined items and future saccade targets. To examine if environmental features can be used to guide search, we used a modified version of the McCarley et al. saccade-target experiment in which several uniquely-colored large static landmarks were added to the display. This allowed us to examine the role that landmarks might play in guiding search when scan path planning and object persistence are unable to guide search. Landmarks appeared in colors different from the search stimuli and were an order of magnitude larger. Surprisingly, the presence of these non-potential targets led to smaller memory spans than when they were absent. This suggests that accidental environmental cues, rather than enhancing memory, instead compete for the memory representation of examined items. In addition, the role of object-persistence and knowledge-in-the-world for examined and to-be-examined items will be discussed.

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MO19
Visual preferences in early infancy are distinct from adult preferences
Ruxandra Sireteanu (sireteanu@mpi-halle.mpg.de), Iris Bachert, Henrike Planert, Silvia Pröhl; Institute for Psychology, University of Frankfurt; Max-Planck-Institute for Brain Research, Frankfurt, Germany –
Purpose: To investigate the visual preferences of human infants and toddlers, using tasks borrowed from adult visual search literature. Method: Infants aged between 2 and 12 months and children between 1 and 4 years, grouped in five age groups (3, 6, 10, 18 and 36 months old; 12 subjects/group) were tested with a preferential looking procedure. The stimuli were presented on cardboard cards containing a target item among 15 distracting items. The task of a naive observer was to make a forced-choice judgement on the side of the card preferred by the subject. Correct guesses yielded a positive score, incorrect guesses a negative one. The tasks investigated were “brightness contrast” (a single dark blob amidst white blobs, or a bright blob amidst dark blobs, on a gray background) and “orientation contrast” (a tilted line amidst vertical lines, or a vertical line amidst tilted lines). Results: Three-year-old children always preferred the discrepant target. Their preference showed an asymmetry consistent with adult visual search asymmetry: they had a higher preference for the darker blob and the tilted line than for the brighter blob and the vertical line. In contrast, three-month-olds showed a positive preference for the darker blob, but no preference for the brighter blob or for lines differing in orientation from their surround. Transition from the infantile to the mature pattern of visual preferences occurred around the end of the first year of age. Conclusion: These results corroborate earlier findings (Sireteanu & Encke, IOVS 1999; 40;4:343, Sireteanu, Wagner & Bachert, IOVS 2001; 42;4:122) and show that the human infant enters the world with a visual repertoire dramatically different from that of adult observers. The sharp transition between infancy and toddlerhood points to the emergence of different brain mechanisms, which mediate a qualitatively different pattern of visual preferences.

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Intruder effects in cued visual search

MO20
Afroditi Panagopoulos1 (panag@ux2.concordia.ca), Michael W von Grunau1, Cesar Galera2; 1Department of Psychology, Concordia University, Montreal, Que, Canada, 2Department of Psychology, University of São Paulo at Ribeirão Preto, Brazil — Purpose: We have shown that cueing exogenously and endogenously the area that contains the relevant stimulus locations in visual search is effective, and is sensitive to the shape of the configuration of the relevant stimuli. Results suggested that valid cues correctly guided subjects' attention to the relevant stimuli (VSS 2002). We used this paradigm to measure certain properties of the search light metaphor. Abrupt onsets capture attention when the visual system is in a focused attention mode. We investigated to what extent the intruder would affect visual search. We also examined the difference between the intruder being inside or outside of the focused area and whether the intruder was compatible or incompatible to the target stimulus. Methods: Two configurations (horizontal vs vertical) of 4 stimuli, one of which was the target, were presented. A variable time before the stimuli, either a valid or invalid endogenous cue was given (a letter “V” or “H”). On some trials, an intruder would appear. On the trials where the compatible or incompatible intruder was present, it would appear with a delay of 0, 250 or 500 ms relative to the stimuli. Results: Valid cueing produced faster response times than invalid cueing. When the intruder was present, target detection was slower than without intruder. It also took longer to find the target when the intruder was inside the attended area. The intruder was most detrimental when it appeared 500 ms after the stimuli. Contrary to expectations, the compatible and incompatible intruder conditions did not differ significantly.

Conclusion: Visual search is influenced by two distinct mechanisms: an automatic and a voluntary mechanism.

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Search isocontours as a tool for understanding visual search

MO21
Sei-Hwan Oh (sho@psylab.yonsei.ac.kr), Min-Shik Kim; Yonsei University, Korea (ROK) — According to ‘biased-competition model’ (Desimone & Duncan, 1995), the contents of working memory (WM) guide the allocation of selective attention. Recent work by Downing (2000) with human observers supported this model using probe discrimination task. In contrast, it has been failed to demonstrate this guidance effect during visual search (Downing, 2000; Houtkamp, Spekreijse, & Roelfsema, 2002). However, in the typical visual search task such as this, it is possible that a target template stored in WM is behaviorally most relevant, so that the other contents in WM do not guide selective attention. To investigate this possibility, we used two different types of visual search task. In one task, the search target was defined as an object whose shape was symmetric around the vertical axis (Chun & Jiang, 1999). In the other task, the search target was defined as a specific shape. The guidance effect of WM was measured by the difference in search response times between the matched condition (in which the WM item was presented in the search array as a distractor), and the non-matched condition (in which the WM item was not presented in the search array). The significant guidance effect of WM was found when the target was defined as vertically symmetric but not when the target was defined as a specific shape. These findings suggest that WM items can guide attention in visual search in the absence of behaviorally more relevant items in WM-such as target templates in the context of visual search.

Search isocontours as a tool for understanding visual search

MO22
Ruth Rosenholtz (rruth@parc.com); Palo Alto Research Center, USA — Models of visual search typically input a target and a distribution of distractors (along with other parameters), and output a prediction of search ease, e.g. reaction time, percent correct performance, or some qualitative measure. Models can also input only the distractor distribution, and output a threshold, i.e. a prediction of the target satisfying some minimal requirements for search ease. For example, in search for a target of a unique size a model might report the minimum target size required to achieve a certain percent correct performance at the search task.

In N-D feature spaces, the concept of a threshold generalizes to search isocontours — a set of locations in feature space representing a set of targets, each satisfying the desired requirements for search ease. E.G. for a given set of distractors, a search isocontour might indicate the set of all targets yielding a certain percent correct performance. Isocontours can be predicted by a model, or determined empirically.

Search isocontours give us, at a glance, a more complete image of the relationship between the target, distractors, and search ease. Predicted isocontours elucidate differences between models, and identify key experiments for choosing between those models. Isocontours offer a new pictorial way of seeing the effects of set size, distractor heterogeneity, and other factors.

Saliency Model (Rosenholtz, Vision Research, 1999; Perception & Psychophysics, 2001) isocontours are just ellipses representing the covariance of the distractors. (Rosenholtz, J. Exp. Psychology, 2001) demonstrated how to make predictions of signal detection theory models for arbitrary distributions of targets & distractors, and for N-D feature spaces. Based on this, one can determine search isocontours for SDT-based models. I will present search isocontours for several models and a number of examples. In addition, I will discuss issues in efficiently finding search isocontours empirically.

Searching for the gap - comparing young and older adults

MO24
Elizabeth T. Davis (ed15@prism.gatech.edu), Terry Shikano, Scot A. Peterson, Rachel K. Michel; Georgia Institute of Technology, USA — Purposes: When do age-related differences in visual search performance occur and what causes them? Are they due to qualitative differences in processing information? Are older adults always worse? To answer these questions we decomposed search into components of (a) target-distractor discrimination, (b) attention sharing, (c) target detection & location accuracy, (d) confusions about target location, and (e) limitations due to decision noise vs. capacity. Methods: We tested 23 young adults (18 to 30 years old) and 25 older adults (65 to 79 years old). A Landolt C target was embedded among either O’s or mirror-image Landolt C’s. For search experiments, target-distractor discriminability was equated both across participants and visual search conditions; the set size was 2 or 4. Results: Older adults had significantly larger discrimination thresholds and required gap sizes approximately 3 times larger than did young adults. After equating target-distractor discriminability, however, older adults
were better at sharing attention across spatial locations and showed less confusion about the target’s location than young adults. For both age groups, performance was worse for the mirror-image search, suggesting capacity limitations, than for the simple feature search (Landelt C vs. O), where decision noise could explain performance. Conclusions: Although visual function may decline with age so that visual acuity becomes worse, one can overcome mild deficits by equating target-distractor discriminability in visual search. When this is done, older adults may perform as well or better than young adults on some components of visual search. Differences in search performance found between older and young adults suggest qualitative rather than quantitative factors. That is, age-related differences in search performance are not due to changes in demands placed on attention or in search strategies.

MO25
Constraints on the rapid interpretation of cast shadows
Ronald A. MO25 Rensink1 (rensink@psych.ubc.ca), Patrick Cavanagh2, 1Depts of Psychology and Computer Science, University of British Columbia, 2Vision Sciences Laboratory, Harvard University—Visual search experiments (Rensink & Cavanagh, 1993) have shown that rapid (preattentive) vision can interpret small regions of an image as cast shadows, provided that these regions are dark and lighting is assumed to be from above. Several experiments are presented that extend these results, mapping out the constraints used by this process in regards to color, texture, and the item casting the shadow.
Displays consisted of a set of vertically-oriented rectangles, with each rectangle having an attached region that could correspond to a cast shadow. Observers were asked to search for a target with a distinctive orientation to its attached region. In agreement with earlier work, when these regions were black and attached to the bottom of the rectangles (so that items corresponded to shadowed posts lit from above), search was slower than when the displays were rotated upside down (corresponding to lighting from below). This difference was not found when the attached regions were white, indicating that shadow interpretation did not occur for this condition.
Interpretation also did not occur when a dark region was outlined by a darker or lighter line, or had a dot along its boundary. It also did not occur when a texture was restricted to the region. However, results on blue and red regions and region outlines showed little evidence for purely chromatic constraints.
Interpretation occurred when the item casting the shadow was an outlined triangle and the attached region corresponded to a shadow cast by a rectangle, showing that geometrical constraints are not strong. But it did not occur when a gap was placed in the outline of a shadow caster, indicating that the process distinguishes between surface and line elements, with only the former considered capable of creating a shadow.

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MO26
Is opacity a basic feature? It’s not transparent
Randall S Birnkrant1 (randy@search.bwh.harvard.edu), Jeremy M. Wolfe1, 2Hermie Mendoza1; 1Brigham and Women’s Hospital; United States, 2Harvard Medical School; United States—If a visual property serves as a “preattentive” basic feature, then that property will support efficient visual search. When the target in a search task has that feature while the distractors do not, reaction times (RTs) will be largely independent of the number of items present. Several surface properties (shading, shininess) have been identified as basic features in this sense. Do the surface properties of transparency and opacity support efficient visual search? In Exp. 1, we found that search for transparent targets among opaque distractors (and vice versa) in a static display was very inefficient (> 30 ms/item). In Exp. 2, stimuli were horizontal green-tinted bars that moved over a random, achromatic texture of disks of different luminance levels. Opaque surfaces were generated by having the tinted random texture move with the bar. Transparent surfaces were generated by having the texture of the bar change over time such that the background texture appeared to remain stationary while a green filter moved over it. Static examples of transparent and opaque bars would be indistinguishable. Search for the opaque target among transparent distractors was quite efficient (5.3 ms/item); search for a transparent target among opaque distractors less so (16 ms/item). One confounding factor is the different pattern of motion of the texture within opaque and transparent bars. To determine if Os could use this motion cue, we presented the same horizontal bar search stimuli on a blank background. Mean RTs were much slower in these conditions. Now the moving (formerly ‘transparent’) texture was easier to find amongst the unmoving (‘opaque’) textures (17 ms/item) than vice versa (71 ms/item). It is possible that cues other than opacity/transparency contribute to detection of these items on a textured background. Nevertheless, these data suggest that opacity may serve as a basic visual feature.

MO27
What the presentation of two visual targets with varied contrasts, sizes and temporal asynchronies tells us about the process of target selection in humans and monkeys
Peter H. Schiller (pchesill@mit.edu), Christina Carvey, Jennifer Kendall, Warren M. Slocum; Department of Brain and Cognitive Sciences, Massachusetts Institute of Technology, USA—Target choice and the decision times involved were determined in humans and monkeys using a two-target task in which the contrast, size and the temporal asynchrony between the targets were varied. Stimuli were presented in the left and right hemifields at eccentricities of 3-8 degrees. For comparison in performance, single targets were intermingled with the presentation of the paired targets. Targets were selected either by making a saccadic eye movement or by pressing a lever. In the two-target task, target choice was strongly influenced by relative stimulus contrast and by size as specified by the temporal offset required to have both targets chosen with equal probability. For equal probability choices in monkeys performing the two-target task saccadic reaction times were 12-47 ms longer for single targets; in humans performing the lever press task reaction times to paired targets were 160-300 ms longer than those obtained to single targets. Targets were chosen with equal probability most frequently when the two targets were identical and were presented simultaneously. Reaction times dropped rapidly with increasing temporal asynchronies between the targets. With a temporal asynchrony of 34 ms, reaction times decreased by more than 125 ms in humans but only by 15-25 ms in monkeys. Unilateral frontal eye field (FEF) but not medial eye field lesions in monkeys produced major shifts in equal probability target choice that persisted even four years after FEF lesions. Equal probability choice in the paired target task after an unilateral FEF lesion required the presentation of the target in the affected hemifield 60-120 ms earlier than the target in the intact hemifield indicating a major decrease in the speed of processing as a result of the lesion. A study examining the effects of brain infarcts in human subjects on these tasks is under way.

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MO28
Statistical bias predicts many illusions
Cornelia M. Fermüller (fer@cfar.umd.edu); University of Maryland, USA—There is a principle underlying visual computations that previously has not been recognized. This principle is about the effects of uncertainty. Many visual computations are estimation processes. Because of noise, and there are many sources of noise in the formation and processing of images, systematic errors occur in the estimation. In statistical terms we say the estimation is biased. To avoid the bias would require accurate estimation of the noise parameters, but this because of the large number of unknown parameters (the geometry and photometry of the changing scene) in general is not possible. Visual computations, which are estimation processes include the low level processes of feature extraction and the middle level processes of visual recovery. We hypothesize that the bias in the estimation of image features, that is points, lines, and image movement, is the main cause for most geometrical illusions as well as
illusory motion patterns. Because of bias the location of image features is estimated erroneously and the appearance of patterns is altered. It is shown that many geometrical optical illusion patterns are such that the bias is highly pronounced. We analyzed the bias in visual shape recovery processes and found that it is consistent with what is empirically known about the estimation of shape. It has been observed from computational as well as psychophysical experiments, that for many configurations there is a tendency to underestimate the slant. The bias predicts this underestimation of slant. To demonstrate the power of the model we created illusory displays giving rise to erroneous shape estimation.

http://www.optical-illusions.org

MO29
Colour vision brings clarity to shadows Frederick A A Kingdom
(fred.kingdom@mcgill.ca), Catherine Beauce2, Lynsay J Hunter1; McGill Vision Research Unit, Department of Ophthalmology, McGill University, Montreal, Canada, 2School of Medicine, McGill University, Montreal, Canada, 3Illinois School of Optometry, Chicago, USA—We have examined the effects of chromatic surface-variation on the identification of shadows. We employed a 6-luminance display comprising a simulated shadow overlaid on a tripartite background. The three background luminances were drawn randomly from a specified distribution that was identical for all conditions. The three conditions were a) achromatic - the stimulus was a monochromatic grey; b) chromatic - background and overlaid shadow sectors were assigned the same hue, with hues drawn randomly from the gamut available on the monitor; c) chromatic-all-border - the same as the chromatic condition except that the background and shadow sectors were assigned different hues. Using a 2IFC task, subjects had to decide which of two displays contained the shadow that looked most “natural”. The natural shadow stimuli were created by setting all three shadow sectors to 0.5 x the luminance of the background sectors upon which they were overlaid, whereas the unnatural stimuli were created by setting two sectors to 0.5 x background luminance and the third to a value that deviated from 0.5 by various specified amounts. Results showed the following order of performance: chromatic > achromatic > chromatic-all-border. This finding supports the hypothesis that the visual system has an in-built assumption that chromatic variations arise from surfaces, while uncorrelated, pure-luminance variations result from differential illumination. The results also reveal a new role for colour vision in identifying the spatial layout of the scene, specifically in helping discriminate shadow from surface.

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MO30
Multi-sensory contributions to the perception of up: Evidence from illumination judgements Heather L Jenkin1, (hjenkin@orka.ca), Richard T Dyde2, James E Zacher3, Michael R Jenkin2, Laurence R Harris3; 1Centre for Vision Research, York University, Canada, 2Centre for Vision Research, Department of Computer Science, York University, Canada, 3Centre for Vision Research, Departments of Biology and Psychology, York University, Canada – There are many definitions of ‘up’. Body orientation, gravity and vision each provide their own estimate but they are normally combined into a single percept. Often the cues coincide, as when standing in a well-lit environment. But what happens when they disagree? Does one dominate? Or do they all contribute to an average? We examined the contribution of body orientation, gravity and visual cues on ‘up’ perception when these cues were not in agreement. The perception of 3D shape from 2D shading served as an indirect measure of the perception of ‘up’, as light is normally assumed to come from above in the absence of illumination cues. Observers were (i) sitting upright in an upright room, (ii) lying on their side in an upright room, (iii) sitting upright in a room tilted 90°, or (iv) lying in a tilted room. Stimuli were shown on a grey laptop screen arranged with the keyboard in the normal configuration relative to the body and that was surrounded by a clearly visible room. Each stimulus was a 2D disc shaded from black to white. Each trial started with the disc’s shading axis randomly aligned. Observers rotated the disc until it appeared ‘most convex’.

The pattern of responses indicated that the perceived direction of ‘up’ is influenced by the direction of gravity, the orientation of the body and the orientation of the visual frame. The judgements were modelled as a weighted sum of vectors corresponding to the orientations of the body, gravity and the surrounding visual polarity. These data illustrate how the brain can resolve a common dilemma: how to deal with many sources providing normally redundant information about a single parameter. Knowing the relative weighting of these factors may be helpful in predicting performance on other related tasks, such as balancing, orienting or navigating in normal or unusual environments.


MO31
Verifying objects in minimal scenes Rosemary Belzadeh (belzadeh@usc.edu), Edward A Vessel, Irving Biederman; University of Southern California, USA—In a fraction of a second two people can comprehend novel scenes never experienced previously. To what extent does this capacity derive from familiar relations among clusters of objects? We addressed this question through a search task in which a subject verified a target object in a minimal scene consisting of three objects: two interacting (in physical contact) but the third by itself. Subjects were given a target name, e.g., “watch,” and had to decide whether the target was present in a brief (100 msec) masked presentation of the scene. Half the time the target was present either in the interacting pair or by itself. The critical variable was whether the pair of objects was in a familiar relationship, such as the watch on a wrist, or a novel one, such as the watch on a hammer. If familiar relations reduce scene processing demands, the target, when it is by itself, should be more quickly and accurately identified when the pair is in a familiar relation.

Acknowledgment: Michael C. Mangini

MO32
Explicit and implicit priming in change detection Elizabeth L Walter (ewalter1@darkeing.oregon.edu), Jagdeep K Bala, Paul Dassourian; Department of Psychology and Institute of Neuroscience, University of Oregon, USA—Visual change detection can be quite difficult (Rensink, 1997). In general, changes are noticed more quickly and accurately if they occur in the location of the current focus of attention, or in a location that was recently attended. To investigate the types of cues that might serve to guide attention within a scene, this experiment investigated the effects of explicit and implicit semantic priming on a subsequent change detection task. Participants first attempted to read aloud a briefly presented prime word (33 or 200 ms duration, followed by a mask of 250 or 83 ms, respectively), then looked for a difference between two alternating versions of a real-world scene. Successfully read primes (of either 200 or 33 ms duration) were coded as “Explicit”, and unidentifiable primes as “Implicit.” Primes named either the object that changed (Helpful), or named another object in the picture (Misdirected). Across all subjects, Helpful primes yielded faster change detection times than did Misdirected primes. This effect was significant for both Explicit and Implicit trials, although the effect was somewhat larger in the Explicit trials (Explicit Helpful RT = 4273 ms, Misdirected = 8769 ms, Implicit Helpful = 6920 ms, Misdirected = 10023 ms). However, performing a median split on the subjects based on the number of successfully read 33 ms primes showed that the overall effects were primarily driven by those subjects who were able to read more 33 ms primes. It is proposed that those subjects closer to the prime detection threshold were able to more fully process the implicit semantic information than those subjects who were further from
threshold. Having demonstrated the influence of semantic primes on change detection, this approach can be used to characterize the manner in which attention is allocated within a complex scene and to determine how objects in our visual world are semantically encoded.

**Acknowledgment:** University of Oregon, Institute of Neuroscience, Systems Neuroscience Training Grant

**MO33**

Viewpoint changes affect priming of spatial layout  
Carmela V. Gottesman (cgottesman@ou.edu); University of Oklahoma USA – Priming and explicit memory studies have demonstrated that viewers form mental representations of a scene's spatial layout. This study examined whether these representations are dependent on the observer’s current viewpoint. Two experiments using photographs and computer generated scenes looked at the effect of changes in viewpoint within the scene on distance judgments. Participants viewed a prime followed by a target and were asked to judge the location of two items in the target scene. The prime was either the same view as the target or a changed view. The angle between the prime and the target view varied between 0 and 90 degrees. Reaction time increased as the viewpoint change between the prime and the target view increased. The results suggest that these spatial layout representations are view dependent. Implications regarding the use of layout representations are discussed.

**MO34**

How are elements of a scenic layout bound together?  
Thomas Sanocki (sanocki@chuma.cas.usf.edu), Kimberly Michelet, Eric Sellers; University of South Florida, USA – Previous research provides evidence of representations of scenic layout that are broad in scope (in VSTM: Sanocki, Sellers, & Mittelstaedt, VSS01; in a priming paradigm: Sanocki, Cognitive Psychology, in press). The represented scenes involve many objects and surfaces. How could these elements be bound together? Standard explanations involve relations such as Gestalt properties, familiar configural features (e.g., right angle, corner), and semantic belongingness (e.g., same scene-schema). We present a method for testing these hypotheses. The general idea is that, if the representation is bound together by relations, then breaking the relations should disrupt the representation.

Scenic relations were broken by cutting pictures of scenes in two or more pieces and then intermixing the pieces, within and between scenes. The strongest mixup had four pieces, from two scenes, in jumbled positions. The ability to represent such scenes was measured with a priming paradigm. A scenic prime (a mixed or unmixed scene) was presented for one sec, followed by a blank interval, and then a target. The target was identical to the prime except for two spatial probes superimposed on it; observers indicated which probe was closer to viewpoint. With normal scenes, spatial processing is speeded by the scenic prime, relative to uninformative control primes. The prime activated a representation that was useful during the spatial processing of the target. Will mixed primes also speed spatial processing of their identical targets?

We found that they can, when the spatial relations probed in the target are local in nature. The strongest mixups (4 pieces from 2 scenes) speeded spatial processing as much as unmixed scenes. Thus, four separate bundles of local relations were represented. However, when global spatial relations were probed, breaking scene relations greatly reduced the priming effect and, presumably, the integrity of the representation.

http://chuma.cas.usf.edu/~sanocki/research.htm

**MO35**

A content-specific attenuation of change blindness: Preferential attention to animate beings in natural scenes  
Joshua J. New (new@psych.ucsd.edu); University of California at Santa Barbara USA – Considerable changes to an image often go undetected by observers if performed during a brief visual disruption (e.g. a saccade or global mask). This change blindness however is attenuated for regions and objects independently rated as “centres of interest” (Rensink, O’Regan, & Clark, 1997). This suggests that the detection of scene changes is mediated by the subjective “interest” of image features and their consequent attraction of visual attention. To conclude that some objects are preferentially attended due to their greater perceived interest however begs the more fundamental question: Why are some objects more interesting—more attention commanding—than others? One possible dimension for the objective prediction of “interest” and visual attention is that between animate and inanimate objects. In this experiment it was hypothesized that animate objects, because of their evolutionarily-persistent biological importance and propensity to change meaningfully, should be attended more closely than inanimate objects. This hypothesis was tested in a change-detection paradigm wherein subjects viewed a series of complex, natural scenes. In each scene, an object was either alternately added and deleted, reversed in orientation, or left the same in each display of the image. Changes to animate objects (people and animals) were detected more quickly and more frequently than changes to inanimate objects (plants, small artifacts, and large artifacts) in the first experiment and replication. Further experiments revealed that the observed advantages for detecting changes to animate objects were not attributable to low-level visual features or a learned expectation of change. These findings suggest that viewer interest and visual attention to natural scenes—although appearing largely subjective and idiosyncratic—can be partially accounted for by objective dimensions such as that between animate and inanimate objects.

**MO36**

Fuzzy object file theory: A framework for understanding recency effects for objects in scenes  
Gregory J. Zelinsky (gzelinsky@notes.cc.sunysb.edu), Lester C. Loschky2; 1State University of New York at Stony Brook, 2University of Illinois at Urbana-Champaign – Two experiments were conducted to (1) determine how gaze serializes objects in working memory, and (2) study the retrieval process contributing to working memory failure. Both studies used a gaze-contingent working memory paradigm to obtain forgetting functions for objects presented in complex scenes. Exp 1 had observers (n = 6) freely view 9-item scenes in order to remember each object’s identity and location. After gaze left a pre-determined target, observers could fixate 1-7 intervening non-target objects before the scene was replaced with a spatial probe at the target location. The task was to select the target from among 4 alternatives. Consistent with studies using sequential presentation, a steep recency benefit was found over the 1-2 intervening object range (87% and 76%, respectively) that declined into a flat level of pre-recency accuracy (65%) over the remainder of the forgetting function. Exp 2 asked whether the Exp 1 working memory constraints reflected encoding or retrieval limitations. The procedure was identical to Exp 1 except that the test was 9AFC rather than 4AFC (n = 10). Importantly, the encoding conditions were the same between the two experiments. Results showed a dramatic decline in recency relative to Exp 1, with accuracy after 1 and 2 intervening objects dropping by 17% and 14% respectively. We interpret these data in terms of “fuzzy object file theory” in which fixations on intervening objects interfere with target memory by forming forward temporal associations between properties of the target and the intervening objects. Because of these associations, the retrieval of target properties following presentation of the spatial probe is accompanied by the retrieval of unwanted intervening object properties. This “fuzzy” or non-specific retrieval of object properties accounts for the reduced memory accuracy in Exp 2. Given a fuzzy retrieval set, the 9AFC task used in Exp 2 makes it more difficult to exclude response alternatives.

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**MO37**

Judging distance across discontinuities in the frontal plane  
Cary S. Feria1 (feria@aris.ss.uci.edu), Myron L. Braunstein1, George J. Andersen2; 1University of California, Irvine, USA, 2University of California, Riverside,
USA—Recent research on the “discontinuity effect” has shown that perceived distance along a textured surface is reduced when the surface contains a texture discontinuity (e.g., Feria & Braunstein, VSS, 2002; Sinai, Ooi, & He, Nature, 1999). The present study examined the effects of the number and types of boundaries between textured regions and of more local factors in determining judged distance across discontinuities. The displays consisted of a frontal plane containing one or more vertical lines and three dots arranged in an inverted L. Observers judged the distance between the two vertically separated dots by adjusting the separation of the two horizontally separated dots. In Exp. 1, the line texture was continuous or divided into two, three, or four regions by shifting portions of the texture horizontally. Judged distance was reduced when one discontinuity was present and was reduced further with two or three discontinuities. In Exp. 2, the vertical lines were continuous or were offset horizontally along a curved boundary. In a third condition, the line segments produced in the second condition were rearranged randomly in the horizontal dimension to eliminate the implicit boundary contour. More distance was judged in the continuous condition than in the curved boundary condition, with the random condition intermediate. In Exp. 3, either a single continuous vertical line, a discontinuous vertical line (broken into segments that were offset horizontally), or no line was presented with the three dots. More distance was judged when a single continuous line was placed next to the vertically separated dots than when the line was discontinuous or absent. These results suggest that the discontinuity effect results from both a reduction in perceived distance when the extent being judged is interrupted by implicit contours at texture discontinuities. The present study examined the effects of the texture in a local region or the background was textured and the other area was a uniform texture. Three vertical poles were located in this region, arranged in a simulated 3-D scene in determining the judged distance between two objects. The displays consisted of a ground plane containing an irregularly shaped local region. Three vertical poles were located in this region, arranged in an inverted L so that poles 1 and 2 were separated in depth and poles 2 and 3 were separated horizontally. To enhance perceived depth, the displays translated horizontally and were viewed through a collimating lens. Subjects adjusted the distance between the two poles that were separated horizontally to match the perceived distance between the two poles that were separated in depth. In Exp. 1 and Exp. 2 either the local region or the background was textured and the other area was a uniform gray. We found in Exp. 1 that a regular stripe texture was equally effective as the local and global texture, whereas a random dot texture was effective only as the global texture. In Exp. 2 we varied the scale of the textures and found that the increase in the effectiveness of a dot texture as a global texture, rather than a local texture, was greater for smaller scale textures. In Exp. 3 both the background and the local region were textured, with one of four different textures—two regular and two random—used in each area. Judged distance was determined by the texture in the local region and the global texture on a ground plane in a simulated 3-D scene.
MO41
Gaze cues attenuate change blindness in the flicker paradigm
Christopher O’Donnell¹ (christopher.o-donnell@strath.ac.uk),
Stephen RH Langton²; ¹University of Strathclyde, UK, ²University of Stirling, UK—When alternating versions of a scene and a modified version of that scene are separated by a brief blank field, observers take a surprisingly long time to spot even large changes between the two scenes. One theory of this “change blindness” effect holds that attention is necessary to perceive such changes (Rensink, O’Regan and Clark, 1997). In line with this, the two experiments we report here showed that using gaze cues to manipulate participants’ attention produced a dramatic influence on change detection. In Experiment 1, participants spotted the change made to a scene sooner when the gaze of an individual appearing in that scene cued the location of the change than in scenes where no cue was present or when a neutral cue was provided. In Experiment 2 congruent gaze cues again facilitated change detection, but here the inclusion of an incongruent cue condition hindered change detection in comparison with a neutral cue condition. Moreover, data from this experiment indicate a relationship between change detection rate and the angular displacement of the changing object from the line of regard of the individual providing the gaze cue. Together these findings represent suggest that gaze cues trigger shifts of an observer’s visual attention in natural scenes.


MO42
Relative effects of superimposed and lateral masks in discrimination
Lynn A. Olzak (olzakk@muohio.edu), Scott H. Gabree; Miami University of Ohio—We investigated the relative effects of superimposed and surround gratings on the ability to distinguish between 4 cpd grating patterns that differed slightly in spatial frequency. Superimposed gratings were always orthogonal to the base components, and could act as masks or as second cues to discrimination. When two cues to discrimination were present, they could vary together (i.e., both low frequency in pattern A and high in patterns B), or could vary in opposition (low-vertical + horizontal-high vs. vertical-high + horizontal-low). Surround masks were either simple gratings or plaid, and were either in-phase or 180 deg out of phase with the center when surrounds contained gratings of the same orientation as the test. Test and mask contrasts were held constant at 0.1. Each condition was run in a separate block of 80 trials. Differences to be discriminated were adjusted individually for each observer to yield a d’ of approximately 1.5 in no-surround control condition. Moreover, data from this experiment indicate a relationship between change detection rate and the angular displacement of the changing object from the line of regard of the individual providing the gaze cue. Together these findings represent suggest that gaze cues trigger shifts of an observer's visual attention in natural scenes.

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MO43
Do lateral influences in discrimination cross segmentation boundaries?
Stephanie A Saylor (saylor@muohio.edu), Lynn A Olzak; Department of Psychology, Miami University, Oxford OH, USA—Contextual influences on fine spatial discrimination were assessed in two 2AFC signal detection rating experiments. Patches of sinusoidal gratings that differed slightly in orientation were discriminated in the absence and presence of modulated surrounds of the same contrast (0.1). Differences to be discriminated were determined individually for each observer to yield a d’ of approximately of 1.5 and held constant thereafter. In Experiment 1, orientation judgments were made on a 3 cpd vertical test grating alone (control) or in the presence of a 3, a 15, or 3+15 cpd vertical surround. Test and surround were either in-phase or out-of-phase and either abutting or separated by a 30 min gap of mean luminance. Each condition was run in a separate block of 80 trials. Results suggested that relative to control, performance was only suppressed when 3 or 3+15 cpd surrounds were in-phase with no gap. In Experiment 2, we tested the hypothesis that perceptual segregation mechanisms play a role in eliminating lateral suppression, and asked whether segregation between center and surround by a difference in luminance would reduce or eliminate suppression. We replicated the in-phase, 3 cpd, abutting surround condition of Experiment 1, but now with a luminance mismatch between center and surround components. Contrast of center and surround were still held constant at 0.1. Preliminary results suggest that segregation by a luminance mismatch does indeed reduce or eliminate suppressive effects. We conclude that perceptually segregating a scene into parts interrupts lateral influences, and the results suggest that lateral influences affecting discrimination tasks only occur within a segmented area, not across areas.

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MO44
Mapping psychophysical non-classical receptive field with dual masking experiments
Chien-Chung Chen (chen@ski.org), Christopher W Tyler; The Smith-Kettlewell Eye Research institute, USA—Purpose. The visibility of a target stimulus can be affected by other stimuli presented on the parts of visual fields that is outside the target classical receptive field. We investigated the spatial properties of the non-classical receptive field psychophysically by observing how flankers at various locations affect contrast discrimination. Methods. In our dual-masking experiment, observers detected a 4 cy/deg vertical Gabor target superimposed on a vertical pedestal in the presence of either vertical or horizontal flanker Gabors. The distance to the collinear flankers varied from 1 to 7.5 wavelengths. Flanker locations were 0, 11, 22, 45 and 90 deg. away from the collinear axis. The pedestal contrast was from 1% - 50% with flanker contrast at 50%. We measured target thresholds with a 2IFC paradigm. Results. Compared with the no-flanker condition, the collinear flankers decreased target threshold at low pedestal contrasts (facilitation) and increased threshold at high contrasts (suppression) as expected from cat physiology (Chen et al., 2001, Neureport, 655-651). The size of low contrast facilitation increased with distance up to 4 wavelengths and decreased beyond that, while the high contrast suppression showed the opposite trend. For the vertical flankers, the greatest flanker effects (both facilitation and suppression) occurred at the collinear location and decreased monotonically as flanker location deviated from the collinear axis. For the horizontal flankers, the greatest flanker effect occurred at the 45 deg location. Conclusion. These flanker contrast effects are modeled with our sensitivity modulation model (Chen & Tyler, 2001, Proc. Roy. Soc. Ser. B, 509-16). The model suggests that the flanker effects are multiplicative terms applied to both the excitatory and inhibitory terms of a divisive inhibition response function. The model parameters show that the excitatory flanker effect is narrowly tuned in space while the inhibitory effect is broadly tuned.

MO45
A generalized cortical magnification rule predicts low-contrast letter recognition in the visual field
Hans Strasburger (strasburger@uni-muenchen.de); Generation Research Program (GRP), University of Munchen—Recognizing low-contrast patterns off the point of fixation is more difficult than what would be expected on the basis of retinal receptor density or size of projection onto the primary visual cortex (Strasburger et al. 1994, Eur. J. Neurosci. 6, 1583-1588). Nonetheless, estimates of the
cortical magnification factor predict reasonably well, across the visual field, both recognition performance for single, high contrast letters and grating detection contrast sensitivity. After a review of the M-scaling concept, a non-linear descriptive model is presented which predicts single character recognition at arbitrary contrast across the visual field. The model is a simplified version from the one presented previously, based on extensive additional data (Gothe, unpublished thesis; in total 19 sizes, 65 visual field positions, ~160,000 responses, in 17 young subjects). It states a hyperbolic relationship between letter size and log recognition contrast sensitivity, the asymptotes of which depend linearly on retinal eccentricity. Solved for letter size, it represents a generalization of M scaling which at high contrast is reduced to conventional M scaling. The prediction of percent correct recognition is by the psychometric function. A comparison to Gabor detection contrast sensitivity is drawn in the same subjects. The relationships to Levi’s E2 concept and to Bijl’s account of receptive field overlap are discussed. With the provided empirical parameters, the model predicts the proportion of correct recognition performance for singly presented characters of any contrast, of any size and at any position in the visual field.

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MO46
Masking by edge-induced illusory contours depends on contrast polarity Lauren Barghout1,2, (laurenb@spectacle.berkeley.edu), Stephen E Palmer1, Christopher W Tyler2, Smith-Kettlewell; 1UC Berkeley, USA, 2Smith-Kettlewell, USA — Purpose: Recently, we demonstrated that, contrary to predictions by classical hierarchical vision models, global context affects spatial masking (Barghout, Palmer and Tyler VSS 2002 ). Here we examine the effect of global context on masking by edge induced illusory contours on a target both consistent and inconsistent with an induced brightness illusion. Methods: We measured threshold elevation as a function of pedestal contrast (TvC) of a vertical 4 c/d micro-Gabor target in both the sine and cosine phase. Two control configurations controlled for known masking effects. The two experimental conditions manipulated global context by aligning the target with an induced illusory edge. In one condition, the target phase was not consistent with the induced brightness edge percept. In the second condition, the target phase was aligned so that it matched the brightness percept. Results: The target inconsistent with the brightness effect produced no masking or facilitation relative to our baseline control. The target consistent with the brightness percept, however, masked contrast detection and facilitated high contrast masking. Thus, global context introduced by edge induced contours effects local masking when the contrast polarity of the target is consistent with the brightness percept.

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MO47
Comparing contrast sensitivities to angular frequency stimuli and sinewave gratings in aged Naturel A Santos1, Maria Lucia B Sinas2, Renata Maria B.L. Nogueira2; 1Universidade Federal da Paraíba, PB, Brazil, 2Universidade Federal de Pernambuco, PE, Brazil — We measured 12 contrast sensitivity functions for sinewave gratings (CSF) as well as 12 contrast sensitivity functions for angular frequency stimuli (aCSF) using a forced-choice paradigm. Six volunteers (60-65 years-old) with normal vision as assessed by ophthalmologist on the last 12 months participated on the experiments. We used spatial frequencies of 0.5, 1, 2, 3, 4, 6 and 9 c/pd and angular frequencies of 2, 4, 8, 16, 24, 32, 48 and 96 cycles/360° to measure each contrast sensitivity function. Stimuli were computer generated on a 21 inch monitor SONY-BVM-1910. All measures were made at a distance of 150 cm, binocularly, with normal luminance of 6.9 cd/m2. The stimuli were circular with a diameter of 7.25 degrees of visual angle. Maximum sensitivity occurred at 3-4 c/pd for CSF and at 16-32 cycles/360° for aCSF. Sensitivity to angular frequencies (aFSC) was about 1.5 times higher than that for gratings (CSF). This effect was statistically significant at p<0.001. Results show that contrast sensitivities for angular frequencies are higher than for sinewave gratings.

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MO48
Extraretinal factors required for visual illusions Lothar Spillmann1 (lothar.spillmann@zfin-brain.uni-freiburg.de), Baingio Pinna2, Frank Stürzel1, John S Werner2; 1University of Freiburg, Germany, 2University of Sassari, Italy, 3University of California Davis, USA — Visual illusions characterized by brightness enhancement, induced color, relative motion and shape distortion are not entirely determined by bottom-up stimulus parameters defining the pattern. Here, we demonstrate how top-down factors can modify the perceived strength of such phenomena. The Ehrenstein illusion requires freely moving eyes to perceive and sustain enhanced brightness; with fixation the illusion will be diminished and ultimately disappear. Freely moving eyes are also necessary for the perception of the Kanizsa triangle and the watercolor effect.

A second extraretinal factor involves active motion. The two concentric rings of Pinna appear to rotate in opposite directions when the observer moves toward or away from the stimulus. When the same flow field defined by expansion or contraction is imaged onto the retina of a stationary observer, the illusory motion is reduced substantially. This is likely due to the difference in proprioceptive feedback and possibly vestibular signals in the two conditions.

A third important factor affecting the perceived strength of illusions is attention. Shape illusions due to geometric optical distortions, as well as induced brightness and color illusions, require the observer to spread attention evenly across the stimulus pattern. These illusions diminish with focal attention.

Future research may benefit from the quantification of these extraretinal factors and may shed light on our understanding of visual perception under ordinary conditions of viewing. Such studies may reveal the interaction between local and global neuronal processing involved in veridical and nonveridical perception. Extraretinal factors may be considered within the cognitive context of Einstellung (set) proposed by the early Gestaltists. Neurophysiologists aiming to understand these factors require alert behaving animals. Computational models simulating illusions must also take them into account.

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MO49
The time course of visual completion measured by response classification Erin Shubel (eshubel@indiana.edu), Jason M Gold; Department of Psychology, Indiana University, Bloomington, IN, USA — Purpose: Previous studies have used a variety of psychophysical techniques to estimate the temporal properties of visual completion (1-3). Here, we use response classification (4) to directly measure the time course of visual completion by tracing the changes that take place in observers’ templates over time. Methods: “Fat” and “thin” Kanizsa figures were produced by rotating the corners of Kanizsa squares by ±1.75 degrees. Individual trials consisted of the presentation of a fat or thin Kanizsa square defined by either Illusory or Occluded contours in 43 unique frames of high contrast Gaussian white noise over a 500 ms period. Signal contrast was varied across trials to maintain 71% correct performance. For each observer in each condition, the noise movies presented across trials were classified, combined and smoothed with a space-time convolution kernel to form a spatiotemporal classification movie. Results: The resulting classification movie for two observers in both the Illusory and Occluded conditions after 30,000 to 50,000 trials showed that they were using only the regions near the corners at the beginning of the stimulus presentation. Later, by about 150-200 ms, the observers were also using the regions that fell between the corners of the square. Conclusions: These results are consistent with the idea that the visual system requires approximately 150-200 ms to fully construct a completed representation of the Kanizsa
square. To test the possibility that observers simply use the regions between the corners at a later point in time during the stimulus presentation, we are currently measuring spatiotemporal classification images in an additional “Real” condition where these regions are defined by true physical luminance contours.


http://vislab.psych.indiana.edu/~jgold/jmg/vss2003a.html

**MO50**

**Integration of local orientational and positional contour features in shape discrimination**

-Yi-Zhong Wang-

(McGill Vision Research Unit, McGill University, Montreal, Canada—Purpose: The detection of radial deformation of circular shape may involve the pooling of both local orientational and positional contour features. Here we investigated the independent groupings mechanisms for these two features. Methods: Stimuli were Gabor patch-sampled radial frequency (GSRF) patterns. Patch carrier orientation was tangential to the deformed circle at the placement position. With the change of modulation amplitude, patches placed at zero-crossings of the sinusoidal radial modulation had only orientational change from circularity but no positional alteration (orientational GSRF); patches placed at the peaks and troughs of the modulation had only positional perturbations from circularity but no orientation change (positional GSRF). The SD of Gaussian envelope was 0.14 deg; the carrier frequency was 3 cpd; the mean radius was 1 deg and the radial frequency was 4 cpd/360 deg, resulting in 8 patches in a GSRF pattern. The number of modulated patches was 1, 4 or 8. A temporal 2AFC staircase paradigm was employed. Thresholds were estimated by a maximum likelihood fitting procedure. Results: The mean thresholds of 3 normal subjects for detecting the modulation of 1, 4 and 8 elements in orientational GSRF patterns were 2.72±0.44(SD)% 1.16±0.45% and 0.67±0.25%, respectively. The corresponding thresholds for positional GSRF patterns were 2.25±1.0(SD)% 1.47±0.6% and 1.83±1.0%, respectively. While the pooling of local positional perturbations reached a plateau at 4 elements of modulation, the integration of local orientation continued linearly in a log-log scale until all 8 modulated elements were pooled. The slope of orientation pooling was 0.67, more than twice that for positional pooling. Conclusions: While both orientation and position of local contour elements can encode the deformation of circular shape, the pooling of local orientation into global shape is much stronger than that of local position and involves pooling over a larger spatial extend.

**MO51**

The intrinsic differences of lateral interactions in fovea and periphery and their functional impacts on visual perception

-Jing Xing (jing.xing@pha.gov) FFA AeroSpace Medical Institute—The perception of a central stimulus can be affected by the presence of surround stimuli through lateral interactions in the visual system. Xing and Heeger (2000) have demonstrated that surround suppression became markedly stronger as the center-surround stimulus was moved toward the periphery. Moreover, the different center-surround interactions in the fovea and periphery cannot be accounted for by cortical magnification.

This report presented further evidence that center-surround interactions in the fovea and periphery are incommensurable. We performed two psychophysical experiments and found that 1) perception of subjective contour diminished in the periphery; and 2) curvature detection with the presence of surround stimuli significantly deteriorated in the periphery. Once again, these differences could not be account for by cortical magnification. The results suggest that fovea and periphery play different functional roles in human vision. To understand the inhomogeneous functions of lateral interaction, we built an image processing model of the primary vision system with lateral connections embedded. We first adjusted model parameters to make the model have the same performance as human subjects had in fovea and periphery respectively. With those parameters, we then analyzed image perception in fovea and periphery. The results showed that lateral interaction resulted in image integration in the fovea but image segmentation in the periphery. The model also predicted the reduced legibility and reading speed in periphery that could not be explained with cortical magnification. The possible impacts of the results on evaluating perceived information complexity of a visual scene were discussed.

**MO52**

Simulating the development of contour integration

-James Tse (jte@linghamton.edu), Peter Gerhardt; Binghamton University—Long-range lateral interconnections between cells in the striated cortex are characteristic of the adult visual brain. These connections are not present at birth and begin development after the first 2.5 months, a period of rapid synaptogenesis. Improvements in various visual functions such as contour integration have been attributed to this maturation process. We implemented a computational model to explore the role of these developing lateral interconnections in contour integration. Our model is based on the known cortical structures in the primary visual cortex. The model represents the retinotopic spatial layout in the cortex using two dimensions to create a plane. The columns of orientation-selective cells are represented in a third dimension. The model used a facilitation rule that is a function of the Cartesian distance between two cells. In effect, a cell of a particular orientation preference in a particular spatial location sends a sphere of excitatory connection to cells of other orientations on other spatial locations. The goal of the computational model is to locate contours consisting of oriented elements in a background of noise consisting of randomly oriented elements. The preliminary results showed that the model preferred contours whose elements followed “good continuation”. Co-aligned and co-axial elements produced greater levels of activation despite the lack of an explicit co-linearity facilitation rule. Physiological recordings of firing activity in the primary visual cortex have revealed facilitatory interaction of cells separated by several millimeters. These long-range lateral connections may serve to integrate information across multiple receptor fields. These connections are not present at birth and develop after the first two months. The next step will be to manipulate the cortical extent of these lateral facilitatory connections in the model to simulate the effect of the maturation of the primary visual cortex on contour integration.

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**MO53**

Retinal anisotropies in illusory contour formation

-Thomas F. Shipley (tshipley@astro.temple.edu), Philip J. Kellman; Temple University, USA, 2University of California, Los Angeles, USA—We studied changes in illusory contour clarity as a function of retinal eccentricity. We used an adaptive staircase to identify the point of subjective equality (PSE) for pairs of illusory contours at differing eccentricities. In two experiments, subjects were shown two illusory rectangles with circular inducing elements and a fixation cross. While fixating, they judged the relative clarity of the nearest illusory edges. The fixation point appeared at one of five horizontal locations ranging from the midpoint between the two illusory rectangles to 14 degrees to the left (which was inside the left rectangle). In Experiment 1, the vertical distance between the inducing elements of the left rectangle changed from trial to trial. It decreased when the left illusory edge was judged weaker than the right and increased otherwise. In Experiment 2, the size of the inducing elements for the left rectangle changed; the diameter was increased when the left illusory edge was judged weaker than the right, and decreased otherwise.

For ten subjects, in each experiment, the average PSE determined by varying inducing element size and spacing was significantly affected by the location of the fixation point. In general, the nearer the illusory edge was to the point of fixation, the larger the gap needed to match a more
distant illusory edge, and the smaller the inducing elements needed to match a more distant illusory edge.

These results are consistent with decreases in strength of contour interpolation with retinal eccentricity. These findings may be modeled in terms of a modified ratio rule for contour strength, or an eccentricity dependent grouping-kernel size.

The effect of some spatial variables appears independent of retinal size in free viewing of illusory contours. It remains to be determined how retinally dependant grouping will be integrated over time to yield retinally independent grouping.

Acknowledgment: Research supported by National Institute of Health Grant EY13518

MO54
T-junction geometry and angle completion Fantoni Carlo (fantoni@psico.units.it), Gerbino Walter; University of Trieste, via Sant’Anastasio 12, Trieste, Italy – T-junction geometry (i.e., the amount of deviation from orthogonality, T-dev) is known to affect the strength of occlusion information ( McDermott, Weiss, & Adelson 1998), but remains only a candidate factor for the amodal trajectory’s shape. Unlike most visual interpolation models, our field model (Fantoni & Gerbino 2001) can embody T geometry as an effective factor. The field model smoothly interpolates T-stems by chaining resultants of good continuation (GC) and minimal path (MP) vectors. When T-dev is different from 0, two hypothetical mechanisms could be operating:

(1) T-junction normalization. Non-orthogonal stems are shifted towards orthogonality (Hearing 1861). This shift implies a corresponding GC-field’s rotation and a consequent modification of the whole set of GC-MP resultants compared to orthogonal T-condition.

(2) Orthogonality-dependent modulation of GC strength. Orthogonal T-stems are better extrapolated than non-orthogonal ones (Gillam 1987). As T-dev increases the GC-field’s strength decreases.

To test among these hypotheses we probed interpolation trajectories in 9 displays in which one angle of a diamond was symmetric occluded by another diamond. Support ratio and retinal separation between T-junctions were constant. The 9 displays were obtained by combining 3 occluded angle sizes (70, 90, 110) and 3 T-devs (-10, 0, 10). By definition, T-dev is positive when the surfaces intersection’s area is smaller than in the orthogonal case. When T-dev is negative both hypothetical mechanisms predict that the interpolated trajectory is flattened (relative to the orthogonal condition). When T-dev is positive the two mechanisms generate contrasting predictions. Observers judged if a briefly flashed probe was inside/outside the amodally-completed angle.

Independent of the interpolation-angle size, the penetration was smaller when T-dev= -10 than when T-dev= 0 , consistent with both mechanisms. Penetration was maximal when T-dev= 10 , consistent only with the T-junction normalization mechanism.

Acknowledgment: Support: MIUR-COFIN2000
http://www.psico.units.it/users/fantoni/T-geometry&completion.ppt

MO55
The grouping of contours into an L-Vertex depends on contrast polarity: Evidence for the incorporation of image statistics into mechanisms of perceptual grouping Irving Biederman (biede@usc.edu), Edward A. Vessel, Michelle R. Greene; University of Southern California, USA – The grouping of line segments into a single long contour is independent of changes in contrast polarity. That is, a contour is as readily perceived when some of its elements are lighter and some darker than the background as when all the elements are lighter or darker. This result is consistent with what might be expected if the mechanisms for smooth continuation were shaped by image statistics insofar as it is relatively common for contrast reversals to occur along an extended contour. An L-vertex provides strong evidence for the end of a surface. Would the perception of an L-vertex be invariant to a change in contrast polarity at the point of cotermination of its two segments? If the coding of such vertices has been shaped by image statistics, the perception of L-vertices would be expected to suffer from a polarity change insofar as it would be rare for a change in contrast to occur right at the cotermination point. Subjects named line drawings of common objects, drawn in black or white against a gray background, in which gaps were introduced in the longer contours. Lines were added orthogonal to the object contour at each side of the gap to form either two L-vertices at each gap in some versions of an object or two T-junctions at each gap in other versions. The added lines could be the same direction of contrast as the object’s contours at the gap or the opposite contrast. Whereas grouping would be expected to continue through a gap bridged by matching T-junctions, L-vertices would be expected to interfere with the grouping of the lines across the gap, resulting in poorer naming performance. This indeed occurred — when the legs of the L were of the same direction of contrast. When the legs of the L differed in contrast, performance improved to that of the T-junctions (which were unaffected by the direction of contrast), suggesting that the L was no longer effective in defining the end of a surface.

MO58
Neural mechanisms in border ownership assignment: motion parallax and gestalt cues
Rüdiger von der Heydt1 (von.der.heydt@jhu.edu), Fangtu T Qui2, Zijiang J He3; 1Dept. of Neuroscience and Krieger Mind/Brain Institute, Johns Hopkins University, Baltimore, Maryland, USA, 2Krieger Mind/Brain Institute, Johns Hopkins University, Baltimore, Maryland, USA, 3Dept. of Psychological and Brain Sciences, University of Louisville, Louisville, Kentucky, USA – Purpose: We have recently demonstrated border ownership coding in area V2 (Zhou et al, J Neurosci 20:6594, 2000). This study focuses on the role of motion parallax and dynamic occlusion cues in figure-ground organization and their interaction with Gestalt mechanisms. Gestalt mechanisms tend to interpret the inside of a closed contour as figure; motion parallax provides local border ownership cues. Methods: Single unit responses were recorded in alert monkeys during behaviorally induced fixation. We analyzed neuronal responses to the edge of a square figure that was defined by contrast as well as relative motion between random-dot textures inside and outside the figure. The edge was centered in the receptive field at the preferred orientation. Between fixation periods the figure was flipped about this edge, contrast was reversed, and motion conditions were changed. Results: Of 100 orientation selective cells tested in V2, 24% showed selectivity for the direction of occlusion at the edge as given by motion cues; 42% were selective for the side of the figure (Gestalt factor); and 18% were selective for both. In 78% of the latter (14/18, P<0.02), the preferred side of figure was also the occluding side of the preferred motion border, indicating that these cells utilized the different sources of figure-ground information consistently. Selectivity for motion-defined direction of occlusion was more frequent in V2 than in V1 (24/100 versus 1/23; P<0.05). Conclusion: Neurons in V2 are sensitive to motion parallax (or dynamic occlusion) and combine motion cues with Gestalt cues in a manner that is consistent with 3D object perception. The result complements our previous findings on the combination of stereoscopic cues with Gestalt mechanisms in V2 (Qiu et al., Neuroscience Abstracts 2001). Together, they reveal the emergence of explicit cue-invariant border ownership coding in V2.

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MO59
Collinear Inhibition in Williams Syndrome? Melodie Palomares1 (palomat@jhu.edu), Barbara Landau1, Howard Egeth2, James Hoffman2; 1Johns Hopkins University, USA, 2University of Delaware, USA – Williams Syndrome (WS) is a rare genetic disorder with a distinct cognitive hallmark: relatively spared language and profoundly impaired visuospatial cognition. This profile is of interest because it suggests that genetic deficits might target specific cognitive systems, in this case, the system spatial cognition. Most studies WS have used complex visuo-motor tasks such as drawing or block construction to evaluate their visuospatial abilities. Some have suggested that these deficits are not linked to "low-level" visual functions such as stereopsis and acuity (e.g. Atkinson et al, 1999). However, neuroanatomical studies show that V1 has decreased volume (Reiss et al, 2000) and has abnormal connectivity (Galaburda and Bellugi, 2000) in WS.

To explore the contribution of "low-level" visual functions in WS deficits, we measured threshold contrast for detecting a grating with and without collinear flankers. In normal adults, collinear flankers facilitate grating detection (Polat and Sagi, 1993), which is thought to be mediated by the long-range horizontal connections in V1. We found that WS participants (12-33 years old) have contrast thresholds for detecting an unflanked grating that is as good as normal adults, and better than normal 3- to 5-year old children. However, we found that WS were actually worse (i.e. inhibited) in the presence of collinear flankers regardless of their distance from the target (at 3 and 9 lambda), while normal children showed no significant effects of flankers, and normal adults showed facilitation. Normal detection thresholds in WS indicate that their mechanism underlying their feature detection is intact, while the lack of collinear facilitation in WS suggests that visual tasks requiring spatial integration is impaired, perhaps reflecting abnormal V1 connectivity.

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MO60
The influence of stimulus information on human perceptual learning: An ideal observer analysis
Christoph Rasche (rasche@psych.ucsb.edu), Rith T Pham, Miguel P Eckstein; Department of Psychology, UC Santa Barbara, CA – Introduction: Measured human perceptual learning (or lack of) for a given task is generally attributed to properties of the human perceptual system. However, as in other domains (e.g. object recognition, Tjan and Legge, 1998), the amount of task-inherent stimulus information to be learned will also influence the amount of human perceptual learning. Here, we investigate the effect of stimulus information on human learning in a localization task where the observer learns about: 1) the orientation of the signal, 2) orientation and polarity. Ideal observer analysis is used to objectively assess the maximal amount of stimulus information that can be learned. Method: We used a rapid-perceptual learning paradigm (Abbey et al., 2001). A learning set consisted of 4 trials. One out of 4 signals was randomly chosen and used throughout a set. On each trial, the signal appeared randomly in 1 out of 8 image locations embedded in image noise. Three observers had to localize the target on each trial and identify it on the 4th trial of the learning set. The signal set consisted of elongated Gaussians with 4 different orientations (0º, 45º, 90º, 135º). In the orientation (ORI) condition the signals had the same polarity, while in the orientation/polarity (ORIPOL) condition the 0º and 90º signals were Gaussian increments and the 45º and 135º signals were Gaussian decrements. Observer participated in 1200 learning sets per condition. Result: Human learning performance (averaged across observers) was 2.8% (±0.8%) and 7.63% (±1.17%) across the 4 learning trials for the ORI and ORIPOL condition, respectively. Ideal observer learning performance was 6.0% and 14.9%, respectively, suggesting that the greater human learning in the orientation/polarity condition reflects stimulus information. Conclusion: In any learning task, the stimulus information needs to be taken into account before attributing human perceptual learning (or lack of) to properties of the perceptual system.

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MO61
Pseudo-hallucinations in patients with visual field defects during spontaneous and training-induced recovery
Dorothe A Poggel1 (poggel@gpp.inwz.uni-muenchen.de), Eva M Mueller-Oehring2, Janna Gottho, Sigrid Kenkel3, Erich Kaster2, Bernhard A Sabel2; 1Generation Research Program, University of Munich, Germany, 2Medical Psychology, University of Magdeburg, Germany, 3Nova Vision Center for Visual Therapy, Magdeburg, Germany – Visual pseudo-hallucinations are associated with spontaneous recovery after visual system lesions. They are observed in 10-15% of patients with homonymous field defects. We investigated whether visual illusions also occur during visual restitution training (VRT), a computer-based treatment for the detection of white light stimuli at the visual field
border. The phenomenology of training-induced illusions was compared to pseudo-hallucinations during spontaneous recovery.

In a prospective study, 19 patients with post-geniculocortical lesions performed perimetric baseline examinations before and after a period of six months of VRT and were repeatedly interviewed, including questions on illusions. Additionally, a group of 119 patients with different pre- and post-geniculocortical lesions answered a questionnaire on pseudo-hallucinations after VRT.

In the prospective trial, 52.6% of the patients reported mainly complex visual illusions during spontaneous recovery (moving, colored, geometrical forms, real objects, or scenes). During training, significantly more patients experienced pseudo-hallucinations, but only those who had perceived those phenomena after the lesion. Training-induced illusions were usually simple (white flashes or spots) and associated with functional recovery temporally as well as topographically. In the larger sample, 36.4% had perceived pseudo-hallucinations in the context of the lesioning event, and 15.4% reported training-induced illusions. Pseudo-hallucinations during treatment occurred significantly more often in those patients who reported an increase of visual field size. Visual illusions presumably reflect spontaneous activity in (partially) lesioned brain areas which may be the basis for functional recovery. After a lesion, V1 and higher cortical regions are activated, generating mostly complex illusions. During VRT, V1 is specifically activated, triggering more simple pseudo-hallucinations associated with training-induced visual field increase.

**MO62**

A computational model of perceptual learning through incremental channel re-weighting predicts switch costs in non-stationary contexts Alexander A Petrov1 (apetrov@uci.edu), Barbara A Doser1, Zhong-Lin Lu2; 1University of California Irvine, USA, 2University of Southern California, USA – Error-driven channel re-weighting of early sensory representations accounts for temporal dynamics and switch costs of perceptual learning in a non-stationary environment. Learning was evaluated for orientation discrimination of peripheral Gabor targets (+/-10 deg) in two filtered noise "contexts" with predominate orientations at either +/-15 deg. The training schedule alternated two-day blocks of each context. We tested 3 target contrast levels. Training with feedback improved both discriminability and speed within and across blocks. However, there was a cost at each context switch. Cost magnitude (about 0.3 d') remained constant over 5 switches (9600 trials). For context-congruent targets, accuracy paradoxically decreased slightly with increasing Gabor contrast; for context-incongruent targets, accuracy increased substantially with Gabor contrast. A computational model accounts for all these results. Visual stimuli are first processed by standard orientation and frequency tuned units that incorporate contrast gain control via divisive normalization. Learning occurs only in the connections to decision units; the stimulus representations never change. Weights are updated by an incremental error-correcting rule that tracks the statistics of the environment. Task-correlated units gain strength while irrelevant frequencies and orientations are suppressed, producing a gradual learning curve. The optimal weight vectors are impacted by context because the background noise corrupts the predictive value of congruent channels. If the context shifts abruptly, the system lags behind as it works with suboptimal weights until it readapts, creating switch costs of approximately equal magnitude across successive changes in context. The normalization and nonlinearities in the system cause greater damage to the congruent channels, making the incongruent ones more predictive. This accounts for the counterintuitive congruence-by-difficulty interaction.

**Acknowledgment:** Supported by NIMH & NSF

**MO63**

Learning a novel 3D object category Leslie Welch (Leslie_Welch@brown.edu), Yao Boachie; Brown University, USA – Earlier work (Sinha, Heindel and Welch, 2000) has shown that learning a simple category (nine-dot configuration) was possible in the near periphery but did not transfer to other retinotopic locations. This was surprising because category learning had been considered a cognitive task, not a perceptual one. But if the category learning paradigm were included in our understanding of perceptual learning then the results are less surprising. In our experiments, we examined whether using the same task but a different visual stimulus would also show no learning transfer. Our category consisted of line drawings of a novel 3D object, comprising a four-sided pyramid with three curved cylinders attached to its sides. Category and non-category shapes were defined by the cylinders’ locations along the pyramid's sides A category learning task has two phases: a training phase when subjects are familiarized with several category members, and a testing phase when subjects are asked to distinguish between category members and non-members. We trained subjects in one retinal location and tested them in three locations, including the training location. Performance in all locations was indistinguishable. Category learning transferred to all locations tested. This indicated that the category learning paradigm alone could not dictate what level of visual processing actually occurred; stimulus characteristics could influence depth of processing. In this case, the pyramids and dot-configurations were different on many dimensions and a question for future work is what are the important stimulus differences that result in more or less learning transfer?

**Acknowledgment:** supported by Brown University

**MO64**

Perceptual learning without signal Nicolas Dupuis-Ray (nicolas.dupuis-ray@umontreal.ca), Frédéric Gosselin; Département de psychologie, Université de Montréal, Montréal, Canada – On the one hand, perceptual learning (i.e. a performance improvement in a given perceptual task following practice) has been shown to depend on low-level, “bottom-up” processes (e.g. Crist, Li & Gilbert, 2001; Gold, Bennett & Sekuler, 1999, Karmi & Sagi, 1991). A recent series of experiments by Watanabe, Nahez & Sasaki (2001, 2002) even demonstrated that it could occur in the absence of high-level, presumably “top-down” factors such as awareness. On the other hand, several studies suggest that “top-down” processes can at least modulate perceptual learning (e.g. Shi & Pashler, 1992; Ahissar & Hochstein, 1993; Ito, Westheimer & Gilbert, 1998). Nobody, however, has ever examined “top-down” perceptual learning in the absence of “bottom-up” perceptual learning. Here, we report such an experiment.

We employed the “superstitious perception” paradigm developed by Gosselin & Schyns (in press). We instructed our subjects (n = 10) to indicate the presence or absence of a noisy ‘X’ letter -- that was described to them but never shown-- in each of the1000 (n = 5) or 5000 trials (n = 5) that they were presented. Unbeknownst to them, the stimuli in all trials contained only white Gaussian noise. After this purely “top-down” treatment, the sensitivity of each subject was computed classically. Preliminary results indicate that perceptual learning can take place in the absence of bottom-up signal.

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**MO65**

Object concept learning from non-normalized data Jake V Bouvier (jv@mit.edu), Pavan Sinha; Dept. of Brain & Cognitive Sciences, Massachusetts Institute of Technology, USA – How does the human visual system learn object concepts from a series of example images? This is a difficult computational challenge given that natural images are often complex and contain many attributes that are irrelevant to the concept that needs to be extracted. Typical computational schemes for concept learning require that the system be provided with a training set of images showing the target object isolated and normalized in location and scale. While such a “pre-processed” training set simplifies the problem, it also renders the approaches unrealistic and circular, because in order to normalize an image, one needs already to possess the object concept.
To address these issues, we propose a computational model for visual object concept learning, motivated by experimental studies of object perception in infancy as well as following recovery from blindness. The model is designed to work with non-normalized training data. Given a set of images, each of which contains an object instance embedded in a complex scene, the system attempts to infer what the object concept is. More specifically, the model uses an unsupervised learning strategy at the outset to formulate hypotheses about possible concepts. At this stage, the processing is, of necessity, bottom-up. The only means of complexity reduction are low-level image saliences and a priori regularity within an object class. As visual experience accumulates, however, the object concept undergoes concurrent refinement, allowing the model to employ a top-down strategy in an effort to reduce search complexity in subsequent images. Such a mixture of bottom-up and top-down modalities represents a plausible computational analogue to the gradual use of prototypes in object recognition as observed experimentally in humans.

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**MO68**

**Investigating perceptual and decisional mechanisms for the dynamics of perceptual learning: Theory, models, and data**

**Authors:** Angelina M. Copeland, John J Rieser, Herbert L Pick

**Institutions:** University of Notre Dame, USA

**Abstract:**
Improvements in perceptual performance due to extended experience have been hypothesized to arise from a variety of perceptual mechanisms. Detection and discrimination thresholds have been the primary measure of performance in support of such hypotheses. The present work explores the possibility that decisional information may also play a role in perceptual skill acquisition, at least over some portion of the acquisition period. We present the results of an experiment designed to provide evidence for the potential roles of both perceptual and decisional factors. Stimuli were gray-scale Gabor patches and the critical variation was stimulus contrast. Individual observers each provided data used for estimates of detection and discrimination thresholds, discriminability and bias measures, reaction times, and scaling of magnitude estimates. In addition, we provide a description of a dynamic model capable of simultaneously predicting performance on all of these measures. The model is specified as a system of differential equations augmented with stochastic elements and decisional thresholds. The modeling architecture is flexible enough to allow a set of competing hypotheses regarding the roles of perceptual and decisional influences to be represented. These representations (a) are compared with respect to their ability to simultaneously fit all of the dependent measures, and (b) are used to identify experimental conditions that and empirical regularities that allow the candidate hypotheses to be tested and falsified.

**Acknowledgment:** supported by Brown University

**MO69**

**Does chunking by color facilitate category learning?**

**Authors:** Deborah J Silverman, Leslie Welch

**Institutions:** Brown University, USA

**Abstract:**
It is known that perceptual learning often does not transfer to other locations in the visual field. As an example, category learning with nine-dot displays did not transfer to retinal locations away from the training location. However, category learning did transfer when the stimulus was a line drawing of a novel 3D object. While the nine-dot and line drawing stimuli differed in many ways, one important difference could have been that the dot displays contained nine features and the line drawings that we used contained only three features. In the dot displays, nine dot positions were either consistent with the category (members) or random (non-members). In the line drawing displays, three cylinders were attached to three faces of a pyramid and the relative locations of the cylinders determined if the stimulus was a category member or not. Our current hypothesis was that color could be used to promote chunking of the nine dots, thereby reducing the apparent number of features to three. If an important difference between the nine-dot and line drawing displays were nine vs. three features, then we would predict category learning with colored dots would transfer to other locations. The results will be discussed in terms of the possible underlying physiology.

**Acknowledgment:**

**MO70**

**Alteration of the direction of throwing: multiple levels of adaptation**

**Authors:** Hugo Bruggeman, Christine L Eid, John J Rieser, Herbert L Pick

**Institutions:** University of Minnesota, USA, Vanderbilt University, USA

**Abstract:**
Movements are organized at multiple levels, including that of muscles & joints, space, and functional actions. Adaptation paradigm studies offer a method to investigate such organization. Typically, these studies are limited to the former two levels by altering either the motor system (e.g. change in force field), or the visual system (e.g. displacement of the visual field). To investigate movement organization at the functional action level, we induce perceptual learning by altering the perceptual event. For example, walking on a moving belt alters the perceptual event for translatory locomotion. Adaptation to such context transfers to functionally equivalent movements such as sidestepping, but not to other leg...
movements such as turning by stepping in place (Rieser et al., 1995). Other studies altered the perceptual event for the direction of hurling movements; participants are seated on the periphery of a rotating carousel and throw underhanded at a directly opposite target. In this context, adaptation reliably alters the direction of underhand throwing from a static position on the ground. This negative aftereffect transfers to functionally equivalent movements such as overhand throwing. Besides altering the perceptual event, throwing while seated on a turning carousel likely alters the forces that act upon the arm. This paper presents a series of studies that tease apart the relative contribution of adaptation to such forces and to the perceptual event.

Adaptation to throwing on the turning carousel results in a negative aftereffect in the direction of throwing, which has an initial magnitude of 5.1 degrees. This decays over test trials to an asymptote of 3.8 degrees. Subsequent experiments suggest that the decay is due to readaptation over time of the force contribution while the perceptual event adaptation remains constant. These results will allow future studies to pursue a more detailed investigation of the multiple levels of movement organization.

http://umn.edu/~brug0030/VSS03.html

MO71
Episodic short-term memory for spatial frequency: Is a series of stimuli remembered as a single prototype or as distinct exemplars? Feng Zhou (zhou@brandeis.edu), Michael J Kalena, Robert Sekuler; Brandeis University, USA — We used a novel psychophysical technique to determine whether a series of visual stimuli is remembered as a single prototype or as distinct exemplars. On each trial of our experiment, participants saw a series of three briefly-presented gratings, two Study items followed by a Probe item. Each grating comprised a vertical and a horizontal sinusoidal component; within a trial, the spatial frequency of the vertical component varied. Relying on memory of the Study items' vertical component, participants judged whether the Probe was the same as one of the Study items or differed from both. Individual discrimination thresholds of spatial frequency were used to scale the spatial frequency of the gratings. Between blocks of trials, the difference in spatial frequency between the two Studies assumed one of four values: 1, 2, 4, or 8 threshold units. Over trials, the Probe's spatial frequency varied relative to that of the Study items, thereby testing recognition over a range of perceptual distances between Probe and Study items. The results were summarized by "mnemometric functions," which relate memory performance to inter-stimulus perceptual distance. With Study items separated by 4 or 8 threshold units, the mnemometric functions' bimodality, shape and peaks indicate that Study items were represented in memory as distinct, noisy exemplars that are centered on the spatial frequencies of the Study items. The mnemometric functions were well fit by a three-parameter, signal detection model, whose representation of the first Study item was twice as noisy as the representation of the second Study item. The model also shows that individual discrimination thresholds closely approximate decision criteria in episodic recognition, which represents a near-optimal rule for deciding whether a Probe had been in a Study set. The quantitative links between visual stimuli and memory performance demonstrate that multiple items are stored as noisy exemplars in episodic short-term memory.

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http://people.brandeis.edu/~fzhou/publications/ns.pdf

MO72
Temporal stability of image statistics in visual working memory Mary M. Conte (mconte@med.cornell.edu), Jonathan D. Victor; Weill Medical College of Cornell University, USA — Images can be represented in visual working memory (VWM) not only on a pixel-by-pixel basis, but also in a more abstract way, in terms of their statistical structure. We previously showed (ARVO, 2002) that for 1st-order statistics (luminance) and local 4th-order statistics (higher-order structure), this representation is graded, not categorical. The goal of this study is to examine the timecourse of pixel-by-pixel and statistical representation of images in VWM. Stimuli exhibited three kinds of statistical changes: changes in a 1st-order statistic (luminance), changes in a local 4th-order statistic (isodipole structure), and changes in a non-local statistic (presence or absence of mirror symmetry). In a 4-AFC task, subjects (N=5) viewed four 8x8 arrays of black and white checks and were asked to determine which one (the target) changed from S1 (600ms) to S2 (200ms). A blank ISI was set to either 200 or 1000ms in alternating blocks of trials. In half of the trials, 16 checks within the target changed in luminance between S1 and S2, without producing a change in image statistics. In the other half of the trials, the change in the target from S1 to S2 induced a change in its statistical structure. Across all subjects and stimulus conditions, fraction correct (FC) and reaction time (RT) improved with a change in statistics (FC increased by .20, RT decreased by 144ms). For local statistics, a larger improvement in performance was observed for the 1000ms ISI condition (1st-order: 39 FC increase, 321ms RT decrease; 4th-order: .22 FC increase, 173ms RT decrease) than in the 200ms ISI condition (1st-order: 29 FC increase, 156ms RT decrease; 4th-order: .19 FC increase, 102ms RT decrease). For mirror symmetry there was only a minimal effect: .10 FC increase, 81ms RT decrease at 1000ms; .04 FC increase, 56ms RT decrease at 200ms ISI. We conclude that the representation of image statistics in visual working memory plays a larger role with a longer retention interval.

Acknowledgment: NIH EY7977

MO73
Slot-like versus continuous representations in visual working memory Weiwei Zhang (weiwzi-zhang@uiowa.edu), Steve J. Luck; Department of Psychology, University of Iowa, USA — Several sources of evidence suggest that people can maintain only 3-4 items in visual working memory, each of which contains multiple features (but not multiple parts). Is the working memory system that stores these items best conceived as (a) a set of discrete, fixed-resolution “slots,” or (b) a resource that can be allocated flexibly to provide more or less accurate representations depending on the number of items represented? To address this question, we are conducting a series of experiments examining change-detection performance for simple features such as color and orientation. In some experiments, we are manipulating the discriminability of the change and the number of items to be stored in memory. In others, we are using attention-directing cues to examine whether working memory resources can be flexibly allocated. Preliminary results are consistent with the proposal that the basic elements of visual working memory are stored as discrete, fixed-resolution, slot-like representations, although continuously variable resources may be used to combine these primitive elements into more complex structures.

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MO74
The decay characteristics of size, color, and shape information in visual short-term memory Lisa A Vandenbeld (lisa@interchange.ubc.ca), Ronald A Rensink; University of British Columbia Canada — Previous studies of the decay of information in visual short-term memory have made the assumption that all visual properties decay in the same way. The present study challenges this assumption by investigating the individual decay characteristics of size, color, and shape information in visual short-term memory using a partial report method. Twelve observers were shown a display of six objects that were either small or large, red or blue, and a circle or a triangle. After a certain delay period (inter-stimulus interval), observers were cued to report the size, color, or shape of one of the six objects. ISIs ranged from 100 ms to 5700 ms over a series of three experiments. The experimental logic was that decreases in accuracy with increasing ISIs reflected decay of the visual short-term memory representation. In each of the three experiments, unique decay
characteristics were found for the properties of size, color, and shape. Color information showed significant decay between 100 and 700 ms, and then it stabilized and showed no further decay until the longest ISI of 5700 ms. Size information showed no decay between 100 and 1900 ms, after which it decayed gradually until an ISI of 5700 ms. Shape information gradually decayed after 100 ms across all the ISIs. The discovery of different decay characteristics for size, color, and shape information has implications for how properties are stored in visual short-term memory, as well as how properties are integrated to form object representations.

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MO75
Episodic recognition memory for high-dimensional, human synthetic faces Yuko Yotsumoto1, Yuko@brandeis.edu), Hugh R Wilson2, Michael J Kahan3, Robert Sekuler4, Brandeis University, 2York University, Canada—Purpose: We investigated the human visual memory for faces, and evaluated the effects of perceptual similarity on visual memory performance with varying sets of study and test items. By using realistic, computer synthesized faces as stimuli, we could systematically vary the perceptual similarity among the items to be remembered, thereby gauging inter-item similarity's effect on visual memory. Methods: In Experiment 1, Sternberg’s recognition memory paradigm was applied to a set of 21 synthesized faces. On each trial, from 1 to 4, briefly presented Study faces were followed by a single Probe face. Subjects indicated whether the Probe had or had not been among the Study faces. To force reliance on episodic memory, Study and Probe items varied from trial to trial. In Experiment 2, the method of triads, followed by multidimensional scaling (MDS), was used to characterize subjects’ perceptual similarity space for the faces. Results: Experiment 1 showed that recognition memory was strongly influenced by the number of faces comprising a study set, and by the recency of a face’s occurrence on a trial. Expressing differences among faces in terms of distances derived from the MDS similarity space, we found that perceptual similarity among faces accounted for much of the variance in recognition memory performance. Finally, between-subject differences in the face-similarity space were relatively small. Conclusion: Inter-item similarity has powerful effects on episodic memory. We applied further analysis to examine the effects of similarity between the probe and the most similar lure, the similarity among all lures, and the similarity between the probe and all other lures. The fitness of visual memory models will be discussed in light of these results.

MO76
Sex differences in binding color to spatial location in picture recognition memory Kazunori Morikawa1 (kaz@res.otaru-uc.ac.jp), Bartlett W Mel2, Otama University of Commerce, Japan, 2University of Southern California, USA—We investigated the effects of color on picture recognition memory using 240 color photographs of rooms, which were categorically homogeneous and difficult to verbalize. In the learning phase, subjects were shown 60 color photos and 60 grayscale photos for 5 seconds each. After a 30-minute delay, the testing phase began, in which 120 old photos and 120 new photos were presented, one at a time. In Experiment 1, half of the old color photos were rendered in grayscale, and half of the old grayscale photos were presented in color. Recognition performance was best for C/C, and became lower for G/G, C/G, and G/C in this order. Experiments 2 & 3 examined whether representations of colors in memory are tied to representations of spatial location. Ten male and ten female subjects participated in each experiment, totaling 40. In the testing phase, half the old color and old grayscale photos were left-right reversed. For grayscale photos, reversal had no effect on recognition, suggesting that memories of grayscale shapes are only weakly bound to spatial location. In females, reversal had no effect on recognition of color photos, which was better than recognition of grayscale photos (p< .01). In males, recognition of unaltered color photos was better than recognition of unaltered or reversed grayscale photos. This sex difference was evidently not due to differences in intentional memory strategies. These results suggest that in males, colors are bound to spatial location in picture memory. The female recognition of shapes, on the other hand, may rely on representations of objects that are more spatially independent.

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MO77
Spatial scale of attention strongly modulates saccade latency, but not by modulating stimulus saliency Mark R. Harwood1 (mharrwood@sci.ccny.cuny.edu), Laurent Madelain2, Richard J. Krauzlis3,4,5, Josh Wallman1, 2Dept. of Biology, City College, City Univ. of New York, USA, 3Salk Institute for Biological Studies, USA—Purpose: During smooth pursuit of a compound stimulus (2 concentric rings, one 0.8 deg, the other 8 deg), the latency of saccades to a 1.5 deg perturbation is shorter when the spatial scale of attention is narrow (directed to small ring) than when it is broad (Madelain, Krauzlis & Wallman, Society for Neuroscience, 2001). A possible explanation for this attentional effect is that a narrow field of attention differentially increases the saliency of the small ring, thereby reducing its spatial uncertainty and leading to corrective saccades more quickly because the position error is detected more quickly. If this is so, increasing the contrast of the inner ring should have the same effect as attending to it.

Methods: On each trial the compound stimulus moved at 10 deg/sec until, at some point, its path was perturbed forward or backward by 1.5 deg, and, simultaneously, the number of radial segments in each ring briefly changed. Three subjects reported the number of segments in either the small or large ring, according to an auditory cue before each block of 24 trials. We measured the saccade latencies in response to the perturbation on 1344 trials for each subject.

Results: Catch-up saccades occurred much later when attending to the large ring than to the small, whether the contrast of the inner ring was 0.2, 0.4 or 0.8 (mean latency: large ring, 437, 427, 436 msec, respectively; small ring, 175,165, 161 msec).

Conclusions: Our results show that saccade latencies are shortened much more by attending to the small ring than by increasing its contrast. Therefore the shorter latencies when attention is narrowed are not due to attentional modulation of saliency. As an alternative explanation, we propose that short-latency corrective saccades are generated when the target leaves the spotlight of attention; with our perturbations this would have occurred only when the scale of attention was narrow.

MO78
Neural correlates for preparatory set associated with pro-saccades and anti-saccades in primate prefrontal cortex Joseph FX DeSouza1 (jdesouza@imaging.roberts.ca), Susan D Iverson2, Stefan Everling2, 1Center for Brain and Mind, Department of Physiology and Pharmacology, University of Western Ontario, London, Ontario, Canada, 2Department of Experimental Psychology, University of Oxford, South Parks Road, Oxford, UK—Difficulties to suppress prepotent responses is one of the hallmarks of the prefrONTAL syndrome. This deficit becomes clear in the anti-saccade task in which subjects have to suppress a reflexive saccade towards a peripheral visual stimulus and instead generate a voluntary saccade towards the mirror location. To investigate the role of the prefrontal cortex (PFC) in anti-saccade generation, we trained two monkeys on a task with randomly interleaved pro- and anti-saccade trials in which the color of the central fixation point instructed the monkeys either to generate a pro- or an anti-saccade upon stimulus presentation. Single neuron activity was recorded from the lateral PFC while monkeys performed the task. The location of the recording chamber was visualized in situ with magnetic resonance imaging and registered with the anatomy. Across all our neurons, we analyzed the neural activity during the pro-saccade and the anti-saccade instruction periods before the presentation of the peripheral stimulus for the saccade and found higher activity levels
when the monkeys were instructed to make a pro-saccade as compared to an anti-saccade (P<0.01). A proportion of the sample of PFC neurons also showed excitatory and inhibitory stimulus-related responses for the peripheral cue. These neurons exhibited a significantly larger stimulus-related response on pro-saccade trials compared to anti-saccade trials (P<0.01). Surprisingly these findings show similar response to what has previously been reported for saccade and visual neurons in the frontal eye fields and superior colliculus. This suggests that the PFC does not provide saccade suppression signals to these two oculomotor areas. Instead, we hypothesize that the PFC participates in the suppression of reflexive saccades by reducing the excitatory input to saccade-related brain areas on anti-saccade trials.

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MO79

Errors in exocentric localization during pursuit eye movement: the effect of spatiotemporal properties of a static reference

Hyung-Chul O Li (hyung@daisy.kwangwoon.ac.kr), Jang-Han Yoon; Dept. of Industrial Psychology, Kwangwoon University, Wolga-Dong, Nowon-Gu, Seoul, Korea (South) – It takes time for the retinal signal of a flashed target to reach the brain. If during pursuit the brain matched the signal to the site of fixation at a given point in time, the perceived location of the target would be biased towards the direction of pursuit. We examined whether the "mismatch hypothesis" could explain errors in exocentric localization. Given that neural processing time depends on the stimulus, it is possible that localization of a target relative to a static reference (exocentric localization) during pursuit would produce errors, but these should not be affected by spatiotemporal properties of the static reference. To test this idea, a target rectangle surrounding a static reference was briefly flashed while subjects were required to pursue a dot moving rightward. The task was to localize the target relative to the reference. We manipulated the adjacency of the target to the reference, as well as the lifetime of the reference (infinite, appearing, and disappearing when the target was flashed). The amount of mislocalization dramatically decreased as the target became closer to the reference in both appearing and infinite conditions, but localization remained accurate in the disappearing condition. The last result may be explained by supposing that both target and the disappearing reference were mislocalized by the same amount in the direction of pursuit. Interestingly, as the interval between the flashed target and the disappearance of the reference increased (up to about 150 msec), the amount of mislocalization approached that of the infinite lifetime condition. These results imply that the "mismatch hypothesis", along with the "latency difference" cannot explain the errors in exocentric localization.

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MO80

What predicts where one will look when viewing artwork?

Susan M. Heidenreich1 (heidreich@usfca.edu), Kathleen A. Turano2; 1University of San Francisco, San Francisco, CA, USA, 2Wilmer Eye Institute, Baltimore, MD, USA – Purpose: To determine whether subjects’ gaze-fixture patterns (scannaths) for representational paintings, viewed in a museum, are predicted by salient-feature models, a global-local viewing approach, content-information which forms the narrative, or aesthetic characteristics of the artwork. Methods: Four naïve observers viewed museum paintings, while wearing a battery-operated, headband-mounted ISCAN eye tracker. Two cameras simultaneously videotaped the eye and the scene; the data were digitized and analyzed off-line. Paintings varied in degree of representation, from French Neo-Classical to Impressionistic (e.g., Ingres to Monet). Afterward, viewers judged six aesthetic properties of each painting, using semantic-differential scales with endpoints labeled by adjective pairs, such as displeasing-pleasing, etc. Results and Conclusions: To quantitatively compare fixations with predictions based on Itti and Koch’s (2000, Vis. Res.) saliency model, we conducted an analysis similar to Parkhurst, et al. (2002, Vis. Res.). Initial fixations did not support the model. Nor did scanpaths follow a global-to-local pattern. Rather, fixation patterns appear to be partly determined by narrative information; furthermore, scanpaths were rather idiosyncratic. Neither mean fixation duration nor viewing time was positively correlated with any aesthetic-judgment scores. The judgments for pleasingsness were most often correlated with other scales. Results contradict current theories of scene perception and aesthetics that assume that areas of high saliency "drive" the eye.

MO81

Eye movements and response accuracy in comparative visual search

Laurence R Gottlob (gottlob@uky.edu); University of Kentucky, USA – In a comparative visual search experiment (Pomplun, Sichelschmidt, Wagner, Clermont, Rickheit, & Ritter, 2001), two halves of a display (12, 15, or 18 items per half) contained visual primitives of various shapes (circles, triangles, squares) and colors (green, blue, red). On 50% of trials, a single primitive differed between the two halves in form, color, or form/color; on the other 50% of trials, the two halves were identical. The observers’ task was to make a yes/no decision to the presence of the different primitive. Eye movements, response latency, and response accuracy were measured as a function of both display size and difference type.

Display size affected responses: As display size increased, hit rate decreased. Also, with increases in display size, response latency increased in proportion to the increase in the number of fixations, but mean fixation duration was constant. Display-size effects may be described in terms of limitations on VSTM.

Difference type (form, color, or form/color) also affected hit rate, but did not affect numbers or mean durations of fixations. Detection of form mismatch was more difficult than detection of color mismatch, and there was a hit-rate redundancy gain at all display sizes: Form/shape differences yielded higher hit rates than differences in only shape or only color. The redundancy gain may be described by a horse-race model between searches for form and color differences.

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MO82

Development of object concepts in infancy

Scott P Johnson (sj75@cornell.edu), Dima Amso, Jonathan A Slemmer; Department of Psychology, Cornell University – Concepts of objects as enduring and complete across space and time rely on perceptual filling-in of gaps imposed by occlusion. Rudimentary object concepts have been documented in infants within several months after birth, but little is known about how such concepts arise. We examined development of existence constancy by presenting 4- and 6-month-old infants with a display consisting of a ball moving back and forth, the center of its trajectory occluded by a box (the experimental condition). We recorded eye movements with a corneal reflection eye tracker. We reasoned that a representation of the continuity of the object across occlusion would be revealed by a consistent pattern of anticipatory eye movements. We tested a second group of 4- and 6-month-olds in a training condition; these infants were first exposed to an unoccluded trajectory for 2 minutes prior to viewing the occluded-trajectory display. As expected, 6-month-olds in the experimental condition produced reliably more anticipations than did the 4-month-olds, implying a more robust representation of the object under occlusion. We found also that there were no age differences in anticipation in the training condition, and that 4-month-olds who received training produced a similar proportion of anticipations in response to the occlusion display relative to 6-month-olds in the experimental condition. Simple oculomotor maturation between 4 and 6 months, therefore, is unlikely to be responsible for the improvement in performance from training in the younger infants. In sum, 2 minutes of training with a moving, unoccluded object leads to knowledge of continuity across
MO83
Trans-saccadic Integration for Low-level Visual Information
Steven L Prime (sprime@yorku.ca), Matthias Niemeier, Xi-Gang Yan, John D Crawford; York University, Canada – Trans-saccadic integration is a process by which visual information from separate gazes are integrated to form a unified and stable perceptual representation of the visual world. Previous research has suggested that trans-saccadic integration is limited. The purpose of this study is to investigate if certain object features such as luminance, orientation, and shape may be retained and integrated across saccades. Subjects participated in a task which involved comparing two sequentially presented probes in terms of their luminance levels, orientation, and overall shape. Subjects performed this task under two conditions. In the first condition subjects were required to maintain eye fixation as both probes were presented. Conversely, during the second condition subjects were required to make a saccade in the delay interval that separated the two probes. Also, probe presentation varied in terms of their retinal and spatial locations. In one half of the trials both probes were presented directly on the subjects’ fovea. The other trials the first probe was presented on the subjects’ periphery and the second on their fovea. The magnetic eye coil technique was used for monitoring eye movements to ensure that subjects did not make extraneous eye movements. Results showed that the subjects’ accuracy were statistically the same between the conditions comparing saccade conditions with eyes-fixed conditions. Moreover, there was a significant difference found for probe presentation, subjects were more accurate when both probes were presented on the fovea. This would suggest that luminance, orientation, and shape information are retained and integrated across saccades at approximately the same accuracy as when eyes are fixated.

MO84
The spatial deviation of reaching to the same point under the different gaze directions
Taro Maeda (maeda@agr.br.h.t.nt.c.jp), Hideyuki Ando, Maki Sugimoto; NTT Communication Science Laboratories, 3-1, Morinosato Wakamiya, Atlugi-shi, Kanagawa Pref, Japan – It is an empirical phenomenon that the visual space is not homogeneous in the visible area. The retinal visual space and the eye-directional visual space should be correctly coincident in order to keep the equivalent continuity of the visual space under the free eye movements. It is a sensory integration process between eye directions and retinal spatial images, and under such sensory integration process, empirical phenomena of spatial deviation are observed frequently. In this report, the deviations between these visual spaces were measured psychophysically on the reaching tasks with upper limbs. Under the different eye directions, the reaching points are also different toward the same spatial point perceived not moving. Following the spatial deviations, the temporal deviations were also measured under the reaching tasks via the fixation point. In this experiment, Three points are arranged on the horizontal plane in front of the subject which are the start point, the target point and the fixation point. The subject starts his hand for the reaching task from the start point to the target point via the fixation point The subject has to fixate the point until the change of color on the point. After the change, the subject shifts the gaze to the target point before the end of reaching task. When the change is insufficiently earlier than the start of reaching, the hand reaches to the point as if the subject gaze the fixation point all time. When it is sufficiently earlier, the hand reaches to the point as if the subject fixated the target point all time. From the results, it is observed that the shift of fixation before the start of hand is necessary to change the reaching point. It is supposed that this sensory integration process would have more direct connection to the motor command than the process of ordinarily visual spatial perception because of the short latency.

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MO85
Automatic and intentional memory processes in saccade target selection
Jason S Mccarley (mccarley@uiuc.edu), Arthur F Kramer, Walter R Boot, Angela M Colcombe; University of Illinois at Urbana-Champaign – Short-term memory traces are known to encourage “visual foraging” by inhibiting eye movements toward objects or locations that have recently been inspected (e.g., Klein & Machnies, 1999). Here, we employed a variant of Jacoby’s (1991) process dissociation procedure to examine whether the memory processes involved in saccade guidance are primarily automatic or intentional. Subjects performed a saccade targeting task with gaze-contingent stimulus presentation. Each trial included a series of two-alternative, forced-choice events on which the subject could saccade toward either an old item, one which had been seen and fixated earlier in the course of the trial, or a new item, one which had not yet been seen. Three experimental conditions were employed. In the go-to-old condition, the subject was asked to saccade toward the old item. In the go-to-new condition, the subject was asked to saccade toward the new object. In the go-to-either condition, the subject was asked to saccade toward whichever of the two items he or she preferred. Data revealed that subjects were poor at targeting old items, even when explicitly instructed to do so; performance in the go-to-new condition was high, while performance in the go-to-old condition was near chance. Performance was similar in the go-to-either and go-to-new conditions. Results indicate that the memory processes that facilitate visual foraging are largely automatic, and difficult to suppress through intention.

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MO86
The effects of reversible inactivation of Frontal Eye Field and Superior Colliculus on saccade target selection
Robert M McPeek (rmm@ski.org), Edward L Keller; The Smith-Kettlewell Eye Research Institute, USA – Last year, we reported that temporary inactivation of a portion of the superior colliculus (SC) in rhesus monkeys results in a target selection deficit in a color-oddball search task. Specifically, after a microinjection of lidocaine or muscimol into the intermediate layers of the SC, saccades can still be made to visual targets in the affected part of the field when distractors are absent. However, when the target must be selected from distractors, monkeys make a greater proportion of erroneous saccades to distractors. We have now observed a similar, although less pronounced, target-selection deficit after temporary muscimol inactivation of a portion of the frontal eye field (FEF). Saccade target selection has been hypothesized to involve a winner-take-all competition across a map of visual salience. Our results suggest that the salience of stimuli in the affected field for the saccadic system is effectively reduced by inactivation of SC or FEF. To test this idea, we manipulated the perceptual salience of the search target by varying the difference in color between target and distractors. After inactivation of either SC or FEF, the magnitude of the search deficit was strongly affected by target salience, consistent with a salience-based target selection deficit, rather than a purely motor impairment. Although the effect on target selection of inactivation of either SC or FEF was similar in most respects, we found that performance after SC inactivation grew markedly worse when more distractors were present, while the opposite trend was seen after FEF inactivation. This suggests that the selective mechanisms in the SC depend more strongly on local inhibition among neighboring stimuli than in FEF. Overall, our results indicate that both SC and FEF play a functional role in saccade target selection.

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MO87

The time course of localization errors for repeatedly flashing stimuli through a saccade Junji Watanabe1 (junji@star.t.u-tokyo.ac.jp), Taro Maida2, Susumu Tachi1, 1Graduate School of Information Science and Technology, The University of Tokyo, Japan, 2NTT Communication Science Laboratories, Japan – When a repeatedly flashing stimulus is presented during a saccade, we perceive a dotted line called ‘Phantom Array’ (P.A.). Thanks to this phenomenon, by arranging LEDs (light emitting diodes) in a vertical line and flashing them repeatedly, we can see a 2D image when we make a saccade across the LEDs. Though the relationship between eye movements and perception of P.A. must be investigated in order to know how we perceive a 2D image during a saccade, there are few researches on the time course of the P.A. So we investigated the time course of the perceivable P.A. before, during, and after a saccade. We found that the P.A. starts to move as our eyes begin to move and stops as begin to stop. So, the time when we can perceive the P.A. is same as duration of a saccade. This result differs from the expected time course of localization errors for briefly flashing stimuli. The localization errors for briefly flashing stimuli begin approximately 100ms before the saccade offset. From our research, it is assumed that before and after a saccade we localize stimuli using relative position information on the retina, and during a saccade, as the retinal image is displaced rapidly, we localize stimuli by comparing the retinal images with eye position information. The perceptual difference between a repeatedly flashing and briefly flashing stimulus comes from whether we can use relative position information on the retina before and after saccades.

http://www.star.t.u-tokyo.ac.jp/~junji/saccade/

MO88

Cues to the relative spatial locations of visual targets presented in the dark Leanne Boucher (leanne.boucher@vaniercollege.ca), Robert Hendrich, Howard C. Hughes; Dartmouth College, United States – Information about eye position is used to make accurate saccades to stimuli in the environment. This study addressed the question of whether eye position is used in making perceptual judgments of the relative spatial locations of two successively presented visual targets. Subjects sat in a completely darkened room with their heads immobilized in a chin rest. A fixation light appeared straight ahead of the subject and was extinguished for a period of time between 1-30 seconds (dark interval duration). Subjects were instructed to keep their eyes directed at the remembered fixation location throughout the dark interval. At the end of the dark interval, a target light was presented for 1 ms in either the same physical or retinal location as the fixation point. Subjects responded whether the target light was in the same or different location as the fixation location. Eye position was monitored throughout the trial and confirmed that the eyes strayed away from the fixation location during the dark interval. If subjects are able to keep track of their eye position, then they will answer “same” only when the target light falls on the same physical location as the fixation light. Results indicate that as dark interval duration increased, subjects relied on retinal error information to make their response – they responded “same” when the target light fell on the same retinal location as the fixation light. This suggests that subjects are not able to monitor changes in eye position in the absence of visual cues.

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MO89

Event-related fMRI of saccadic response inhibition Mark W Greenlee (mark.greenlee@uni-oldenburg.de), Jale Ozcuyru, Roland M Ruschmann, Ignacio Vallines; University of Oldenburg, Germany – Inhibition of on-going or planned movements as well as monitoring errors is essential for adaptation to changing environments. We performed event-related functional MRI to examine neural correlates of inhibition and error processing in a saccadic Go/NoGo task. Contrary to the procedure in block designs, the BOLD response is recorded in each trial type separately, thus allowing us to sort trials depending on whether the trial was correct or incorrect. Gradient-echo EPI was performed on a 1.5 T scanner with a TR of 3 sec and 24 slices. Saccades and fixations were monitored using the MR-Eyetacker. Results from 7 subjects reveal NoGo dominant activity in dorsolateral prefrontal cortex (BA 9, 10, 46) and in the anterior cingulate (BA 24). Errors of commission on NoGo trials evoked stronger activation in right frontoocularpulsatious (BA 47), right DLPF (BA 9) and left orbitofrontal (BA 11) cortex compared to that found in Go trials.

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MO90

Eye position influences contrast responses in V1 of alert monkey Andrzej W Przybylszewski (przy@ei.harvard.edu), Igor Kagan, Max D Snodderly; Scheppens Eye Research Institute, Boston, USA – Do our cells in V1 respond differently when we look in different places? To answer this question, we have studied neuronal responses to moving bars in V1 of an alert monkey while it maintained different directions of gaze. The monkey was trained to fixate on an LED attached to the stimulus screen while the screen was placed in three positions: straight ahead or 0 deg (position 0), approximately 10 deg to the right (10R) or to the left (10L) in the horizontal plane (h) in a constant vertical position (v). Recorded mean +/- SE eye positions in minarc were: for position h,v = (2.5 +/- / 5.7, 5.3 +/- /-3.8), for 10R position (516 +/- /-16, -32 +/- /-3), for 10L position (-540 +/- /12, 31 +/- /5). We have recorded contrast responses in 21 cells. Changing eye position significantly influenced the maximum amplitude of the response in 13 cells. In 4 cells where maximum responses were unchanged, responses to lower contrasts changed significantly for different eye positions. In 7/17 cells in position 0 in 5/17 cells in 10R position and in 5/17 in 10L position, responses were larger than in other two positions. We have fitted contrast responses r(c) with the Naka-Rushton equation: r(c) = Rmax*(c^n / (c^n + c50^n)), where Rmax is the maximum response, c - contrast, c50 -contrast at the half of Rmax, n - nonlinearity. We have analyzed only those responses with a sufficiently good fit (estimated by the RMS). In most cases changing the eye position had small influence on n, but significant influence on Rmax and c50. We have analyzed 18 contrast responses to increment and decrement bars. Rmax changed, more than 20%, in 12 cases and c50 in 14 cases. In 10 measurements both Rmax and c50 changed as the eye position changed. Our preliminary data also suggest that the eye position could differently influence the size of the increment and decrement zones in the classical receptive field of V1 cells.

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MO91

Perceived slant influences vergence responses during horizontal gaze shifts across a surface Boris M Sheligia (bms@fsr.nei.nih.gov), Frederick A Miles; The National Eye Institute, USA – A flat surface in the frontal plane appears slanted about a vertical axis when the image in one eye is vertically compressed/expanded relative to the image in the other eye (induced effect). Such changes in the vertical magnification of one image also reduce or enhance the perceived slants induced by horizontal compression/expansion of the other image (geometric effect). We asked if these changes in perceived slant caused by changes in vertical magnification influence the vergence eye movements associated with horizontal transfers of gaze between targets located on a surface plane. We recorded the horizontal eye movements of 4 human subjects (Ss) viewing a random dot pattern on a tangent screen in a dichoptic viewing arrangement. Ss shifted their gaze horizontally across the pattern, which was compressed horizontally at one eye by 3-6%. The patterns were extinguished as soon as the Ss initiated the gaze shift (open-loop responses). In half the trials, prior to the gaze shift, Ss were additionally required to vertically compress/expand the pattern at the other eye until the binocular image appeared to be fronto-parallel (“nulling”). We found
that “nulling” reduced the vergence accompanying the horizontal transfers of gaze, on average, by 37% (SD ±8%, p<0.001). This reduced vergence was not simply due to degradation of the binocular depth signal(s) by the sometimes considerable vertical disparities: In a separate experiment, we showed that if these same vertical compressions/expansions were applied but with the opposite sign (“anti-nulling”), then gaze shifts were accompanied by an increase in vergence (216%, p<0.001). We conclude that perceived slant can influence the planned changes in vergence that accompany gaze shifts across a surface.

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MO92
A new form of saccadic compression of space Matthias Niemeier1,2, (matthias.niemeier@utoronto.ca), J. Douglas Crawford2, Douglas Tweed1,2. 1Departments of Physiology and Medicine, University of Toronto, Canada, 2Canadian Institutes of Health Research, Group for Action and Perception; Centre for Vision Research, York University, Toronto, Canada—Humans make saccadic eye movements to collect visual snapshots of the world, and from the resulting sequence of images we build a unified percept by a process called transsaccadic integration. We have recently suggested that transsaccadic integration works by optimal inference from the brain's imperfect visual and eye position signals and that, as a natural consequence, people show saccadic suppression of displacement: they have trouble perceiving stimulus jumps that happen during saccades. Computer simulations of our model predict that these jumps should appear compressed, so that perceived jumps are a nonlinear function of actual jump size. We tested this prediction experimentally. Eight subjects made saccades towards a target that jumped parallel to the saccade. Using a mouse they then moved the target back to what they felt was its presaccadic position, thereby indicating the perceived jump size. All subjects showed the predicted nonlinear compression in their perception of jumps. We suggest that other forms of distorted space perception may also arise from principles of optimal inference.

Acknowledgment: Supported by the NEI

MO93
Color shifts from patterned backgrounds: Spatial frequency selectivity and contrast sensitivity Patrick Monnier (pmonnier@uchicago.edu), Steven K Shevell; Visual Science Laboratories, University of Chicago, USA—BACKGROUND & PURPOSE: Background patterns composed of concentric circles alternating between 2 levels of S-cone stimulation (e.g., concentric circles that appear purple or green) can induce larger shifts in color appearance than a uniform background at either chromaticity. A model based on a neural unit with an antagonistic +/-s center-surround receptive field, like those found in V1 (Conway, 2001), can account for these color shifts. The neural model makes two further and heretofore untested predictions: 1) the color shifts should reveal spatial-frequency selectivity, and 2) the magnitude of the color shifts should increase with S-cone contrast within the background. Experiments tested both predictions. METHODS: Color appearance of a test field was measured using asymmetric matching. Spatial frequency: With a test-ring fixed in width at 9 min (3.3 cpd), the spatial frequency within the inducing background was varied from 1 to 10 cpd. S-cone contrast: S-cone contrast within the background was varied between 0.10-0.86 Michelson contrast. RESULTS: Spatial frequency: The largest color shift was observed when the test-ring and the concentric circles within the background were equal in width (i.e., equal in spatial frequency). Color shifts were observed with either an increase or decrease in the spatial frequency within the inducing background. S-cone contrast: Increasing S-cone contrast within the inducing background directly increased the induced color shifts. CONCLUSIONS: The measurements demonstrate the predicted band-pass characteristic with respect to inducing background spatial-frequency, and the monotonicity with respect to background S-cone contrast. Both properties are as predicted by the +/-s receptive-field of the kind found in cortical area V1.

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MO94
Cone inputs controlling color context effects: Detection and appearance James M Hillis (jmhillis@CATTELL.psych.upenn.edu), David H Brainard; University of Pennsylvania, Department of Psychology, USA—Purpose. The perceptual representation of color is context dependent: both color detection thresholds and color appearance vary with background color. We pursued two related questions: 1) Do the same neural mechanisms mediate both threshold and appearance context effects? 2) What are the L, M, and S cone inputs to the mechanisms that integrate context for each task? Methods. Stimuli were presented on a calibrated RGB monitor with 14-bit intensity resolution for each channel (provided by a CRS BITS++ device). In both detection and appearance experiments, test spots (2 deg in diameter, 4 deg eccentricity) were presented for 200 ms against either uniform or bipartite backgrounds. Background colors were selected from a set that differed in L+M or S-cone intensity. In the detection experiment subjects indicated whether a single test spot appeared left or right of fixation. Multiple interleaved staircases controlled the magnitude of L+M or S-cone increments/decrements. In the appearance experiment, left and right test spots flashed simultaneously. Between flashes, subjects adjusted spot color on one side to match a fixed spot color on the other side (chosen from a set of L+M or S-cone increments/decrements). Results. Detection and matching of S-cone spots was affected by S-cone background changes but not by L+M background changes. Detection and matching of L+M tests was affected by L+M background changes but not by S-cone background changes. Conclusion. For our stimulus conditions, the same pattern of cone inputs controls the mechanisms mediating threshold and appearance context effects. Moreover, the cone inputs controlling the context effects were matched to the color direction of the test. These results are consistent with the hypothesis a) the context effects we measured are mediated by neural mechanisms common to detection and appearance and b) these mechanisms are situated at a site prior to combination of signals from S cones with signals from L and M cones.

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MO95
Color-spreading selective for shape and configuration Dau-An Wu1 (dau-an@calleck.edu), Ryoji Kanai2, Shinshke Shimojo2,3, 1California Institute of Technology, USA, 2Utrecht University, the Netherlands, 3NTT Communication Science Laboratory, Japan—It is commonly held that filling-in phenomena stop at luminance edges (e.g. Troxler Fading). Previously, we reported a counter-example where edges facilitated color-spreading. Subjects fixating on a color gradient containing dark gaps perceived the central color to spread and replace the peripheral colors, 'jumping' over the gaps (Shimojo, Wu & Kanai, 2002, Perception 31, suppl.). Here, we show that the configuration of multi-colored patches present near the fixation point can spread into the periphery, as can multiple color-shape pairings.

A) Subjects fixate on a dark field containing an array of color patches. Each patch consists of a 'square' surrounded by a 'frame'. Squares vary from red to green in a graded fashion: they are red near fixation, green in the periphery. Frames are all green (so peripheral patches are homogeneous). Subjects perceive the configuration present at the fovea to spread, until all patches appear as red squares surrounded by green frames.

B) Color-spreading persists when both squares and frames vary in color. It is fastest when they are given opposite color gradients (center = red squares & green frames, periphery = green squares & red frames). Often, the extreme periphery quickly takes on the foveal pattern, even as areas of intermediate eccentricity retain their actual color (homogeneous yellow) for a time. This suggests that color-shape misbinding can facilitate the process of color-spreading.

C) For the above stimuli, color-spreading is weaker when patches are not colinear. However, for stimuli consisting only of frames (or squares),
spreading is independent of colinearity. In a third condition, if squares and frames are both present - but as separate objects - color-spreading is again independent of colinearity; the percept is of red squares and green frames lying on separate surfaces. We propose that interference between different elements on the same perceptual surface is alleviated by segregation onto different surfaces.

http://neuro.caltech.edu/~daw-an/spreading.html

**MO96**

**Combining information about color and line length in visual search**

Travis L. Young (travis.young@wright.edu), Allen L. Nagy; Wright State University, Dayton, Ohio, USA – Previous research in our lab has shown that observers can combine information in different cardinal color mechanisms to facilitate search and supports a non-linear model of the information combination. In the present experiments we investigated whether information about color and line length could be combined to facilitate search. Observers searched for a single longer line among distractor lines subtending a visual angle of 0.47 deg, in a brief display. A spatial 2AFC procedure was used to estimate thresholds for detecting the longer line. Either 2 or 10 stimuli were presented with half to the left and half to the right of fixation. The observer indicated whether the longer line appeared to the left or the right. In uniform conditions all lines within a display were the same chromaticity, and were green, white, or red in different experiments. In the variable conditions 2 target lines (1 to the left and 1 to the right) of known color were presented among 8 distractors. One of the target lines was longer than the other 9 lines. A cue informed the observer of the target line color for each block of trials. Targets were saturated green, desaturated green, or white. Distractors differed from the targets in color and varied in appearance from green to red in each display. Results from the uniform conditions show that line color had no effect on thresholds, but thresholds for 10 stimuli were 2.3 times higher than thresholds for 2 stimuli. In the variable conditions thresholds were lower than in the uniform condition with 10 stimuli for saturated green and white targets, but not for desaturated green targets. Results show that information about color and length can be combined to facilitate search in some cases, and are consistent with a linear model of the information combination rather than the non-linear model that described the combination of information in different cardinal color mechanisms.

**MO97**

**Combining information in different color mechanisms in visual search**

Kelly E. Neriani (kelly.neriani@wright.edu), Allen L. Nagy; Wright State University, Psychology Department, Dayton, OH, USA – Previous research in our lab has shown that observers can combine information in different cardinal color mechanisms to facilitate search. The purpose of this study was to investigate the efficiency for combining information. A yes-no task was used in all experiments. Stimuli were small disks that differed in luminance from a uniform gray background. Disks were presented for 200 msec within an annular region centered on a fixation point. In preliminary experiments we determined psychometric functions for detecting a white target stimulus among distractors that differed in L chromaticity and matched in S chromaticity. Nine stimuli were presented on each trial. These data were used to estimate L chromaticity differences in the red and green directions that corresponded to 98% correct. In the primary experiments we determined thresholds for detecting an increment in the S chromaticity of the white stimulus. In one condition the white stimulus was presented among 4 red and 4 green distractor stimuli set to the chromaticity differences determined in the preliminary experiments or to one half these chromaticity differences. S thresholds in these conditions were compared with S thresholds when all 9 stimuli were white and also when only 2 white stimuli were presented on each trial. Results showed that when the white stimulus was presented among red and green distractors, S thresholds were lower than when all 9 stimuli were white, suggesting that information in the L and S cardinal mechanisms was combined to facilitate performance. Furthermore, when the chromaticity differences were set to the level corresponding to 98% correct, thresholds were lower than when only 2 white stimuli were presented on each trial. We conclude that there is little or no information lost when information in different cardinal color mechanisms is combined. Similar experiments will be reported for luminance and chromaticity information.

**MO98**

**Color constancy as probabilistic inference: managing the tradeoff between the illuminant prior and scene evidence**

Eric T Ortega (eto@usc.edu), Bartlett W Mel; University of Southern California, United States of America – Color is a powerful cue for object recognition. To maximize the utility of color cues, however, a vision system must try to eliminate the colorizing effects of the illuminant to access the true underlying colors of object surfaces. Starting with a foundation in Bayesian statistics, we have developed a heuristic approach to color constancy which combines an illuminant prior with evidence from the scene to estimate the most probable lighting. This estimate is a linear combination of the a priori most probable illuminant and the average chromaticity over the set of S surfaces in the scene. To determine the scene's average surface color we preprocess using anisotropic diffusion, determine the distribution of chromaticities in the scene, and then fit with a constrained mixture of gaussians using S as a parameter. The mean color of the S gaussian generators is taken as the average scene color. A weighting factor B(S) sets the relative contributions of prior vs. evidence: the more colorful the scene, the heavier the weighting of the evidence. The function B is a saturating curve whose basic form emerged from Monte Carlo simulations using gaussian distributions for the illuminant and reflectance priors. To benchmark our algorithm, we developed a difficult color-based recognition task using 1,500 total images of 100 objects using 3 backgrounds and 5 lighting conditions. We analyze and discuss the relative strengths and weaknesses of our algorithm in comparison to grey world, brightest-is-whitest, and several other published methods including Retinex in Matlab (Funt, et al, 2000), Comprehensive Color Image Normalization (Finlayson, et al, 1998), and Multi-Scale Retinex (Jobson, et al, 1997). We end by speculating as to the neural basis for the operations involved in illuminant color estimation and color constant visual perception.

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**MO99**

**Attentional modulation of simultaneous chromatic contrast**

Kit Wolf (kit@bram.ncl.ac.uk), School of Biology, Anuya Hurlebert; University of Newcastle upon Tyne, UK – The colour of a surface is, under certain conditions, largely determined by its chromatic contrast with surrounding surfaces. Evidence suggests that the neural mechanisms underlying simultaneous chromatic contrast occur early in visual processing. On the other hand, chromatic contrast may be linked to colour constancy and other perceptual phenomena integral to our conscious experience of surface properties; if so, it may be mediated or strongly influenced by higher-level processing. Here we investigate whether attentional modulation affects the strength of simultaneous chromatic contrast, in a dual-task paradigm (similar to Li et al. PNAS, 99:9596-9601).

Our paradigm combines a serial search task that modulates attention with a concurrent 2afc task that measures the strength of simultaneous contrast. In the search task, five jumbled Ls or Ts are presented centrally for a brief time. The observer must indicate whether all five letters are the same (LLLLL, TTTTT) or different (LLLLL, TTTTL), whilst simultaneously performing the second task, which is to report the colour ('reddish' or 'greenish') of a very briefly flashed peripheral square against a red background. The colour of the square varies in constant steps along a red-green axis passing through the fixed background chromaticity and the neutral point. Contrast strength is measured as the chromatic distance between the square colour that appears neutral, and the neutral point itself. A neutral screen is displayed for a short time between trials to maintain long-term DC adaptation. In the control experiment, the
background remains neutral throughout.

Our results show that simultaneous chromatic contrast influences colour appearance even when attention is diverted to the central search task. Yet, preliminary findings indicate that contrast is weaker in the dual-task than in the single-task condition, suggesting that simultaneous contrast is modulated by neural mechanisms beyond the pre-attentive level.

MO100
A failure of the talbot-plateau law: temporally asymmetric chromatic flicker
Sherif Shady (sherif@psy.ucsd.edu), Donald I. A. MacLeod, Scott T. Mitten, Jennifer Liang; University of California, San Diego, Psychology Department – Purpose: Is the color of temporally asymmetric, chromatic flicker correctly predicted by linear temporal integration of intensity (the Talbot-Plateau law)? Methods: Exp 1. The point of subjective isoluminance (flicker null) for a 25 Hz, red-green (RG), square-wave flicker was determined across multiple values of the duty cycle–expressed as the proportional duration of the green phase of the flicker cycle–from 0.25 to 0.75. Exp 2. For a range of frequencies (30-80 Hz) and duty cycles (0.25, 0.5, 0.75), subjects matched the time-average color of isoluminant (based on Exp 1) RG flicker, by adjusting the RG intensities of a steady field. Results: Exp. 1 for a fixed-intensity red (or green) phase, the longer was the green (or red) phase of the flicker cycle, the higher (up to fourfold) was its intensity at the flicker null. Exp. 2 For a duty cycle of 0.25 or 0.75, the long phase of the flicker cycle dominated the flicker color, but not to the extent predicted by the linear integration. The color-matched steady field required a lower intensity, by as much as 20% at 30 Hz, than the flicker’s time-average intensity of the long-phase color. This deviation was measurable out to 70 Hz, beyond the CFF. Conclusions: (1) Dependence of the flicker null on duty cycle can be explained if selective adaptation of the cone type (L or M) most sensitive to the long phase of the flicker cycle calls for a higher intensity during that phase. (2) The color matches suggest an input from an early temporal-contrast nonlinearity. If this nonlinearity is located during that phase. (3) The color-modulated steady field is also accounted for by an early temporal-contrast nonlinearity.

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MO101
Chromatic selectivity of the mechanisms underlying object detection and color categorization
Daniel C Kiper (kiper@uni.tuebingen.de), Marie-Juliette Mandelli, Kristen S Cardinal; Institute of Neuroinformatics, Univ. of Zurich and Swiss Federal Institute of Technology, Zurich, Switzerland – In the early stages of color processing, color opponent neurons combine the signals from the various cones linearly. Their selectivity in color space is broad, and explains behavioral thresholds for the detection of uniformly colored discs. Is selectivity sharper for targets with more complex spatial properties, that are probably detected at later stages of the visual pathways?

We measured the chromatic selectivity of mechanisms responsible for the detection of static, circular Glass patterns (CGPs). In a display with a fixed number of dot pairs, we measured the proportion of pairs contributing to the CGP necessary for its reliable detection. To isolate the early stages of CGP processing, we varied the color of the dots within a pair. Human observers’ thresholds were lowest when both dots had the same color, and increased in proportion with the color difference between the dots. The selectivity of the underlying mechanisms is broad, consistent with the notion that they combine their inputs linearly. To isolate late stages of CGP processing, we used uniformly colored CGPs embedded in static noise. We varied the color of the noise relative to that of the CGP. As reported previously (Cardinal and Kiper, 2000), detection was easiest when noise and CGP had opposite colors, and hardest when they had the same color. The selectivity of the mechanisms involved in this task is also consistent with a linear combination of their inputs. We compared the selectivity of CGP mechanisms to those underlying color categorization, measured with a single hue-scaling procedure. Relative to those involved in CGP detection, the mechanisms involved in color categorization are narrowly tuned. Our results suggest that the human visual system relies primarily on broadly tuned mechanisms for the detection of colored objects.

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MO102
Detection of chromatic gratings in noise: field sensitivity and additivity within chromatic channels
Delvin T Lindsey (lindsey.43@osu.edu), Angela M Brown; 1Psychology, Ohio State University, Mansfield, Ohio, USA, 2Optometry, Ohio State University, Columbus, Ohio, USA – In spite of 20 years of research, there is little consensus as to the number or sensitivity profiles of the higher-order channels that mediate chromatic sensitivity in human color vision. We have studied the problem in a chromatic noise masking experiment using a combined field sensitivity and field additivity paradigm. Our goal was to evaluate the suggestion of D’Zmura & Knoblauch that channels seem narrowly tuned because the subject uses different channels to detect a test stimulus under different masking conditions (“off-axis looking”). We used an orange/blue isoluminant test grating, and dynamic isoluminant chromatic noise masks, with variable azimuth but constant (gray) average chromaticity and 5% luminance jitter within a rescaled DKL color space. We measured the field sensitivity of the mechanism(s) that detected our test grating, and found a profile that was most sensitive to the red/green (“RED”) noise masker and much less sensitive to the orange/blue (“ORANGE”) and yellow/purple (“YELLOW”) maskers. This suggested that our test grating was detected via a narrowly tuned “red” mechanism. We compared detection thresholds for our orange/blue test grating presented with a strong RED masker, a strong YELLOW masker, and both maskers combined. The threshold-elevating power of the YELLOW masker was 15 times greater when combined with the RED masker than when it was presented alone. This suggested that the orange/blue grating is detected via a “red” channel when it is presented alone or with the YELLOW masker, but shifts to a “yellow” or “orange” channel when the RED masker is used. The color appearance of the orange/blue test grating changed in agreement with this interpretation: it looked strikingly red/green in the presence of the RED-YELLOW masker alone, but looked orangeish/bluish in the presence of the RED masker. We conclude that the narrow tuning in our single-masker conditions is probably due to off-axis looking, just as D’Zmura & Knoblauch suggested.

MO103
Effects of language on color discriminability
Jonathan A Winawer (winawer@mit.edu), Nathan Witthoft, Lisa Wu, Lera Boroditsky; MIT, United States – Across languages, verbal codes divide the color spectrum in different ways. Do linguistic codes affect color discrimination? In a 2AFC recognition memory task, it was shown that subjects (Ss) are less likely to false alarm to cross category (CC) than within category (WC) foils, but that this advantage disappears with a verbal interference task (Roberson & Davidoff). This effect might be explained by a verbal contribution to categorical perception, or by language acting as a secondary code to meet the demands of working memory. We asked whether Ss show a CC advantage in tasks with no memory component, whether this advantage is selectively reduced by verbal interference, and whether this advantage can be seen in a language group that has a verbal color boundary and not in one without the same boundary.

Ex 1: In a 2AFC task, Ss saw a blue or green sample square patch, together with a match and a foil patch. No patches abutted. The foil was either WC or CC, with distance in Munsell color space held constant. Ss showed a CC advantage. Crucially, a verbal but not a spatial interference task significantly reduced this advantage.

Ex 2: Ss were shown 2 adjacent square patches (blue or green), and made a
same/different response, essentially reducing Ex 1 to an edge-detection task. We found a CC advantage, but there was no selective effect of verbal interference.

Ex 3: We repeated Ex 1 using only blue stimuli with Russian and English Ss. Russian has separate basic color words for light blue and dark blue. Preliminary results suggest that Russians have an advantage for CC over WC, and that this advantage is reduced by verbal interference. English speaking subjects, for whom all discriminations are WC, do not show this pattern.

We infer that there is an on-line effect of verbal coding on color discrimination (Ex 1), that if the task is made simple enough the effect of language is reduced (Ex 2), and that the effect may be specific to the coding system of the language (Ex 3).

MO104
Infant Color Vision: Spontaneous preferences versus novelty preferences as indicators of chromatic discrimination among suprathreshold stimuli
Andrea L. Civan1 (andreah@u.washington.edu), Davida Y. Teller2, John Palmer3, 1Department of Psychology, University of Washington, Seattle, WA, USA, 2Department of Psychology and Physiology/ Biophysics, University of Washington, Seattle, WA USA – Purpose. Although the presence of a spontaneous preference in infants indicates visual discrimination, the absence of a spontaneous preference does not necessarily indicate non-discrimination. Novelty preference techniques can demonstrate discriminability in the absence of a spontaneous preference. In the context of infant color vision, we investigated the interaction between spontaneous preferences and novelty preferences. Methods. Red and blue stimuli of varying purity were generated on a video monitor. Pairs of disks were identified that had equal or unequal spontaneous preferences. 16-week-old infants were studied with two measurements. Spontaneous preferences were measured using forced-choice preferential looking. Novelty preferences were measured using a forced-choice novelty preference technique. In the second technique, infants are familiarized to a pair of identical chromatic disks. A test phase follows in which the chromaticity of one of the disks is changed (novel). The infant’s preference for the novel stimulus indicates discrimination. Results. When spontaneous preferences were equal, the magnitude of novelty preferences increased with increasing purity difference. When spontaneous preferences were unequal, both spontaneous preferences and novelty preferences increased with increasing purity difference. Familiarization to the stimulus with higher spontaneous preference yielded an increase in preference for the previously non-preferred stimulus, whereas familiarization to the stimulus with lower spontaneous preference yielded no increase in preference for the previously preferred stimulus.

Conclusions. In the absence of spontaneous preference, novelty preference can be used to reveal discrimination among suprathreshold chromatic stimuli.

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MO105
Reaction time reveals that visual search has more memory
Takako Yoshida (q52608@sakura.kudpc.kyoto-u.ac.jp), Hiroshi Ashida, Naoyuki Osaka; Kyoto University, Japan – In visual search tasks, memory of the target features and positions in the past three to ten trials affects the present search performance. This is called “priming of the pop-out” or “repetition effect in visual search”. Using the concurrent tasks of visual search and visuo-spatial n-back tasks, we reported that the capacities and the stored representations between visuo-spatial working memory and the memory system contributing to the effect was not the same (Yoshida, et al., V982002). This time we reports that the same tendency is obtained when observers can not use verbal strategies and when they are required binding of the target color and position in their visuo-spatial working memory.

We used concurrent triple tasks (visual search, visuo-spatial n-back tasks, and articulatory suppression). Observers were required to search for an odd-colored target in a display and to quickly respond to the subtle shape of it, while maintaining the pre-instructed characteristic (color, position, and both) of the targets in the past n trials to judge whether the characteristic of the current target was the same as the target that had been presented n trials back. They also repeated a word out loud every 1 sec.

Observers successfully performed the triple task even if their visuo-spatial working memory was near its upper limit (around three). In all of the n-back tasks, reaction times were affected from a larger number of past trials (at most ten for the position). Moreover, the target characteristics observers did not maintain in their visuo-spatial working memory also affected current search performance. These results suggest that visual system accumulate the memory of the past attentive events even if the observer’s visuo-spatial working memory is full.

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MO106
The attentional blink reflects a delay in selecting T2 for working memory consolidation
Mark R Nieuwenstein (m.nieuwenstein@fse.uu.nl), Ignace TC Hooge, Rob HJ Van der Lubbe; Utrecht University, The Netherlands – The attentional blink (AB) refers to the phenomenon that observers often fail to report the second of two visual targets (i.e., T1 and T2) when these targets are presented within 500 ms in a rapid serial visual presentation (RSVP) sequence of distractors. This phenomenon has been proposed to reflect capacity limitations in working memory consolidation (WMC), such that T2 cannot engage WMC while T1 is being consolidated. However, based on the finding that errors in reporting T2 typically concern intrusions of the item directly following T2 (Chun, 1997), we propose an alternative account. Specifically, consolidation of T2 may fail because T1 consolidation delays the initiation of WMC for T2 to such an extent that T2 has already been overwritten by the following item in the RSVP sequence, thereby leading to intrusions of the item following T2. This account predicts attenuation of the AB when WMC is initiated 100 ms before T2 is presented.

In the present study, we investigated whether a distractor sharing a target defining feature can be used to initiate WMC before actual presentation of T2. Observers were to report two red digits presented in an RSVP sequence of black letters. On one half of the trials, T2 was preceded by a red letter (i.e. cue). The results showed that the AB was significantly attenuated on cued trials. Moreover, the increase in second target identification did not hamper first target identification. Consistent with our account, these findings support the view that detection of a distractor sharing a target defining feature initiates WMC, thereby leading to an attenuation of the AB for T2s that are presented in direct succession to this distractor.

MO107
Access to visual working memory is required for contextual cueing in visual search
Geoffrey F Woodman (geoff.woodman@vanderbilt.edu), Marvin M Chun; Vanderbilt University, USA – When subjects search for target objects embedded in repeating distractor configurations that predict the location of the target, search is faster than for targets appearing in novel distractor configurations. This effect is known as contextual cueing (Chun & Jiang, 1998), and it occurs even though subjects cannot discriminate the repeated arrays from the novel arrays, indicating that the memory for predictive context is implicit. In the present study we examined whether visual working memory is necessary for such implicit contextual learning. Specifically, we asked subjects to concurrently perform visual search with an object change detection task that required visual working memory. We occupied visual working memory with a set of four objects that subjects were required to maintain throughout the search task. We found that filling visual working memory to capacity did not disrupt a general improvement in search performance, but it eliminated contextual cueing. Thus, this study provides novel
MO108 Visual short-term memory encoding requires central capacity

Pierre Jolicoeur 1 (pierre.jolicoeur@umontreal.ca), Biliana Stevanovski 2;
1Department of Psychology, University of Montreal, Montreal, Canada,
2Department of Psychology, University of Waterloo, Waterloo, Canada –

Subjects viewed two visual displays that were separated by a short blank delay. The task was to decide whether the displays were the same or different. The displays sometimes consisted of coloured disks, sometimes of conjunctions of colour and orientation, and sometimes of moving dots. This visual short-term memory (VSTM) task was paired with a concurrent speeded pitch discrimination task. We summarize a series of experiments that revealed mutual interference between the VSTM task and the concurrent speeded choice task. This interference suggests that VSTM encoding requires central processing capacity that is also required for the speeded choice task. The experiments explored the nature of the capacity limitation, the generality of the effect, and the locus of interference.

MO109 Perception and memory in a spatiotemporal visual search

Jun Saki (saki@i.kyoto-u.ac.jp); PREST-IST, and Graduate School of Informatics,
Kyoto University, Japan – Studies on roles of memory in visual search have been focusing on memory for distractors or interference of memory tasks on visual search. This study investigated roles of memory for a target-relevant feature in visual search. Does preview of a target-relevant feature bound to the target location facilitate visual search? I devised a spatiotemporal visual search task to search for a target defined by a spatiotemporal change of its feature. Eight rectangular color bars moved horizontally, then they were partially occluded by squares, and the occluded parts reappear with a color either the same as or different from the visible part. Observers were precued a subset (from 1 to 4) of the bars, and judged the presence of a color changing target among the precued set. In the complete condition, where color information is available for the entire trial, observers could search for a target by comparison of two percepts, memory and percept, or both. To evaluate the role of memory and perception, two additional conditions were used. In the memory condition, color information of visible part is eliminated at the time of bars’ reappearance, forcing observers the search by memory-percept comparisons. In the perception condition, bars’ color information is unavailable until the bars’ reappearance, forcing observers the search by percept-percept comparisons. The threshold duration of bar reappearance increased as the set size, suggesting a spatiotemporal visual search. There was a significant threshold elevation in the memory condition for the set size of 3 or more, but there was no difference among the three conditions for the set size of 2 or 1, suggesting that search efficiencies by memory-percept and percept-percept comparisons are equivalent within the set size of 2, but that simultaneous availability of memory and percept does not improve search efficiency. Preview of colors at cued locations for more than 1000 ms does not facilitate spatiotemporal visual search. An acknowledgment: Support from JMEXT (#13610084, and #14019053), JSPS-RFTP99P01401, and PREST.

MO110 Allocation of attention affects the time-course of metacontrast masking

Marc 2, Carter 1 (marc.carter@hofstra.edu), Vincent R Brown 1, Bruno G Breitinger 1, Paul R Havig 1; Hofstra University, USA – 2University of Houston USA, 1Logicon Technical Services, Inc., USA – A modified version of the masking paradigm first introduced by Averbeck and Sperling (1961) was used to explore the effects of spatially-cued attention on metacontrast masking. Eight stimulus characters were presented in a circular array; following a variable delay (the target-prompt SOA), observers were prompted to classify the target as a digit or a letter; this basic procedure showed an expected decline in accuracy as a function of SOA, reflecting the decay of iconic memory. When the prompt was accompanied by a circle surrounding the target character, accuracy was a U-shaped function of SOA, showing a metacontrast masking effect. Both these results replicate Averbeck and Sperling (1961). However, when the character array was preceded by a valid cue to the target location, accuracy was increased, and the cue eliminated the decline in accuracy with increasing target-prompt SOAs. After the effects of cueing on the availability of the target in iconic memory were accounted for, an additional effect of the spatial cue on masking remained: although the U-shaped metaccontrast masking function remained in both cue conditions, validly cued targets were more accurately classified, and invalidly cued targets showed a smaller but significant decline in accuracy, relative to the control condition. The most relevant effect of the spatial cue for current theories of attention and perception is that directing attention to the target location decreased the target-mask SOA at which target classification accuracy reaches its minimum (that is, the masking function shifts to the left). This is important because previous results show that if display luminance and/or contrast are used to increase the salience of a masked target, the masking function is shifted to the right. This suggests that with respect to the metacontrast masking, stimulus intensity and attention operate in different ways.

MO111 Glare disability with attention impairment

Nicole Skaa (matthew-rizzo@uiowa.edu), Matthew Rizzo, Laura Sterman; The University of Iowa, Iowa City, IA, USA – Purpose: Glare is a vexing effect of intense light and reflections off object surfaces or ocular media. We tested if glare disability increases with visual attention decline. Methods: 107 licensed drivers participated: 79 were neurologically normal, 7 had mild AD, and 21 had focal cerebral lesions, mostly from stroke. Acuity on the ETDRS chart was scored in terms of log minimum angle resolvable (Ferris et al., 1982). To assess glare disability, we subtracted acuity scores under standard lighting from acuity scores under 3 glare levels (21.68, 234.6 & 1096 cd/m2) provided by a light shining in the viewer’s eye (Marco Inc., Jacksonvile). We measured selective attention using the Visual Attention Analyzer 3000 (subtest 3, Vision Resources, Chicago), and contrast sensitivity using the Pelli-Robson chart. Results: As a group, subjects showed progressive drops in acuity with increasing levels of glare (P=0.001). Drivers with selective attention defects (>350 ms to achieve 75% correct identification of a target among 23 similar distracters; N=16) had greater disability at high glare levels (P=0.005) than those with normal attention; the difference at medium glare approached significance (P=0.055). Degree of glare disability correlated positively with selective attention impairment (Spearman r=0.337; P<0.001) and negatively with contrast sensitivity (r=-0.303; P=0.002). Conclusions: Drivers with attention impairments from differing causes show greater glare disability. They are less able to ignore irrelevant distractions and recover signal from a noisy background created by glare. Glare disability is not explained by poor acuity but does correlate with impaired contrast sensitivity.

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MO112 Intact task switching in schizophrenia with a novel Arrow-Stroop task

Junghee Lee (junghee.lee@vanderbilt.edu), Takashi Sato, Sohlee Park, Department of Psychology, Vanderbilt University, USA – Task switching refers to an ability to switch flexibly from one behavior to another behavior in response to environment contingencies and is associated with the integrity of the prefrontal and anterior cingulate cortices. Task switching and cognitive control have been suggested to be impaired in schizophrenia. However, neuropsychological instruments used in previous studies, such as the Wisconsin Card Sorting test, are multidimensional and it is not easy to separate task switching from other factors in these instruments. We tested task switching in schizophrenia with a novel Arrow-Stroop task, where green or red arrows were used as
stimuli. Participants switched between two randomly ordered tasks, where an instruction cue preceded the target stimulus and indicated which task to execute. In the Arrow task, participants were required to respond to the direction of the arrow regardless of its color. In the Color task, they responded to the direction of the arrow when it was green, but to the opposite direction of the arrow when it was red. Overall schizophrenia patients showed the same amount of task switching cost as normal controls did, suggesting that task switching is intact in schizophrenia. In both groups, the switching cost from the Color task to the Arrow task was greater than the switching cost in the reverse direction. These results suggest that the deficit observed in previous studies might not derive from deficit in task switching, but from other aspect of cognitive control, implicating that “cognitive control” as a unitary concept should be re-examined.

**MO113**

**The time course of the useful field of view: The effects of aging and learning**  
Eric D Richards (eric@ncnmaster.ca), Patrick J Bennett, Allison B Sekuler, McMaster University, Canada – To examine age-related attentional deficits, young and old observers’ Useful Field of View (UFOV) was assessed in focused and divided attention conditions. The UFOV is the region of visual space from which an observer can extract information at any one time. Previous research examining the UFOV has shown that older observers have larger performance deficits than younger observers under divided-attention conditions (Sekuler et al., 2000). The goal of the present study was to examine the time course of these deficits, and any age-related interactions.

In this study observers were presented with 2 tasks: central letter identification and peripheral target localization. The central task required individuals to indicate (4AFC) the identity of a single letter presented at fixation, while the peripheral task required individuals to localize a peripherally presented target. Observers performed each of these tasks either individually (focused attention) or simultaneously (divided attention). The attentional costs (focused – divided attention performance) were assessed for each task, and the time course of these costs was examined by varying stimulus duration. The results indicate that older adults had more pronounced attentional costs than younger adults for the peripheral task, replicating previous research. In addition, these costs are differentially affected by the amount of processing time made available to observers (i.e., stimulus duration). Whereas peripheral task performance costs declined for younger observers with increasing stimulus duration, these costs persisted for older observers with increasing stimulus duration. These results indicate that younger individuals can overcome initial attentional costs, while older individuals cannot overcome these costs, when provided with additional processing time. The effects of practice and learning on these age-related attentional costs will also be discussed.

**MO114**

**Reversal of age-related deficits in visual attention: How long do the gains last?**  
Kathryn J Sifrit1 (kjsifrit@wichita.edu), Alex Chaparro1, Laszlo Stumpfhauser2,  
1Wichita State University Wichita, Kansas, USA, 2Department of Psychology, University of Iowa, USA — To examine age-related attentional deficits, young and old observers’ Useful Field of View (UFOV) was assessed in focused and divided attention conditions. The UFOV is the region of visual space from which an observer can extract information at any one time. Previous research examining the UFOV has shown that older observers have larger performance deficits than younger observers under divided-attention conditions (Sekuler et al., 2000). The goal of the present study was to examine the time course of these deficits, and any age-related interactions.

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**MO116**

**Effect of an attention demanding visual task on postural control in young and old adults**  
Nicole L. Rogers1 (nlrogers@wichita.edu), Alex Chaparro1, Michael E. Rogers2, 1Department of Psychology, Wichita State University, USA, 2Center for Physical Activity and Aging, Wichita State University, USA — Balance measures including Sway Index (SI), Sway Amplitude in the anterior-posterior (Amp-AP), Medial-lateral planes (Amp-ML), and Sway Speed in these planes (Spd-AP, Spd-ML) were obtained. RESULTS: The young and old adults differed significantly (p>.05) on all balance measures for the C and

**MO115**

**Increased reliance on attentional precues in normal aging**  
Rebecca A. Sheffield1 (rebecca-sheffield@uiowa.edu), Matthew Rizzo1, Shaun P. Vecera2, 1Department of Neurology, University of Iowa Hospitals and Clinics, USA, 2Department of Psychology, University of Iowa, USA — Results from studies of normal aging and Alzheimer’s disease suggest these individuals have larger attentional cuing effects than younger participants or non-demented controls. However, such studies have tended to use either speeded peripheral detection tasks or speeded discrimination tasks. Such tasks do not permit determinations of the mechanism of the attentional effect. For example, in speeded detection tasks, an attentional effect could be produced by shifts in perceptual sensitivity or response criteria; discrimination tasks, in which accuracy is often near ceiling, could contain hidden speed-accuracy tradeoffs. To address these shortcomings, we tested neurologically normal younger and older participants in a cued discrimination task in which accuracy was measured. We ensured accuracy was below ceiling by following a target digit with a single masking stimulus, a procedure that minimizes the contribution of later decision-level effects on attention (Shiu & Pashler, 1994). We found that the younger participants showed a smaller attentional effect (accuracy difference under “valid” minus under “invalid” cues) than older participants (4.39% versus 9.54 %, p < 0.01). Results support the conclusion that attentional effects are increased in normal aging. This increase could be produced by (a) increased allocation of attentional resources to the precued location in older participants or (b) increased levels of decision-level uncertainty, or noise, in older participants. Ongoing experiments will allow us to distinguish these alternatives, but the present results clearly indicate that older participants are more reliant on attentional precues in an unspeeded discrimination task.

**Acknowledgment:** Funding provided by the Wiedemann Foundation

**MO112**

**Effect of an attention demanding visual task on postural control in young and old adults**  
Nicole L. Rogers1 (nlrogers@wichita.edu), Alex Chaparro1, Michael E. Rogers2, 1Department of Psychology, Wichita State University, USA, 2Center for Physical Activity and Aging, Wichita State University, USA — Research indicates the attentional demands for balance increase with age. Age-related declines in balance may further increase the attentional demands associated with maintaining stability. PURPOSE: A dual-task paradigm was used to study the effects of an attentionally demanding visual task on postural control. METHODS: The static balance of ten young (22.7 ± 3.9) and ten older (75.7 ± 7.1) adults was evaluated under 3 conditions (Control [C], Word STROOP [WS], and Color STROOP [CS]). The STROOP task presents words printed in mismatching colors (e.g. “red” presented in blue ink). Participants are instructed to read aloud the word (WS) or the color the word is printed in (CS). The CS task is a more difficult and attentionally demanding task. Balance measures including Sway Index (SI), Sway Amplitude in the anterior-posterior (Amp-AP), Medial-lateral planes (Amp-ML), and Sway Speed in these planes (Spd-AP, Spd-ML) were obtained. RESULTS: The young and old adults differed significantly (p>.05) on all balance measures for the C and
WS conditions; under the CS condition the groups differed (p>.05) in SI, Amp-ML and Spd-ML. There were no significant balance differences between the C and CS conditions suggesting speaking does not impact balance. The older adults displayed significant (p<.05) differences for SI, Amp-ML and Spd-ML between C and CS; and significant differences (p<.05) for Amp-AP and Spd-AP between C and CS. The young adults displayed significant (p<.05) differences for SI, Amp-AP and Spd-AP between C and CS and WS and CS. CONCLUSION: The results indicate that an attentionally demanding visual task negatively impacts balance for both young and old. Interestingly, the secondary task increased older adult sway in the M-L plane, whereas young adults sway more in the A-P plane. These results also suggest that visual attention processes may play an important role in the maintenance of static balance in older adults.

Acknowledgment: A special thanks to Loren Groff and LGWare for providing the software

MO117
Visual pop-out in infancy: Effects of set-size on the latency of their eye movements Jazmine V. Opriego (jazmine@yorku.ca), Scott A. Adler; Department of Psychology and Centre for Vision Research, York University, Canada—PURPOSE. Visual pop-out is the phenomenon in which a unique item is rapidly detected from among a set of homogeneous distractors. Adult studies have attributed the phenomenon of visual pop-out to the functioning of early visual processing that registers all items in an array in parallel. Previous studies with infants have suggested that visual pop-out can be observed in them as well (e.g. Adler, Inslicht, Rowe-Collier, & Gerhardtstein, 1998). However, these previous studies have observed pop-out occurring on the order of several seconds to minutes whereas in adults pop-out is observed in milliseconds. It is therefore possible that the pop-out observed in infants is not due to early visual processing. Further, in adults, pop-out is unaffected by the number of homogeneous distractors in the array (set-size effect), an effect that has not been examined in infants. The present study examined whether the visual pop-out observed in infants is similar to that observed in adults.

METHODS. Three-month-olds' eye movement latencies were assessed as they viewed either a feature-present, pop-out array consisting of a single unique + among distractor L's or a feature-absent array consisting of all L's. To determine the effect of array set size on infants' eye movement latencies, both feature-present and feature-absent arrays consisted of either 1, 3, 5, or 8 items. RESULTS. The unique + popped out such that eye movement latency was unaffected by the number of distractors in the feature-present array, but increased with set size in the feature-absent array (set-size effect), an effect that has not been examined in infants.

Acknowledgment: Supported by NSERC grants 503860 and 506430

MO118
Age-related deficits and involvement of frontal cortical areas as revealed by the attentional blink task Kinmro L Shapiro (k.shapiro@bangor.ac.uk), Frances Garrad-Cole; University of Wales, UK—The attentional blink (AB) method represents a useful way to study the dwell-time of attention and has been the subject of a considerable number of experiments in recent years. In a standard AB task, participants are required to report two targets, separated from trial to trial by a variable stimulus onset asynchrony (SOA). The robust result of such an experiment is that, after having identified the first target (T1) correctly, there is a pronounced deficit in report of the second target (T2) for approximately 500 msec. Although the phenomenon has been well characterised in adults, few findings have been reported as regards its developmental aspects. Based on the reasoning that 1) frontal cortical areas continue to develop into early adult years, and 2) the AB outcome requires executive function and working memory to perform the task, we anticipated developmental differences to be revealed in the degree of AB exhibited by variously aged groups of participants. We tested four age groups with mean ages of seven, twelve, fifteen, and twenty on a modified version of the AB task that did not require reading. Participants were required to report whether T1 (masked) pointed up vs. down and whether T2 (masked) pointed left vs. right. Results showed a large deficit in AB performance in the youngest group, failing to recover until approximately 1500 ms. Performance in the twelve-year-old group revealed a more pronounced AB than did older children and adults and did not recover until approximately 1100 ms. A follow-up experiment reveals a deficit in the youngest group on a task requiring executive function. We conclude that the inability in young children to recover attentional function as well as their older age counterparts is likely due to lack of development of frontal cortical areas. These results corroborate well with studies of adult patients with lesions in similar brain areas.

Acknowledgment: Supported by NIH grant EY12925 & NSF graduate study fellowship

MO119
The role of competing stimuli in feature-based attention Melissa Saenz1,2, (saenz@slsc.edu) Geoffrey M Boynton2; 1UC San Diego, CA, 2Salk Institute for Biological Studies, La Jolla, CA—We used functional MRI in humans to evaluate the role of competing stimuli in non-spatial, feature-based attention. We have previously shown that attention to a stimulus feature (a particular motion direction or color) increased human visual responses to a spatially distant stimulus that was ignored, but had the attended feature (Saenz, Buracas & Boynton, 2002). In that experiment, selecting the target stimulus required filtering out an overlapping distracting stimulus. In the spatial attention literature, the strongest neuronal modulations are typically found when multiple stimuli compete for attentional selection. Here, we repeated our feature-based attention experiment without the overlapping stimulus to assess the role of distractors. Two stimuli, one attended and one ignored, were presented to the left and right of fixation. In the previous experiment, the attended stimulus was a circular aperture of two transparently overlapping fields of upward and downward moving dots; subjects performed a speed discrimination task on the upward vs. downward moving fields in alternating blocks during each scan. In the new experiment, the attended stimulus was a single field of dots moving upward vs. downward in alternating blocks and subjects performed the task on that field. In both experiments, the ignored stimulus was a circular aperture of a single field of dots moving either upwards or downwards, unchanging in direction during each scan. As in our original experiment, we again found that responses in multiple cortical visual areas (V1, V2, V3, V4, V3A, MT+) to the unchanging, ignored stimulus increased when subjects attended the matching direction of motion in the attended stimulus. The magnitude of the effect was similar in the experiments with and without distractors. Thus, neuronal modulation due to feature-based attention did not require the presence of competing stimuli.

Acknowledgment: Supported by NIH grant EY12925 & NSF graduate study fellowship

MO120
Task-set is vulnerable to exogenous resetting during target identification Jun-ichiro Kawahara1 (jikawa@hiroshima-u-a.ac.jp), James T Enns2, Vincent Di Lollo2; 1Hiroshima University, Japan, 2University of British Columbia, Canada—Perception of the second of two rapidly sequential targets is impaired if the temporal lag between them is short ("attentional blink"). We show how this can arise from an exogenously-triggered change in task-set. Observers saw a rapid stream of distractors (digits) centred on the screen. In the THREE-LETTER condition, observers reported three successive letters embedded in the stream of digits. In the TWO-LETTER condition, a digit replaced the second letter, with observers reporting only the two letters. Identification accuracy for the final letter was significantly higher in the Three-letter than in the Two-Letter condition, even though memory load was higher in the former. We propose (1) that the intervening digit triggered an involuntary change in
task-set from letters to digits, and (2) that this was only possible while the system was busy identifying the first target. Thus, perception of the final letter in the Two-Letter condition was impaired because it did not fit the new task-set imposed by the intervening digit.

Additional studies confirmed this account. First, the final-letter deficit remained when observers reported the intervening digit as well as the two letters. Second, the deficit vanished when the intervening distractor in the two-letter condition was rendered virtually invisible by an abrupt spatial shift in the location of the stream after the first target. Third, a central stream of preceding digits interfered much less with target-letter identification than a stream of preceding letters.

We propose that an endogenously-established task-set can be maintained quite effectively during the period in which a target letter is anticipated, permitting the efficient exclusion of task-irrelevant distractor digits. However, as soon identification of the target letter begins, the task set becomes vulnerable to alteration by exogenous distractors, making it now optimally tuned to the stimuli exemplified by the distractor digits instead of the letters.

Acknowledgment: This work was supported by grants from the Japan Society for the Promotion of Science to JK and by the Natural Sciences and Engineering Research Council of Canada to JTE and VDL.

MO121

The Guidance of Visual Attention: Using and Acquiring Knowledge about the Probability of Change

Melissa R. Beck (mbeck1@kent.edu), Daniel T. Levin; Kent State University, USA—Previous research using visual search tasks and target localization tasks demonstrates that the visual system can implicitly learn base rate information and then use this information to guide visual attention. Furthermore, it appears that this information is often implicit. Here we investigated whether similar effects can be found with a change detection task. In this task, subjects were shown an array of six colored shapes (each being one of four possible shapes and one of four possible colors). After viewing the array for 2 seconds, one of the shapes changed color. The subject’s task was to identify the postchange color in a 4AFC recognition question. One hundred training trials were presented, during which we manipulated the probability of change for each shape (each shape changed color on either 65, 25, 10, or 0 of the 100 trials). Following 100 training trials, subjects completed 20 test trials during which each shape was equally likely to change color. Accuracy during the test trials was higher for shapes that had a high probability of change during the training phase than for shapes that never changed. Therefore, when the relevant items were in distinct locations, search was harder when the irrelevant subset was of high-contrast. This was not true, however, when the same experiment was repeated with different contrast levels presented in different blocks (Exp 4). Overall, the results suggest that selective attention to either high- or low-contrast is readily achieved, although this capability is not always utilized. The results challenge the most obvious linkage between attentional function and neurophysiological findings concerning contrast and attention.

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MO123

Midstream order deficit in phonological encoding

Yasuho Chiba (ychiba@L.u-tokyo.ac.jp), Kazuhiko Yokosawa; University of Tokyo, Japan—Holcombe, Kanwisher, and Treisman (2001) reported that apprehending the relative order of a 4-letter sequence is easier in a single presentation than in a cycling presentation, in which a 4-letter sequence is presented many times. They termed this phenomenon the midstream order deficit (MOD) and concluded that MOD reflected the difficulty of apprehending relative order in an undifferentiated stream. In this study, using Japanese Kanji characters for stimuli, we investigated how relative order was encoded in the occurrence of MOD and whether the heterogeneity of items in visual complexity would heighten the correct report of relative order in the cycling presentation. In Experiments 1 and 2, four letters had different pronunciations and participants were required to report relative order verbally. On the other hand, in Experiments 3 and 4, four characters had the same pronunciation and participants were required to report relative order in connecting the printed four letters by arrows. As a result, the difference in relative order accuracy between the single and the cycling presentations did not depend on the heterogeneity, although the higher relative order accuracy in the heterogeneous condition compared with the homogeneous condition was observed. In Experiments 1 and 2, the lower relative order accuracy in the cycling presentation compared with the single presentation showed the occurrence of MOD, which was not explained by the higher letter identity accuracy in the cycling presentation than in the single presentation. In contrast, the opposite difference in relative order accuracy between the single and the cycling presentations was found in Experiments 3 and 4. Our results suggest that MOD can occur only when relative order is phonologically encoded and that phonological and visual codes have different properties in order encoding.

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MO124

Change detection is impaired in poor readers for both letter and object targets

David P Crewecher (dcreuchether@bri.wmin.ac.uk), Jacqueline S Rutkoski, Sheila C Grechther; Brain Sciences Institute, Swinburne University of Technology, Australia—We have raised the question of whether performance in a change detection task relates to reading ability in children. Using a Display-Gap-Display paradigm with 4 letters in circular place-holders, we showed that poor readers required longer exposure to the first Display in order to detect change as well as normal readers. In this experiment we pursued the question of whether masking provided by the target place holders, surrounding the target letters contributed to the change blindness, whether poor readers needed less masking to impair their detection of change than good readers and whether the choice of letters as targets was critical to the difference in performance between good and poor readers. Change detection performance was measured by measuring the threshold luminance contrast of circular place holders filled with dynamic random noise in an adaptive thresholding process. Stimuli were created and presented using VPixx. 16 poor readers (Neale Analysis reading age (M=7.8), chronological age (M=10.1)) were compared with 15.
Effect of location and feature cues on the masking function for location

Stefano Baldasseri1, Stefano Baldasseri2, Preeti Verghese2; 3

1Dipartimento di Psicologia, Universita' di Firenze, Florence, Italy; 2Smith-Kettlewell Eye Research Institute, San Francisco, CA, USA — Last year we showed that the orientation tuning function in the presence of a superimposed mask was cue-specific. When the mask varied in orientation with respect to the test, an orientation cue narrowed the tuning function, while a location cue reduced the amplitude of the masking effect over the entire tuning function. In this study we explore the effect of cueing the location or the orientation of a test patch in the presence of a pair of masks that vary in location with respect to the test. The test was a Gabor patch presented in one of two locations, symmetric around fixation, and in one of two orthogonal orientations, vertical or horizontal. Each potential test location was masked by two 1D noise patches (one for each possible orientation), whose distance from the test location was varied to obtain a masking function for location. In the first experiment, the test was 7 degrees away from fixation and the mask components moved away along an iso-eccentric circle. As in case of the tuning function for orientation the masking effect was cue-specific. The effect of the location cue on the tuning function for location was wide and unspecific but the orientation cue improved thresholds over a narrow range of mask locations around the test. We wondered whether the failure to obtain location specificity with the location cue was due to the large distance between the two possible locations rather than to a signature of the location cue. So, in a second experiment we moved the two locations to only 1 degree of eccentricity, reducing the separation between the two locations to 4 lambda. At this reduced separation, the orientation cue continued to be effective over a narrow range of mask locations and the location cue showed the same broad tuning as before. The specific narrowing with the orientation cue clearly indicates that cueing the feature and cueing the location cause two distinct effects on the tuning of the underlying detectors.

Role of attentional salience in localized attentional inhibition

Jeffrey RW Mounts (mounts@geneseo.edu); SUNY-Geneseo, USA — A set of experiments examined the effect of an attentionally salient distractor item on target shape discriminations (i.e., orientation of a T). Previous research has found that target discriminations are impaired when the target is near an attentionally salient distractor, such as a color singleton or an abrupt onset (e.g., Mounts, 2000, P&P). The current experiments manipulate the relative attentional salience of the distractor item and the target to determine the effects on this Localized Attentional Inhibition (LAI). Both stimulus-based (e.g., size changes) and strategic (e.g., probability) manipulations were used to manipulate the attentional salience of target and distractor items. The results suggest that LAI occurs when the distractor has greater attentional salience than the target. As the attentional salience of the target is increased relative to the distractor, LAI diminishes and eventually disappears. If the relative attentional salience of the target is further increased, the pattern reverses, and target performance is facilitated when the target neighbors an attentionally salient distractor. This pattern of results obtains for both stimulus-based and strategic manipulations of relative distractor and target attentional salience. The results suggest the operation of two attentional mechanisms: a preparatory attention mechanism that facilitates the processing of items in a given region, and a selective attention mechanism that inhibits the processing of items neighboring an attentionally selected item, with relative attentional salience governing initial selection.

Role of dynamic transients in attentional capture by irrelevant onsets

JingLing Li (jingl@ms27.hinet.net); Suling Yeh; Department of Psychology, National Taiwan University,Taipei, Taiwan — The goal of this study was to examine the conditions under which an abrupt onset captures attention, and by doing so to determine whether explanations based on dynamic transients or new objects better account for the onset capture effect. If the transient change caused by an onset stimulus is the reason for its capturing attention, the capture effect should be modulated by the amount of transient changes. The new-object account, however, predicts no effect caused by these transient changes. We used an Inattentional Blindness (IB) task, in which a color task was designed for the participants to develop the attentional set for color, and an unexpected onset was used in the inattention trial to probe the effect of attentional capture by the onset. Luminance difference between the color target and the unexpected onset was manipulated in the first two experiments. In Experiment 3, the unexpected onset remained on the screen continuously after its appearance (i.e., no offset in the display). In Experiment 4, two colors were presented simultaneously for discrimination. Results showed that the unexpected onset could capture attention in the color detection tasks, but the capture effect was varied with luminance manipulation (Experiment 1 and 2). The onset capture effect disappeared, however,
when the onset was not followed by an offset (Experiment 3), and when two color changes were to be discriminated. Since the onset capture effect was sensitive to changes in luminance, the presence of offset, and the number of changes, we conclude that the onset capture effect observed in the IB task resulted from transient changes.

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MO129
Voluntary indexing requires serial visitation
Vidal I Amman, Jr. (avidal@ruccs.rutgers.edu), Zenon Pylyshyn; Center for Cognitive Science, Rutgers University, USA – Last year, we showed that targets in Multiple Object Tracking (MOT) can be indexed voluntarily as well as involuntarily. However, whereas involuntary indexing is automatic and simultaneous, voluntary indexing requires that each target object be visited serially. This year we present further evidence to support this claim.

In experiment 1, the observer was asked to track 3 out of 8 gray, disk-shaped objects on a black screen. The targets were either the objects on which a vertical line flashed (flash condition), or the objects on which the vertical line did not flash (nonflash condition). We varied the amount of time available for indexing by having the vertical line flash once (300 ms) or three times (900 ms). We hypothesized that if serial visitation was necessary, then we should see better performance with the longer indexing interval. As expected, for the flash condition, the results showed no difference in tracking performance across indexing intervals. For the nonflash condition, tracking improved with the longer indexing intervals. This is consistent with the serial visitation hypothesis. However, a similar result could also be obtained if the automatically assigned indexes first had to be detached from the flashed objects and re-applied to the nonflashed target objects, a process which could itself explain the additional time it takes to index nonflashed items. Experiment 2 controlled for automatic indexing by having horizontal and vertical lines flash on all 8 objects simultaneously, instead of requiring observers to track nonflashed objects. Observers had to track the 3 objects that were cues with either horizontal lines or vertical lines. The results of this experiment show the same pattern of performance as the nonflash condition, suggesting serial visitation. This study provides further evidence in support of a serial visitation explanation of voluntary indexing.

MO130
Surprise Blindness: A distinct form of attentional limit to explicit perception?
René Marois (rene.marois@candide.vanderbilt.edu), J. Jay Todd, Christopher M Gilbert; Department of Psychology, Vanderbilt Vision Research Center, Vanderbilt University, Nashville, TN – The cost of attending to a visual event can be the failure to detect other events. Are these costs the same regardless of whether attention is summoned in a top-down (goal-driven) or bottom-up (stimulus-driven) fashion? The attentional blink paradigm demonstrates that searching for and attending to a target presented in an rapid serial visual presentation (RSVP) of distractors can dramatically impair one’s ability to detect a second, probe target (Raymond et al., 1992). In the present experiments, we asked whether the presentation of novel, task-irrelevant and unexpected stimuli could also lead to failures in probe detection.

Subjects searched for a single target in an RSVP of distractors, with the rare (%12) presentation of ‘oddball’ stimuli occurring at different lags prior to the presentation of the probe target. For half of the 24 subjects, the targets and distractors were letters and the oddballs were faces, while for the other half the target/distractor and oddball sets were reversed. For both groups, subjects were profoundly impaired at detecting the probe when it occurred 370 ms, but not 730 ms, after oddball presentations. Strikingly, this perceptual deficit was extremely short-lived, as the impairment vanished by the 4th oddball presentation. Control experiments rule out that this perceptual deficit is a result of masking, startle-induced eye blinks or memory impairment. A final experiment in which the oddballs consisted of a heterogeneous set of visual stimuli showed again a rapid, but time incomplete, habituation pattern with moderate levels of deficit leveling off by the 4th oddball and persisting across the 6 oddball presentations.

These results suggest that the presentation of novel, unexpected stimuli lead to a profound but extremely short-lived perceptual deficit. The lifespan of this impairment leads us to speculate that it represents a novel and distinct form of attentional deficit to explicit perception.

Acknowledgment: Acknowledgements: This work was supported by Japan Society for the Promotion of Sciences. And we thank Yasuhiro Ishii of Toyota CRDL, for his support in this study.

MO132
Exploring the temporal dynamics of shifts in spatial attention with changing subject certainty
Vivian M Ciaramitaro (vee@cns.nyu.edu), Paul W Glimcher; New York University New York, NY USA – Introduction: It has been shown that subjects are faster and more accurate at detecting or discriminating stimuli when they are more certain of where a stimulus will appear. We have shown that a probability paradigm, in which observers use the probability of where a stimulus is likely to occur, can direct the allocation of resources and improve accuracy with increasing probability, or spatial certainty (Ciaramitaro et al, 2001). We now study the temporal dynamics of attention across probability transitions, to investigate how quickly observers track shifts in probability, as the certainty of where to attend changes.

Method: Six observers performed an orientation discrimination task, viewing an extrfoveal stimulus (102ms) that was followed by a mask (102ms) after a delay of 17, 35 or 52ms. The probability of stimulus occurrence in the left or right hemifield switched between 20% and 80% in several blocks of ~200 trials each. Behavioral data were convolved with a gaussian to derive a trial-by-trial running estimate of fluctuations in performance over time.

Results & Conclusion: When probability transitions were signaled, observers’ overall performance improved as probability increased across blocks, whereas when transitions were not signaled, and observers may have been less certain of the probability condition, their overall performance was not well matched to changes in probability. On a trial-
by-trial basis, performance within a block was not always stable, potentially obscuring overall differences between blocks, and performance changes across blocks often showed rapid transitions, suggesting that observers learned the new probability quickly. Quantifying the dynamics of changes in behavior over time is an important step if we ultimately want to link such changes to dynamic changes at the neuronal level as we switch attention to different locations.

MO133
Control of the location and extent of visual attention  Kazuya Matsubara (kmore@graduate.chiba-u.jp), Michihiro Nakazawa, Takashi Hama, Satoshi Shioiri, Hirohisa Yaguchi; Chiba University, Japan – [Purpose] The spotlight metaphor of visual attention suggests shifts of the location attended, and the zoom-lens metaphor suggests changes of the spatial extent attended. The purpose of the study is to examine how one controls the attention center and extent.

[Experiment] We compared the attention center and extent among conditions with different attention states required, measuring spatial tunings of contrast sensitivity while the observer was tracking a moving object (Shioiri et al, 2002). The observer tracked a target rotating apparently either in the clockwise or counter-clockwise direction around a fixation point in an ambiguous apparent motion display. The display consisted no net motion energy in either direction so that attentional facilitation on contrast sensitivity was isolated from any influences of low-level motion signals. Measurements of sensitivity at variable locations would provide the spatial tuning of attentional facilitation. To investigate whether the observer can adjust his/her attention state to cover possible probe locations with tracking the target, we used various sets of probe locations used in a session. Experiment 1 used probe sets with different ranges centering at the tracked disk, and Experiment 2 used probe sets with the same range centering at different locations relative to the tracked disk. In each session, the observer had knowledge of the possible flash locations.

[Results and Discussions] In Experiments 1, the sensitivity function peaked near the target position while the spatial extent of the function tended to increase with increase in the probe location range. In Experiments 2, the sensitivity function peaked also near the target position instead of the center of the probe location range. These results suggest that the spatial extent of attention can be varied centering at a location, but attention cannot be divided into two locations at least in our experimental condition.
Temporal Processing, Perceptual Organization, Multimodal: Touch, Sound, & Integration, Motion 4: Shape & Depth, Letters/Reading, Face Perception, Depth/3D Shape, Depth & Motion, Attention 5

Tuesday Posters

 Authors Present: 2:30 – 4:30 pm

TU1
Backward masking with sparse masks: Models and experiments Yang Seok Cho (yscho@psych.purdue.edu), Gregory Francis; Purdue University – Recent experimental work (e.g., Di Lollo et al., 2000) has noted that strong masking can occur even for a sparse mask (containing only four dots). In experiments where attentional focus is distributed, such a mask can produce strong effects. Recent modeling work (Francis & Hermens, 2002) showed that sparse masks and attentional focus could be modeled by weak signals generated in response to the mask. We now report additional modeling and experimental efforts that further explore this possibility. We find that although the effects of attention can be modeled as a change in the strength of the mask signal, the effect of the sparse mask seems to also be changing the properties of the target signal. We describe the significance of this finding for furthering the development of quantitative models of backward masking.

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TU2
Investigating the relationship between performances on the Attentional Blink and Change Detection tasks Murray L. Lawson (M.Lawson@latrobe.edu.au), Bendon Booth, Karen Burns, Elizabeth Davis, Matthew Fuller, Georgina Labropoulos, Somer Thorneycroft, Sheila G Crewther; School of Psychological Science, La Trobe University, Australia – Both the attentional blink (AB) and change blindness (CB) paradigms represent temporal limitations on cognitive processing resulting in functional blindness for attended visual information. The AB refers to the refractory period following the identification of a target stimulus, during which the performance of a second target detection is impaired. Change blindness, on the other hand, refers to an inability to detect rapid spatial and temporal changes in the visual field. Neuro-imaging evidence suggests that the two processes may involve similar brain areas and both have been explained with reference to models of visual short-term memory. However, no clear evidence exists to suggest a link between performances on the two tasks. Thus, the aim of the current experiment was to examine the relationship between attentional blink duration and the time needed to detect change in the visual environment. Fifty-four participants between the ages of 18-49 completed an adaptive threshold method of estimating the AB duration (defined as 79% correct detection of the second target) and a second task estimating the time required for detection of change in the visual scene. The participants were presented with two tasks in random order and with other measures of short-term memory, processing speed and non-verbal mentation, however this experiment only focused on ascertaining the relationship between AB and CB and possible links with short-term memory function. The results showed no significant correlation between performance in terms of time on the AB and CB tasks, nor between the either task and other measures of short-term memory. Thus, although the CB and AB tasks may involve some common neural mechanisms, the current results suggest that they may represent different limitations on visual processing and do not necessarily relate to conventional measures of short-term memory functioning.

TU3
Role of nonlinear brain dynamics as a defensive mechanism against photosensitivity Joydeep Bhattacharya1,2 (joydeep@caltech.edu), Katsumi Watanabe3,4, Shinsuke Shimojo1,4; 1Division of Biology, CalTech, Pasadena CA USA, 2Commission for Scientific Visualization, Austrian Academy of Sciences, Vienna, Austria, 3Laboratory of Sensorimotor Research, National Eye Institute, Bethesda, MD USA; 4NTT Communication Science Laboratories, Atsugi, Kanagawa, Japan – Photosensitive epilepsy is the most common type of stimulus-induced (i.e., visually triggered) epilepsy; however, the dynamical nature of the defensive mechanism which prevents the cortical hyper-excitation for control subjects is largely unknown. We investigated the dynamical characteristics of evoked magnetoencephalographic (MEG) signals for isoluminant flickering (10 Hz) stimuli of different color combinations (red-blue, red-green, and blue-green) from a group of control subjects, and from a photosensitive patient (seizure free intervals only). Wavelet based time-frequency analysis showed that two distinct responses – fundamental (corresponding to stimulus frequency), and harmonic (corresponding to first harmonic) – were found for control subjects, whereas only fundamental but no harmonic response was found for the patient. Three nonlinear measures – approximate entropy (measuring complexity), smoothness index (measuring determinism), and a second index (measuring interdependency) – were applied in combination with the method of phase randomized amplitude adjusted surrogate data. Strong indications of nonlinear structures in the MEG signals for control subjects were found, whereas remarkable absence of nonlinearity was reported for patient. Although such nonlinear structures were observed for all three chosen stimuli, the degrees of the applied nonlinear measures were found to depend on the color combination, thus suggesting a possible correlation between cortical excitation and chromatic sensitivity. These findings put forward the hypothesis that the neuronal responses to photic stimulation in healthy human brain are significantly nonlinear which might reflect an inherent mechanism defending against hyper excitation to chromatic flickering stimulus, and such nonlinear mechanism is likely to be impaired for patient with photosensitive
epilepsy.

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TU4

Individual Differences in Dynamic Visual Processing
Jeremy B Wilmer (wilmer@cshl.harvard.edu); Harvard University, USA—Measures of dynamic visual processing (e.g. motion processing) have received increasing interest as potential markers of subtle neural dysfunction in clinical conditions as varied as dyslexia and schizophrenia. However, there has been little work establishing the basic psychometric properties of such tasks. This research investigates the reliability and validity of a number of dynamic visual processing tasks in a naive, non-clinical sample in order to identify those that may show potential for use in clinical samples. The particular hypotheses that are tested for each task are a) that it is capable of efficiently isolating reliable individual differences, and b) that these individual differences show convergent validity on theoretically related tasks and discriminant validity on theoretically unrelated tasks. Additionally, estimates are made of the extent to which reliability of performance drops over the course of a 1-2 hour experimental session. Such establishment of reliability and validity of individual differences on a task, as well as robustness to fatigue, are essential prerequisites for using a task as a clinical instrument.

TU5

Characterizing and modeling temporal dynamics of perceptual decision making
Wilson Chiu (wilsonch@usc.edu), Zhong-Lin Lu, Barbara A. Dosher; Laborato de Brain Processes (LOBES), Univ. of Southern Calif., Los Angeles, CA; Memory, Attention and Perception (MAP) Laboratory, Univ. of Calif., Irvine, CA—We combined the external noise method (1) with the cue-to-respond speed-accuracy trade-off (SAT) paradigm (2) to characterize the temporal dynamics of perceptual decision making. Observers were required to identify the orientation of one of eight briefly presented peripheral Gabor targets (+/- 12 deg) in both zero and high noise. An arrow, occurring in the center of the display cued the observer to the target location 234 ms before the onset of a brief target display; an auditory beep, occurring at one of eight delays (SOA=25 to 800 ms) after the target onset, cued the observers to respond. Five Gabor contrasts, spanning a wide range of performance levels, were tested in each external noise condition. Increasing accuracy of discrimination (d') was measured over processing times from 210 to 940 ms (as a function of SOA to the cue) in each external noise and Gabor contrast condition. All ten SAT functions were well fit by exponential functions with identical time constant and intercept but different asymptotic levels. This suggests that, despite enormous variation in the external noise and contrast energy in the stimulus, and in the ultimate accuracy of performance, information accumulated with the same rate and starting time across all the external noise and contrast conditions. In addition, we conducted a standard response time version of the experiment both before and halfway through the SAT procedure. Data from the response time version of the experiment were all consistent with the speed-accuracy trade-off data, but primarily differed in response accuracy. A simple elaboration of the perceptual template model (3) with a dynamic decision process in which information accumulates with the same rate but with step sizes proportional to the signal to noise ratio in the perceptual representation of the visual input fully accounts for the results.

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TU6

Interhemispheric Transfer as assessed with the Poffenberger paradigm: What kind of signal is transferred?
Cristiana Cavina Pratesi (cristiana.cavinaprasesi@univr.it), Bricolo Emanuela, Barbara Pellegrini, Carlo Alberto Marsi; Department of Neurological and Vision Sciences, University of Verona, Italy, Department of Psychology, University of Milano-Bicocca, Italy, CeBiSM, Research Center for Bioengineering and Motor Science, University of Brescia, Italy—Interhemispheric transfer (IT) time through the corpus callosum (CC) can be measured with a manual reaction time (RT) to lateralized visual stimuli (the so called Poffenberger Paradigm) by subtracting mean RT of faster uncrossed hemifield-hand combinations (not requiring IT) from slower crossed combinations (requiring an IT). However, the nature of the signal transmitted by CC is still uncertain. In the present study we wanted to verify whether IT occurs at controlled (i.e. perceptual or pre-motor) or ballistic (i.e. motoric) stages of RT. In a first experiment we employed a stop signal paradigm, that is, a visual RT task in which go-trials are interspersed among stop-trials in which subjects are supposed to refrain from responding following an acoustic tone. We found that crossed stimuli were easier to inhibit than uncrossed stimuli. This suggests that IT occurs at the controlled stage of RT and therefore prior to the point of no return (PNR), i.e. the point beyond which the response cannot be inhibited. Since the locus of the PNR is still uncertain, in a second experiment we used response force as a dependent variable reflecting the activation of the motor cortex. We found that none of the force parameters studied (peak force, impulse size and response duration) differed between crossed and uncrossed stimuli while temporal parameters confirmed the presence of an advantage of the uncrossed combinations.

All together these results suggest that callosal transmission occurs at the stage of controlled processes and rule out the possibility of a IT at the motoric stage.

TU7

Temporal characteristics of bilateral symmetry perception: Predominant effect of visible persistence
Kazuhiko Yokosawa (yokosawa@i.u-tokyo.ac.jp), Ryousuke Niimi, Katsumi Watanabe; University of Tokyo, Japan; National Institutes of Health, USA—Bilateral symmetry is highly salient visual feature. The visual system seems to have efficient mechanism to perceive symmetry. However it is not fully understood what type of visual information is used for symmetry perception. The present study investigated the temporal characteristics of symmetry perception. In Experiment 1, the minimum time for symmetry perception was assessed by a backward masking experiment. A bilaterally symmetric dot pattern (40 dots for 13ms) was followed by a random dot mask (160 dots for 160 ms) with various stimulus onset asynchronies (SOAs). Results showed that symmetry detection required 50 ms to be completed, during which had to be free from physical stimulation. We hypothesized that symmetry perception can occur based on visible persistence of stimulus elements. To test this hypothesis, we employed a temporal integration task, where subjects had to integrate two asymmetric patterns over time to detect symmetry (Experiment 2). A symmetric dot pattern was divided into two asymmetric patterns so that each half contained half the number of dots. The halves were presented with various SOAs. Symmetry was detected successfully with SOAs up to 70 ms. This result strongly supports that symmetry perception depends on visible persistence of stimulus elements and does not require a common onset/offset of the elements. Corroborating the visible-persistence hypothesis further, we observed the inverse-intensity effect of visible persistence. Interestingly, however, we also found that a smaller number of dots leaded to better performance in the integration task (Experiment 3), but not in the masking task (Experiment 4), implying an additional effect of temporal synchrony of symmetric elements. We conclude that visible persistence can be the basis of symmetry perception but the temporal synchrony (common onset/offset) of elements is important for efficient symmetry perception.

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TU8

Posters

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TU8
Computational model of transcranial magnetic stimulation: temporal property and subthreshold prolongation of visual suppression induced by neural population
Yoichi Miyawaki (yoichi.miyawaki@brain.riken.go.jp), Masato Okada; RIKEN Brain Science Institute, Japan
We modeled suppressive effect on visual perception induced by TMS. TMS is widely used in experimental studies about visual perception, however neural mechanisms underlying TMS interference are still unclear, especially in theoretical perspective. Here we used the simplest excitatory-inhibitory balanced network showing orientation selectivity in V1 as a model of neural population and analyzed the response to a TMS-like perturbation, simulating the fundamental property that TMS briefly and simultaneously stimulates neural population in local cortical area under the coil. Applying the perturbation, mean activity of the network transiently increased and then decreased for a longer period followed by a loss of an orientation tuning profile. If afferent input had a large transient and weak sustained component, there was a critical latency period during which the perturbation could completely suppress the network activity. The range of the suppressive latency period increased with decrease of afferent intensity and reached over 100ms if the afferent intensity approach excitation threshold of the network. These results well agree with typical experimental data of visual suppression by occipital TMS. In occipital TMS experiments, applying multiple pulses can facilitate phosphene or suppression even if each single pulse cannot induce any perceptible effects. Such subthreshold accumulation was also observed in the network model in comparable time range to experimental data, but not in isolated single neuron model. In the network model, a subthreshold conditioning stimulus could induce sustained inhibitory bias so that the following suppressive threshold was decreased and the range of suppressive latency period was prolonged, which are also parallel to experimental data of occipital paired TMS. These results suggest that, in addition to effect on a single neuron, inhibitory interaction in neural population plays an important role in TMS-induced visual suppression.

TU9
Serial temporal filters in human vision
Walter Makous1 (wal@cvx.rochester.edu), Stephane J.M. Ratcliff2; 1Center for Visual Science, University of Rochester, Rochester, NY, USA, 2Center for Vision Research, York University, Toronto, Canada
Creating gratings by optical inference offers two advantages for investigating human temporal vision: (1) it allows use of spatial frequencies high enough that antagonistic surrounds or lateral processes are not modulated, and so only center mechanisms are tested; and (2) it allows one to separate some of the serial processes that determine the overall temporal properties of the system. We overcame the difficulty of producing counterpart gratings with interferometers by using ferroelectric crystals to reverse the phase in one arm of the interferometer during each half cycle of modulation. First we replicated classical temporal contrast sensitivity curves at varying spatial frequencies to ensure that these stimuli are comparable to conventional stimuli. Then we presented pairs of interference gratings either as counterphasings or moving gratings. Superimposing a flickering grating on a steady grating creates (one might say 'injects') a flickering distortion product at the site of a nonlinear process within the retina, whereas moving a pair of interference gratings along the bars of the nearly perpendicular distortion grating modulates the signal that produces the distortion grating without modulating the distortion grating itself. With this array of stimuli we measured the temporal transmission preceding and following the nonlinear stage at 5 and 30 c/deg. However, we found that when the spatial frequencies were increased above those than can be imaged on the retina with conventional techniques, frequencies that are too high to allow lateral interactions, temporal transmission can be described by a nonlinear stage sandwiched by two lowpass filters with identical time constants of about 10 msec. The selective attenuation of low temporal frequencies that gives the temporal contrast sensitivity function its characteristic bandpass shape, which occurs only when the spatial frequency is low, is due entirely to attenuation beyond the nonlinear stage.

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TU10
Comparing central and peripheral events: compensating for neural processing delays
Agnieszka Kopinska (kopinska@yorku.ca), Laurence R Harris, Isabel Lee; Centre for Vision Research, York University, Canada
It is well known that different parts of the retina are associated with different processing times. Objects in the periphery are detected long after the same object appearing in the fovea and at different times again if detected by other sensory systems. This is a challenge to perceiving single objects as coherent items when different parts and aspects of the same object might be processed at substantially different rates. Here we measure the relative reaction times to foveal and peripheral visual targets. We compare the difference in reaction times to the delay required for a peripheral target to be perceived as simultaneous with a foveal target.

To measure reaction times, 2 cm diameter circular patches of light were presented unpredictably at either the fovea or 28 degs into the periphery. Spots were presented on a computer CRT display viewed between 35 cm. Reaction times were measured using key presses. In a separate experiment, using the method of constant stimuli, the same two spots were presented with a delay of from 0-100ms in 10ms steps with either the foveal or peripheral dot coming on first. Subjects reported which light was first and psychometric functions were constructed through the data to determine the point of subjective equality. Viewing was either monocular or binocular.

Reaction times were about 40 ±10 ms faster for spots in the fovea than for spots in the periphery. Simultaneity judgements however were on average within 5 ± 3 ms of veridical. Compensation performance was better when viewing was binocular.

It is perhaps not surprising that things appearing simultaneously at different parts of the retina were perceived as occurring together. But the mechanism by which such huge neural delays are effortlessly and continuously compensated for is intriguing.

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TU11
Perceptual consequences of temporal disparities in the visual field: The case of the line motion illusion
Dennis Santella1 (ds709@columbia.edu), Maria Carrasco2; 1Columbia University, USA, 2New York University, USA
Background and Goal. When a line is preceded by a cue, it appears to be drawn from the end where the cue appeared. This is known as the illusory line motion (Hikosaka, Satoru & Shimojo, 1993). In this study, we characterized the changes in perception of the illusion over the visual field to explore whether these changes correspond to temporal performance field asymmetries –information is processed faster along the horizontal than vertical meridian, and at the lower than upper vertical meridian (Carrasco, McElree & Giordano, VSS 2002).

Method. Twenty observers were presented with a 100 ms line either preceded (illusion) or not preceded (control) by the cue. The line appeared on the horizontal and vertical meridians at 4 or 9 eccentricity. In the ‘focused attention’ condition, the cue appeared only at the location adjacent to that at which the line would appear. In the ‘distributed attention’ condition 4 cues appeared adjacent to all 4 possible locations. Observers responded in a 3AFC task with either 2 directions of motion (E vs. W, or N vs. S) or no motion.

Results and Conclusion. (a) With focused attention, the illusion was more pronounced along the horizontal than vertical meridian, and least pronounced at the North location. This pattern of results was consistent with the temporal performance field asymmetries aforementioned. (b)
TU12
Motion constraints on the integration of spatial cues into global form
Stéphane J Rainville (rainvill@yorku.ca), Hugh R Wilson; Center for Vision Research, York University, Toronto, ON, CANADA—Purpose: Global form is easily perceived in visual patterns where structure is defined purely by spatial or motion cues, but how do spatial and motion cues interact in the computation of global form when presented concurrently? While the influence of spatial cues on motion-cue integration is well documented, the influence of motion cues on spatial-cue integration remains largely unexplored.

Method: In a 2AFC task, observers discriminated between spatial tests embedded in motion masks. Stimuli consisted of 36 colinear Gabor elements positioned along a virtual radial-frequency (RF) contour—a circle deformed by a sinusoidal modulation of radius as a function of polar angle. Sinusoidal amplitudes for discriminating between circular and non-circular patterns (75%-correct) defined thresholds for spatial-cue integration. Motion masks were applied by drifting each Gabor’s carrier at a speed determined by a separate variable-amplitude RF contour that coded for speed. Tests and masks were constructive or destructive depending on their relative phases.

Results: Thresholds for static patterns were low and consistent with global spatial-cue integration. Constructive masks produced little facilitation at low mask amplitudes but interfered moderately with discrimination at higher mask amplitudes. Destructive masks interfered considerably with discrimination, and interference increased with mask amplitude. Psychometric functions revealed that motion-defined masks are perceptually confused with spatially-defined tests, and control masks defined by expansion, contraction, flicker, or random speeds, had little effect on spatial-cue integration.

Conclusions: Motion exerts a profound influence on the assembly of spatial cues into global form, but interactions are selective for motion and spatial cues with compatible global properties. Results suggest a model that computes global form separately within cue-specific pathways but allows for competitive cross-pathway interactions.

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TU13
A direct estimate of the size of the illusory spots in the Hermann Grid Illusion
Todd Macuda (tmacuda@uwwo.ca), Kevin Johnston, Brian Timney; Department of Psychology, University of Western Ontario, London, Ontario, Canada—The Hermann Grid Illusion has been used to investigate the properties of human perceptive fields, the psychophysical analogue of physiological receptive fields. Spillman (1994) suggested that the bar width at which the illusion is strongest corresponds to the perceptive field centre size at a given retinal location. Alternatively, Troschianko (1982) argued that this underestimated centre size. He proposed that a closer approximation could be achieved by multiplying the bar width by the square root of two. We investigated these hypotheses using a psychophysical matching procedure in which observers estimated the size of the illusory spots at the intersections of a Hermann Grid. Observers viewed a 6x6 grid in the centre of which was presented a circular field set at the same luminance as the grid bars. Centred within this field was a circular comparison patch with a gaussian luminance profile. We first obtained estimates of the perceived magnitude of the illusion at a range of bar widths. Observers were instructed to match the contrast of the comparison patch with that of the illusory spots. We then obtained estimates of the size of the illusory spots by asking observers to match the size of the comparison patch with that of the spots present at the grid intersections. For this condition, the contrast of the comparison patch was set equal to the observers’ initial contrast estimates. Size estimates were obtained for bar on white and white on black grids, at bar widths ranging from 6 to 60 arcmin-1. Estimates for both grids at all bar widths closely matched the actual width of the grid bars. These data suggest that the bar width at which the strongest illusion occurs represents an accurate measure of perceptive field centre size.

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TU14
Effects of perceptual grouping in human primary visual cortex
Ming Meng (mmeng@princeton.edu), David A Renus, Frank Tong; Department of Psychology, Princeton University, USA—Recent neurophysiological studies suggest that primary visual cortex (V1) may play an important role in the perceptual grouping. For example, V1 neurons exhibit collinear facilitation when a bar placed outside the receptive field is congruently aligned with a bar lying within the receptive field (Kapadia, Gilbert, & Westheimer, 1995). We used fMRI to investigate the effects of perceptual grouping in human visual cortex. Observers were presented with two vertical bars positioned to the right of fixation, above and below the horizontal meridian (vertical separation = 47). The bars oscillated from left to right within a 4° horizontal window (4-8° to the right of fixation), and either moved in phase (grouped condition) or out of phase (separated condition). We identified the retinotopic regions corresponding to the location of the 4x4 gap between the bars by presenting a reference stimulus in this location on separate scans. Preliminary data from three subjects suggested evidence of early perceptual grouping. Greater activity occurred in the V1 region corresponding to the gap when the bars moved in phase as opposed to out of phase. Some effect of grouping was also found in higher visual areas. These results support the notion that human primary visual cortex may play an important functional role in perceptual grouping. Further analyses will compare the magnitude of grouping effects for V1 in relationship to these other areas.

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TU15
A parallel binding solution via separate integration and segregation mechanisms
Frédéric JAM Poirier (jamfpo@yahoo.com), Barrie J Frost; Queen’s University, Canada—Intro. The visual system’s modular structure raises the question of how cues, which are analyzed in separate modules / brain regions, are brought back together (the binding problem). Previous research has shown that contour binding across attributes occurs in parallel, within attribute maps, throughout the visual field, and with an initial “default” bias towards integration (Poirier & Frost, 1998-2002).

Model. The default integration bias suggests that assemblies (and stimulus features) are integrated via fairly “automatic” facilitatory connections, of low spatiotemporal resolutions. In addition, segregation occurs via “intelligent” inhibitory connections, focusing on local specific differences of higher contrast and information value. Binding is dynamic, flexible, uses multiple cues simultaneously, and propagates across assemblies and brain areas. In this model, binding influences tasks because: (1) integrated items are processed as one, reducing visual scene complexity, (2) segregated items “pop-out”, and (3) different items erroneously bond together will share properties, leading to illusions and possibly difficult search.

Implications. This theoretical framework requires re-interpretation of data for many tasks. (1) Visual search measures the efficiency with which a target segregates while distractors integrate together. (2) Redundancy effects measure a stimulus’ ability to stimulate the integration mechanisms. (3) Illusory conjunctions are found when integration occurs but segregation fails, despite spatial separation of items. (4) Texture
segregation differs from single item similarity judgments because the former also uses spatial effects like collinearity (integration) & edge detection (segregation).

Discussion. The model provides a unifying framework that reconciles different results and research areas. Thus, a meta-analysis of several different tasks should reveal many specific integration & segregation cues, along with their spatiotemporal properties.

TU16
How does perceptual grouping synchronize quickly under realistic neural constraints?  
Arash Yazdanbakhsh (yazdan@cns.bu.edu), Stephen Grossberg; Cognitive and Neuropsychological Systems Department, Boston University, Boston, MA, USA – Perceptual grouping is well-known to be a fundamental process during visual perception, notably grouping across scenic regions that do not receive contrastive visual inputs. Illusory contours are a classical example of such groupings. Recent psychophysical and neurophysiological evidence have shown that the grouping process can facilitate rapid synchronization of the cells that are bound together by the grouping, even when the grouping must be completed across regions that receive no contrastive inputs. Neural models of perceptual grouping have clarified how such fast synchronization may occur (Grossberg and Somers, 1991; Grossberg and Grunewald, 1997) by using bipole grouping cells (Cohen and Grossberg, 1984; Grossberg and Mingolla, 1985), whose predicted properties have been supported by later anatomical, psychophysical and neurophysiological experiments (Bosking et al. 1997, Callaway and Wiser, 1996; Eckhorn et al., 1988; Field et al., 1993; Fitzpatrick et al., 1985; Gilbert and Wiesel 1989; Gray et al., 1989; Shipley and Kellman, 1991; von der Heydt et al., 1984).

These models have not, however, incorporated some of the realistic constraints on which groupings in the brain are conditioned, notably the measured spatial extent of long-range interactions in layer 2/3 of a grouping network, and realistic synaptic and axonal signaling delays. This work addresses the question: Can long-range interactions that obey the bipole constraint achieve fast synchronization under realistic anatomical and neurophysiological constraints that will initially desynchronize grouping signals? Our simulations show that the answer to this question is Yes.

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TU17
Grouping by color similarity, orientation similarity and collinearity under conditions of inattention  
Hsiao-Chueh Chang (r89227013@ms89.ntu.edu.tw), Su-Ling Yeh; Department of Psychology, National Taiwan University, Taipei, Taiwan – The issue of whether perceptual grouping can be formed without attention is important especially for object-based theories of attention. While support for both sides has been provided, it is commonly assumed that Gestalt principles of grouping are all processed at the same stage: Either all can be processed without attention, or all must be formed with the deployment of attention. Here we report evidence against such a unifying view. By adopting a sensitive measure concerning the relationship of grouping and attention designed by Moore and Egeth (1997), i.e., a measure of the Ponzo illusion when the background containing the two railroad tracks was unattended using the inattention blindness paradigm (Mack and Rock, 1998), the formation of three grouping principles (color similarity, orientation similarity and collinearity) was examined. Results showed that grouping by color similarity and collinearity can be perceived to render the illusion under conditions of inattention, but this does not occur with grouping by orientation similarity. While color similarity can be grouped even with conflicting orientation information, grouping by collinearity fails with conflicting color information. These results provide evidence against the commonly held unifying view of various perceptual grouping principles, indicating that they are processed at different stages with respect to the deployment of attention.

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TU21
Forest, Trees and Leaves: Interference Effects in 3-Level Navon Figures
Charles A Collin1 (Charles.Collin@nrc.ca), Mary-Ellen Large2, Patricia A McMullen3, 1National Research Council, Canada, 2Dalhousie University, Canada – Navon’s seminal findings on global-local attention suggested that global forms dominate perception. One reason why this might be the case is that, in Navon’s figures the local elements are surrounded by other similar elements while the global level is alone in space. To test this possibility, we examined interference effects in 3-level hierarchical figures, which consisted of a large configuration made up of medium configurations, which were in turn made up of small figures. In this stimulus, the small elements are local to the medium elements, which are in turn local to the large. Subjects were asked to identify digit or arrow targets at all three hierarchical levels under conditions where the two response-irrelevant levels could be compatible, incompatible or neutral with regards to the correct response. Based on previous research, one would expect the medium elements to dominate the small, due to the greater globality of the former. Contrary to this, we found mutual and equal interference between these two levels under these circumstances. We suggest that this is due to the presence of the large level, which serves to equalize the degree of flanking at the global (medium) and local (small) levels of our stimuli. Previous work has found that flanking elements can have positive or negative effects on response latency. By equating the amount of flanking at the two levels in our 3-level stimuli, we have eliminated global dominance.

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TU22
Exogenous spatial attention influences figure-ground assignment
Shaun P Vecera (shaun.vecera@usc.edu), Anastasia V. Fleuris, Joseph C. Filipek; Department of Psychology, University of Iowa, US –
In a hierarchical stage account of vision, figure-ground assignment is thought to be completed before the operation of focal spatial attention. Previous results support this account by showing that unpredictable, exogenous spatial precues do not influence figure-ground assignment, although voluntary attention can influence figure-ground assignment. However, in these studies, attention was not summoned directly to a region in a figure-ground display. In three experiments, we address the relationship between figure-ground assignment and visuospatial attention using a visual short-term memory matching task. In Experiment 1, subjects saw figure-ground displays and an unpredictable peripheralprecue that appeared outside the figure-ground stimulus; we replicated the finding that exogenous precues do not influence figure-ground assignment when they direct attention outside of a figure-ground stimulus. In Experiment 2, unpredictable peripheral precues were placed inside figure-ground display so that attention was directed to one of the possible figural regions. Exogenous attention influenced figure-ground assignment: Subjects were faster to match the precued region from memory than the uncued region. Finally, in Experiment 3, we asked if unpredictable peripheral precues could modulate figure-ground assignment in displays containing a gestalt figure-ground cue (convexity). We found that exogenous attention interacted with the convexity cue in this experiment. When attention was directed to the concave region, subjects were faster to match this region than the uncued, concave region. When attention was directed to the concave region, the figural advantage produced by the convex region was reduced significantly. These results suggest that figure-ground processes are not entirely completed prior to the operation of spatial attention. Exogenous spatial attention acts as a cue for figure-ground assignment and can affect the outcome of figure-ground processes.

TU23
Attention and Figure/Ground Segregation
Rolf A Nelson (nelson@socrates.berkeley.edu); UC Berkeley, United States – What characterizes the processing difference between regions that are segregated into figure and ground? Only one of the adjacent regions "owns" the contour, and that region (the figure) is seen to be in front, while the ground continues amodally behind. Here it is proposed that the same Gestalt cues that that bias figure/ground segregation (such as surroundedness, meaningfulness, and convexity) also act to spread attention to the figural side of the contour. The present experiments demonstrate that processing in the figural region is enhanced, which indicates a preferential allocation of attentional resources. The general method used was a presentation of a two adjacent regions, followed by a variable SOA to a target in one of the regions. It was found that in both reaction time and discrimination measures, processing was improved on the region biased to be perceived as figure over the region biased to be perceived as ground. Factors tested to date include surroundedness and meaningfulness.

TU24
Attention uncovers peripheral collinear facilitation
Revital Shani (revital.shani@weizmann.ac.il), Dov Sagie; Department of Neurobiology, Brain Research, The Weizmann Institute of Science, Rehovot, Israel – The phenomenon of collinear facilitation demonstrates spatial integration and is thought to be mediated by lateral interactions. It was described psychophysically in the fovea (Polat & Sagie, Vision Res. 1993) but could not be found in extra-fovea eccentricities (3-4º) when using Gabor stimuli (e.g. Williams & Hess, JOSA A, 1998). However, physiological studies in the primary visual cortex of the cat (Polat et al, Nature, 1998) and the monkey ( Kapadia et al, Neuron, 1995) showed increased firing rates for co-aligned stimuli around 4º. We tried to resolve this apparent conflict. Here we show that the absence of peripheral facilitation is not a consequence of improper scaling, and that collinear facilitation is reduced or gone when targets are placed outside fixation but still within the fovea
of grouping are not available to awareness without attention. Regardless of the attentional demands of grouping, the products was involved, suggesting that quite an elaborated form of grouping can background elements were grouped into a vertical or horizontal pattern by organization on the speed and accuracy of the same/different judgments. The different background organizations between the two successive displays to disentangle a change in color per se judge as rapidly and as accurately as possible whether the two successive pixels) surrounded by background elements. The observer's task was to central square target (a small square made up of random black and white examined grouping under inattention using the method developed by Driver et al. (2001). On each trial, observers were presented with two successive displays that appeared briefly. Each display consisted of a central square target (a small square made up of random black and white pixels) surrounded by background elements. The observer's task was to judge as rapidly and as accurately as possible whether the two successive target squares were the same or different (only a single pixel changed). The organization of the background elements stayed the same or changed across successive displays, independently of whether the successive target squares were same or different. The colors of the elements always changed between the two successive displays to disentangle a change in color per se from a change in organization. The different background organizations were: Grouping elements into a vertical/horizontal pattern by color similarity, grouping elements into a shape (triangle/arrow or square/cross) by color similarity, grouping elements (or line segments) into a shape with no segregation from other elements, and a connected shape that served as a control. We measured the influence of the background organization on the speed and accuracy of the same/different judgments. After the last trial in each background condition subjects were asked surprise questions about the immediately preceding background. The RT and error pattern in the same/different judgments implies that background elements were grouped into a vertical or horizontal pattern by color similarity, and into a shape when no segregation from other elements was involved, suggesting that quite an elaborated form of grouping can take place without attention. However, grouping into a shape that requires resolving figure-ground relations for segregated units appears to require attention. Regardless of the attentional demands of grouping, the products of grouping are not available to awareness without attention.

**TU26**

The Blanking Phenomenon and its Psychoanatomical Implications  
J. Jason McAnany (jmcanany@uiuc.edu), Michael W Levine; University of Illinois at Chicago, Department of Psychology – If viewed peripherally, a single white disk presented at an intersection of the gray alleys in a grid of black squares is not visible (McAnany and Levine, 2002). This “blanking phenomenon” also applies to black disks and white squares. To determine the origins of this phenomenon, we used stereoscopic stimulus presentations. Patterns were presented on a computer monitor and viewed through a set of first-surface mirrors. To assure proper convergence, the subject fixated on a target that appeared 3D. The task was to determine which of three intersections contained a disk; disk threshold was derived by a staircase search. Experiment I: Black squares on a medium gray field were presented to one eye, and a light disk on a gray field to the other. Upon fusion, the disk appeared centered in an intersection. The fused image should induce blanking; however, the disk remained visible. These results implicate a contribution to the phenomenon from a pre-fusion locus (retina or LGN). The possible confound of improper alignment of the image in each eye was addressed by introducing a grid of outline squares in the “disk” eye. While this increased threshold, the disk remained visible. Finally, as a control for the effectively reduced contrasts, black squares and a light disk were presented to one eye and a gray field was presented to the other eye. Blanking was present in this control arrangement. Experiment II: Black squares and a light disk were presented to one eye while the other received white squares and a dark disk (thus, each eye received a stimulus capable of blanking). The disk was not detected. However, when black squares and a dark disk were presented to one eye and white squares and a light disk to the other (so neither eye received a stimulus capable of blanking), the disk was visible. These results also implicate a significant contribution to the phenomenon from a pre-fusion locus.

**TU27**

A luminance-based mechanism mediates active filling-in of the blind spot  
Frank Tong (ftong@princeton.edu), Department of Psychology, Adriane E. Seifert; Princeton University, Princeton, NJ, USA – Controversy surrounds whether perceptual filling-in of the blind spot involves active neural completion or a passive mechanism in which the absence of information is simply ignored (Ramachandran, 1992; Dennet, 1991; Durgin, 1995). These competing accounts have proven difficult to distinguish because filling-in of the blind spot occurs so rapidly and automatically. Here we show that texture-defined stimuli fail to fill-in the blind spot and that luminance cues are necessary for active neural completion. Methods. A textured bar was presented across the visual location of the blind spot. The uniform background varied from dark to light, and included the mean luminance of the texture. Oriented texture patterns were either parallel (collinear) or orthogonal to the bar orientation. Results. Observers reported poor filling-in of the orthogonal texture when its mean luminance closely matched that of the background. In contrast, large luminance differences between texture and background restored filling-in, not only of the luminance but also of the texture. Failure of filling-in for orthogonal texture could not be explained by poor pattern visibility because strong filling-in occurred when the texture was parallel to the bar orientation, indicating collinear facilitation or grouping across the blind spot. Conclusions. These results indicate that: 1) filling-in of the blind spot involves active neural completion rather than an automatic passive mechanism, 2) this active mechanism relies on luminance-based grouping across the blind spot, and 3) pattern information alone is insufficient for filling-in but the addition of luminance allows for higher-order texture information to propagate across the blind spot. These findings demonstrate the constructive nature of conscious vision and provide constraints on how visual experiences can be actively assigned to field locations that lack direct input.

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**TU28**

Negative compatibility in masking: unconscious inhibition or new feature priming?  
Alejandro Lleras (alleras@psych.ubc.ca), James T. Enns; University of British Columbia, Canada – Recent reports have described a negative compatibility effect (NCE) in visual masking (Eimer & Schlaghecken, 1998, 2002). The sequence of stimulus events for NCE includes a brief prime stimulus, then a pattern mask, followed by a target that receives a speeded bimanual response. Of critical importance is that the prime-target relation can be either response compatible or incompatible. The main finding is negative compatibility: response time (RT) to targets following an incompatible prime is shorter than to targets following a compatible prime. This is interpreted as evidence of unconscious inhibition of the masked prime.
We hold a different view. Rather than the inhibition of unconsciously processed primes, we believe prime-mask interactions give rise to NCE. If the features of the mask include those of the prime and new target-relevant features, then positive priming can occur. The newly visible features of the mask will prime those of the subsequent target.

We tested this hypothesis in three experiments. Two different types of masks were used that were equal in overall energy: RELevant masks shared features with the prime and the target; IRrelevant masks did not share any prime or target features. In a prime-discrimination task, observers tried to discriminate between the two masked primes; in a target-discrimination task, they made a speeded response to the target.

The results were that (1) primes were less visible when followed by relevant than by irrelevant masks, (2) irrelevant masks yielded a standard positive compatibility effect in target-discrimination, whereas (3) relevant masks yielded the negative compatibility effect.

These results indicate that NCE is driven not by the identity of the prime, via unconscious inhibitory processes, but rather by the most recent set of task-relevant features to be displayed prior to the target. An interpretation of these results is given in terms of reentrant visual processing.

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TU29
C-fos expression and accelerated visual cued fear conditioning in mice with visual input directed to the auditory thalamus
Jessica R Newton (jrnewton@mit.edu), Charlene Ellsworth, Tsuyoshi Miyakawa, Susumu Tonegawa, Mriganka Sur; Picower Center for Learning and Memory, Brain and Cognitive Sciences Department, MIT, Cambridge, MA, USA—Neonatal surgery induces retinal axons to innervate the medial geniculate nucleus (MGN) of the thalamus, providing visual input to cells in auditory thalamus and cortex. However, the behavioral consequences of this "rewiring" are largely unknown. In normal mice, a few tone-shock pairings are sufficient to elicit fear to the tone presented alone, whereas a visual cue is less effective: many more light-shock pairings are needed to elicit fear to the light alone. The present study explores whether visual inputs routed to the MGN influence fear conditioning behavior. Bilateral ablation of the inferior colliculus in p0 mice induced retinal innervation of the MGN. As adults, the mice underwent 3 sessions of fear conditioning and behavioral testing. A conditioning session consisted of 10 minutes of habituation followed by 3 cue-shock pairings (30 sec ISI). The cue (auditory or visual) was presented for 5 seconds, co-terminating with a foot shock (2 sec, 0.3 mA). Freezing was subsequently measured in either the conditioning chamber (contextual fear, 24 h) or an altered context chamber (cued fear, 48 h). Thirty minutes after the last testing session, the mice were perfused and immunohistochemistry performed to examine C-Fos expression (c-fos is an immediate early gene and its expression correlates with neuronal activity). After only 1 session of fear conditioning rewired, but not sham-lesion, mice froze more during the light presentation than the cued fear testing habituation period. Most sham lesion mice required several sessions to produce this effect. Contextual fear was comparable for all groups. Consistent with the behavior results, after 1 session of fear conditioning c-fos expression was higher in the lateral amygdala for light conditioned rewired mice than for sham lesion mice. Our results indicate that retinal projections directed to the MGN accelerate visual cued fear conditioning and that this pathway conveys novel information capable of mediating behavior.

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TU30
Auditory and visual motion signals have to be co-localized to be effectively integrated
Sohpie M Wuerger (s.m.wuerger@keele.ac.uk), Florian Roebroeck, Georg F Meyer, Markus Hofbauer, Kerstin Schill, Christoph Zetzsche; MacKay Institute of Communication Neuroscience, Keele, United Kingdom, 2Department of Medical Psychology, LMU, Munich, Germany—We have previously shown that the integration of non-local auditory and visual motion can best be explained by a probability summation model that uses direction-independent signals from modality specific motion detectors [Wuerger et al. (2002), Journal of Vision, 2(7), 663a]. This finding contradicts other perceptual and physiological data which suggests that auditory and visual signals are integrated at an early stage. We hypothesize that this low-level integration crucially depends on the auditory and visual signals to be co-incident and co-localized.

To test this hypothesis we measured motion detection thresholds for auditory, visual and bi-modal motion stimuli, which were presented along a horizontal arc, containing 31 LEDs and loudspeakers, spaced 5 degrees apart. Each motion signal described an arc of 90 degrees in either the left or right hemi-field in front of the observer. The auditory and visual components used for the bimodal stimuli moved independently, hence they could be in the same or different hemi-fields and move in the same or opposite direction. Thresholds were significantly reduced only when the auditory and visual motion signals move in the same direction and are located in the same hemi-field. A neural summation model explains the data for this congruent condition. In all other conditions the bi-modal thresholds could be explained by an independent-decision model.

We conclude that auditory and visual signals have to be co-localized to be integrated effectively. This is consistent with the idea that local auditory and visual signals are integrated before motion is extracted.

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TU31
The cross-modal effect of perceptual organization of sounds on the visual target detection
Maori Kobayashi (maori@dhh.rikkyo.ne.jp), Yoshitaka Osada; Rikkyo University, Japan—Many studies show that temporal proximity plays an important role in cross-modal interactions (Fendrich & Corballis, 2001; Sekuler, Sekuler & Law.1997). However, is it really sufficient to get the cross-modal effect? We presented random dots on a CRT monitor in synchronization with an auditory sequence to check whether the auditory stream segregation is indispensable for cross-modal interaction.

Subjects were instructed to make a quick detection of a target in a rapidly changing sequence of visual stimuli. The sequence of visual stimuli consisted of quartets of dots, and the sequence of auditory stimuli consisted of quartets of tones, three low- and one high-pitched. The visual target was presented in synchronization with a high-pitched tone, while the other stimuli as visual distractors were synchronized with low-pitched tones. In order for subjects to recognize two sound streams, it was essential to repeat the auditory stimuli prior to displaying the dots. To examine the role of the repetition of the auditory sequence, we set four conditions defined by the audio-visual synchronization (or asynchronous) and by four low-pitched tones or three low-pitched plus one high-pitched tone.

In the case where the subject could recognize the auditory stream segregation, its performance increased more significantly than in the case where he could not.

We found that whether the visual target was synchronized with high-pitched tone or not, the latter high tone did not contribute to the detection of the visual target unless the auditory stream segregation could be recognized. Hence, it was important for the subject to recognize two separate streams of sounds (i.e., the auditory stream segregation). This suggests that the perceptual organization of sounds plays a critical role in the cross-modal effect.

TU32
Explicit and implicit perceptual discrimination of videorealistic speech
Gadi Geiger (gadi@ai.mit.edu), Tony Ezzat, Tomaso Poggio; 1CBCL, McGovern Inst.,Brain & Cog. Sci., MIT, Cambridge, MA, USA, 2CBCL, LCS, MIT Cambridge, MA, USA—Visual speech animation techniques
which are “videorealistic” (potentially indistinguishable from real recorded video) are starting to become available. We describe here a perceptual evaluation scheme and its application to a new videorealistic visual-speech animation system, called Mary101.

Two types of experiments were performed: a) distinguishing visually between real and synthetic image-sequences of the same utterances (“Turing tests”), and b) lip-reading real and synthetic image-sequences of the same utterances (“Intelligibility tests”). In the explicit perceptual discrimination task (a), each stimulus is classified directly as a real or synthetic image-sequence by detecting a possible difference between the synthetic and the real image-sequences. The implicit perceptual discrimination (b) consists of a comparison between visual recognition of speech of real and synthetic image-sequences.

Subjects performed at chance level in the first explicit discrimination task (a). However, in the implicit lip-reading discrimination task (b), the same subjects performed significantly better with real image-sequences than with synthetic ones. This was true with recognition of whole-words, syllables and phonemes. This suggests that the latter task is a more sensitive method for discrimination between synthetic and real image-sequences.

TU33
Development of multimodal spatial integration and orienting behavior in humans
Christine VJ Chee-Raier1 (cchee@caltech.edu), Patricia A Neil2, Christian Scheier3, David J Leekwic2, Shinusuke Shimojo1,3,
1California Institute of Technology, USA, 2New York State Institute for Basic Research in Developmental Disabilities, USA, 3NTT Communication Science Labs, Japan – The spatial location of objects and events is often specified by concurrent auditory and visual inputs. Adults of many species, including humans, take advantage of such multimodal redundancy in spatial localization. Previous studies have shown that adults respond more quickly and reliably to multimodal compared to unimodal stimuli localization cues. The current study investigated for the first time the development of audio-visual integration in spatial localization in infants between 1-10 months of age. Infants were presented with a series of unimodal or spatially and temporally coincident bimodal lights and sounds at +/-25 and +/-45 degrees from center, and their head and eye orienting responses were measured frame-by-frame from digital video records. Subjects’ data were aggregated into 2-month age bins with 12 infants per group for both unimodal and bimodal experiments. Results showed that infants older than four months responded significantly faster to bimodal stimuli than to either visual or auditory stimuli alone (p < 0.01), whereas younger infants responded to all stimuli, either bimodal or unimodal, uniformly. Unimodal and bimodal reaction times tended to decrease with age. Characteristic orienting behaviors changed qualitatively with age. Our results are consistent with neurophysiological findings from multimodal sites in the superior colliculus of infant monkeys in showing that multimodal enhancement of responsiveness is not present at birth but that it emerges during the first months of life.

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http://neuro.caltech.edu/infant/presentations/VSS2003.html

TU34
The effects of modality dominance and accuracy on motor reaction times to unimodal and bimodal stimuli
Ayla Barutchu1 (a.barutchu@latrobe.edu.au), Sheila G Creurther1, Antonio G Paolini1, David P Creuther2, 1School of Psychological Science, La Trobe University, Australia, 2Brain Sciences Institute, Swinburne University of Technology, Australia – PURPOSE: Despite limited understanding of the underlying neural mechanisms involved in merging various sensory inputs and, in turn, the construction of a unified representation of the environment, it would appear that multisensory stimuli have a facilitating effect on information processing. It was the aim of this study to investigate multisensory processing using patterns of motor reaction times (MRTs) on a simple discrimination task as a means of categorizing groups of individuals.

METHOD: Twenty-six adults were presented with temporally and spatially coincident unimodal (auditory or visual) and bimodal (auditory and visual) stimuli (100 ms duration), consisting of blue flashes as invalid (Vi) and red flashes as target (Vt) stimuli, and 500 Hz tones as invalid (Ai) and 600 Hz tones as target (At) stimuli. Overall, eight stimulus conditions were used: Ai, Vi, At, AiVi, AtVi, AtVi, and AtVi. Participants were required to press a button immediately in response to target stimuli: MRTs and response accuracy were recorded. Participants were subdivided into groups of visual dominant [Vis-Dom (n=16)] where MRT for Vt < At and auditory dominant [Aud-Dom, n=10] where MRT for At < Vt. RESULTS: Both Vis-Dom and Aud-Dom groups showed similar levels of facilitation for dual target bimodal stimuli (AtVi), i.e., MRTs were approximately 60 ms faster compared to unimodal stimuli and single target bimodal stimuli. Furthermore, MRTs to single target bimodal stimuli mirrored MRTs to unimodal stimuli, i.e., Vis-Dom and Aud-Dom participants’ MRT were faster to AiVi and AtVi stimuli, respectively. An increase in speed, for all stimulus conditions, was also associated with high response accuracy. CONCLUSION: MRTs are partly dependent on an individual’s dominant modality and performance accuracy. Nevertheless, maximum facilitation is achieved with dual target bimodal stimuli.

TU35
A moving visual stimulus progressively drags the perceived timing of a sound
Blairin R Sheth1 (blairin@caltech.edu), Shinusuke Shimojo1,2, Caltech, USA, 2NTT Communication Science Laboratories, Japan – Here, we report a new cross-modal effect. When observers had to time the occurrence of a brief sound (S) relative to a moving visual stimulus, the S appeared to be dragged later and later in time over successive motion sweeps, despite the fact that its timing relative to the motion was the same on each sweep. Over the course of the trial, the perceived drag would abruptly and randomly reset to a value close to the initial one, and then start all over again on the succeeding sweeps. Method: A bright circular disk (100.4 cd/m2, 1 deg. dia., 10 deg. eccentricity below fixation) drifted 21 deg. from left to right (or right to left, depending on the trial) over 465 ms on a dark background. This motion repeated 15 times (sweeps) on each trial. A 2.2 ms long S (65 dBa SPL) occurred at the same instant relative to the visual motion on all sweeps. After all sweeps were concluded on the trial, observers (n=5) had to indicate where the disk was in space when the Ss occurred. Os made two reports with a mouse: the locations of the disks coincident with the first and the last S. Results: Congruent with informal observations, the perceived disk location coincident with the final S was further along in the motion than that of the first S (difference = 3.84 deg. +/- 1.56 deg., p<.001 for n=3, p<.05 for n=1). We asked whether multiple Ss or multiple motion sweeps contributed to the sound drag. In one experiment (2 sounds), we played the S only in the second and last motion sweeps. In another (2 sweeps), we showed the moving stimulus only for the second and last Ss. The sound drag in the motion direction was not as large in either experiment compared to the original (2 sounds: n = 3, difference = -2.27 deg.; 2 sweeps: n = 2, difference = 1.81 deg.). Thus, both the sound and the motion contributed to the sound drag. Other factors and the relationship of the effect with the flash-lag effect (Nijhawan, 1994) and the flash-drag effect (Whitney & Cavanagh, 2000) will be discussed.

TU36
Auditory “capture” of visual motion
Hyungjun Kim (Hyungjun.Kim@ndsu.nodak.edu), Brian Paseka, Mark McCourt; Department of Psychology, North Dakota State University, Fargo, USA – It has recently been shown that aspects of visual perception can be significantly altered by auditory stimuli. We asked whether the perceived direction of visual motion could be affected by auditory signals. The visual stimulus was a spatiotemporally vignetted sinewave grating (0.5 cpd, 5% contrast). Multiple frames of this stimulus were combined into short movies. Each frame lasted 125 ms, and each movie consisted of 3 frames. Between successive frames the spatial phase of the grating was altered, with nine phases sampled, ranging from 90 deg to 270 deg in increments of 18 deg. To investigate the influence of auditory signals on visual motion we paired
the presentation of the movies with auditory stimuli. The auditory stimulus was a binaural amplitude-gated burst of pink noise. The total duration of the noisebursts coincided with the duration of the motion movie. The relative onset, temporal phase and amplitude of the noisebursts were controlled to create a virtual soundsource whose location and motion in 3D auditory space could be manipulated. In the rightward sound condition soundsource onset occurred at a point 2 virtual meters to the left of the head and moved at a constant velocity to a location 2 virtual meters to the right of the head. The opposite occurred in the leftward sound condition. In the no motion control condition the two ears received the same toneburst, and the sound appeared stationary and centered within the head. There was also a no sound control condition. On each trial observers were instructed to ignore the auditory stimulus and to judge the direction of visual motion. The perceived direction of visual motion was strongly influenced by the direction of concurrent auditory motion. Auditory motion not only captured ambiguous visual motion, but could even reverse the perceived direction of unambiguous visual motion. These results suggest that visual motion, a dynamic and spatiotemporal aspect of visual perception, can be altered by sound.

**TU37**

**The visual and haptic perception of natural object shape**

Hideko F Norman (hideko.norman@etsu.edu), J. Farley Norman, Anna M Clayton, Joann Linnehanmmy, Gina Ziecie; Western Kentucky University—Human observers can estimate 3-D object shape using vision or touch. To what extent can visual information about shape be compared to that obtained by touch? Are the representations of 3-D shape derived from vision and touch in a comparable format? J. J. Gibson (1962,1963) described an intriguing cross-modal shape matching task, and concluded that vision and touch “seem to register the same information and to yield the same phenomenal experiences”. Given the obvious sensory differences between vision and touch, finding that they have essentially the same representation of shape would be an important result. It is surprising, however, that Gibson never published any quantitative data that would support this conclusion. Furthermore, he used a set of man-made sculpted objects. The purpose of our experiment was to collect quantitative data using Gibson’s cross-modal shape matching task and evaluate his conclusions. An important second purpose was to investigate the validity of his claim using naturally-shaped 3-D objects. On any given trial, observers haptically explored the shape of one of 12 solid replicas of bell peppers (Capsicum annuum) for 3, 5, or 7 sec. The observers then indicated which of 12 visible objects’ shape matched that of the haptically-presented object. Each observer participated in 5 sessions (120 trials), enabling an evaluation of the effects of increasing experience with the objects. The results showed that while observers could perform the task at reasonable levels of accuracy (40-75 % correct), significant errors in cross-modal matching still occurred after extensive experience. Some haptically-presented objects were accurately matched to their visible replicas. For many other haptically-presented objects, however, they were frequently confused with visible objects that had different shapes but possessed similar global features. We conclude that the visual and haptic representations of object shape are similar, but different.

**TU38**

**Visual and haptic precision and inter-modal perception of curved surfaces**

Carmel A Levitan¹ (carmel@socrates.berkeley.edu), Sergei Gepshtein², Martin S Bande³,⁴; ¹Joint Graduate Group in Bioengineering at UC San Francisco and UC Berkeley, USA, ²School of Optometry, UC Berkeley, USA, ³Vision Science Program, UC Berkeley, USA—It has frequently been reported that stereoscopically-defined, curved surfaces have greater perceived curvature when the axis is horizontal (tilt = 90 deg) than when it is vertical (tilt = 0 deg). This difference, which has been called curvature anisotropy, would be unlikely to occur in haptics. In our experiments, observers made curvature discriminations from visual information alone, haptic information alone, and from both. Visual stimuli were curved surfaces depicted by random-dot stereograms, partially occluded by an aperture. PHANToM force-feedback devices were used to create the haptic stimuli. The parabolic curved surfaces were oriented vertically (tilt = 0 deg) or horizontally (tilt = 90 deg). We found that most observers made finer curvature discriminations visually for tilt = 90 than for tilt = 0 and that haptic discrimination thresholds did not vary with tilt. We used the within-modal discrimination thresholds to set the parameters of a maximum-likelihood estimator for inter-modal visual-haptic judgments. The MLE model predicts how the weights given visual and haptic information should vary with tilt in an inter-modal experiment. The inter-modal results were quite consistent with the predictions. Observers gave predictably more weight to vision when the surfaces were oriented horizontally than when they were oriented vertically. Thus, the relative reliability of visual and haptic information influences inter-modal perception of curvature in a sensible and predictable fashion.

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**TU39**

**Tactile perception facilitates resolution of visual conflict**

Kenneth V Sobel (k.sobel@vanderbilt.edu), Thomas W James, Randolph Blake; Vanderbilt University, Nashville, TN, USA—Ambiguous visual information typically produces unstable visual perception. We have found that unambiguous tactile information about the direction of rotation of a globe significantly influences visual perception of a rotating globe (RG) whose 3D structure is ambiguous. Methods: The RG was created by projecting 240 moving white dots as if randomly distributed across the surface of a virtual globe rigidly rotating at 15 rpm about its vertical axis. Using optical techniques, the visual RG appeared in the same location as an unseen styrofoam globe covered with tiny bumps to simulate dots. This “tactile” globe (TG) was the same perceived size as the RG, and it could rotate at 15 rpm about its vertical axis in either a CW or CCW direction. Results: In one experiment observers tracked the direction of rotation of the RG for 1 minute while touching the TG as it rotated. The perceived direction of rotation of the RG was strongly biased by the direction of rotation of the TG. In a second experiment, the TG began to rotate at the same time that observers began to perceive the RG to be rotating in a given direction. When the rotation directions of the TG and RG were inconsistent, the perceived rotation direction of the RG changed to the opposite direction more quickly than in the condition in which the rotation directions were consistent. In a third experiment, we measured the initial perceived direction of rotation of the RG (1-sec presentation) after observers felt the TG rotating either CW or CCW with eyes closed, thereby engendering perception of rotation in one direction. In spite of the initial exposure to the rotating TG, the initially perceived direction of the RG was uninfluenced by the TG, in turn suggesting that results from Expts 1 and 2 are not attributable to imagery or to attention. Conclusion. Evidently the brain can draw on somatosensory evidence to influence the resolution of visual conflict.

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**TU40**

**The contributions of nonvisual cues, static visual cues, and optic flow in distance estimation**

Jennifer L Campos¹ (camposj@mcmaster.ca), Meredith Young¹, George SW Chan¹, Da-Hui Zhang¹, Colin G Ellard², Hong-Jin Sun¹; ¹McMaster University, Canada, ²University of Waterloo, Canada—This study examined how visual and nonvisual cues are integrated in a distance estimation task by systematically varying cue availability. Distance stimuli were presented in one of three modes: by traversing a distance blindfolded (traversed distance - TD), by traversing a distance with optic flow (TDO), or by visually previewing a target distance from a static location (VPD). Distance estimates were then produced in one of the three modes in which the stimuli were presented. Each of these stimulus modes was paired with each of the three response modes and each subject experienced all combinations. Stimuli were presented in one direction and subjects turned 180 deg before producing their estimates. Experiments were conducted in a large-scale, open, outdoor environment. During conditions in which the stimulus and response were delivered in
the same mode (TD or VPD), when optic flow was absent, constant error was minimal, whereas when optic flow was present (TDO), overestimation was observed. In conditions in which the stimulus and response modes differed, the pattern of responding depended on whether or not optic flow was available. When optic flow was absent, if the stimulus was presented as a VPD and reported via TD (blind walking task), underestimation was observed. However, if the stimulus and response modes were reversed, overestimation was observed. In contrast, when optic flow was present, the opposite results were observed such that, if the stimulus was presented as a VPD and reported via TDO, overestimation was observed and if the stimulus and response modes were reversed, underestimation was observed. These results demonstrate that when optic flow is present in the response phase, overestimation occurs. Overall, the magnitude of error observed in conditions without optic flow was reasonably low, whereas errors in conditions with optic flow suggest that continuous visual monitoring does not necessarily enhance the accuracy of distance estimation.

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TU41 Motion blur applied to eliminate artifacts in apparent motion displays Andrew D Straw (andrew.straw@adelaide.edu.au), David C O’Carroll; Department of Physiology & Centre for Biomedical Engineering, University of Adelaide, SA, Australia – PURPOSE Computer animation simulates motion through rapid presentation of spatially offset images. As well as temporal aliasing, the discrete nature of individual frames leads to an artifact we term ‘ghosting’, perceived as multiple copies of image features. Although only low frame rates are required for perception of motion, ghosting persists beyond the flicker fusion frequency and limits of current computer displays. We consider the basis for such artifacts and the use of synthetic motion blur to eliminate them.

METHODS A model for scene sampling, display, and early visual processing was developed and tested using psychophysical experiments on human subjects viewing either a true motion stimulus (rotating drum) or a computer simulation, with or without artificial motion blur. In an object recognition task, subjects were asked which of two alternative face-sheets moved past an aperture. In a motion detection task, subjects were asked which of two–alternative sequences of (2 or more) frames contained motion.

RESULTS Our model shows that ghosting results from the slow response of photoreceptors (temporal low-pass filtering). Neural images of un-blurred features presented on one frame persist into subsequent frames where they reappear at new locations. Without motion blur, object recognition was possible in animations at velocities far beyond those where performance fell to random levels for true motion. Un-aliased motion energy in animated scenes is not affected by artificial motion blur and we found that performance in a motion detection task was not significantly affected by its use.

CONCLUSIONS Artificial motion blur (temporal anti-aliasing) in computer animation of moving scenes at moderate frame rates eliminates ghosting to produce more realistic simulation of motion. Eye movements may confound this solution, so complete elimination of such artifacts would require frame rates over 1000 Hz, or motion blur based on real-time eye tracking.

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TU42 Differences and similarities in short- and long-range motion processing Nicholas E Scott-Samuels (n.e.scott-samuels@bristol.ac.uk); Experimental Psychology, University of Bristol, UK – A long-standing dichotomy is that between short- and long-range motion processing. Here I present evidence for common early analysis, followed by divergent processing sensitive to spatial form for long-range processing. Subjects observed motion sequences consisting of a vertical, sinusoidal luminance grating (40% contrast, 1.0c/deg) divided into horizontal strips of equal height. Alternate strips drifted leftward and rightward in 90 deg steps. The initial relative phase of adjacent strips was either aligned (0 or 180 deg) or non-aligned (90 or 270 deg); in the former case, extended vertical luminance boundaries were present in every other stimulus frame. The single-interval task was to identify the direction of motion of the central strip. An interstimulus interval (ISI), range 0-400ms, was inserted in between consecutive image frames (each presented for 33.3ms) in the motion sequence, and the threshold strip height (TSH) was determined for veridical performance. In the non-aligned condition, the TSH was 7 minarc for all ISIs. In the aligned condition, the TSH was 11 minarc for all ISIs except 0ms (7 minarc) and 50ms (19 minarc). The constant TSH value in the non-aligned condition implies a common physical limit to both processes, perhaps initial processing by the same front-end filters; the figure of 7 minarc agrees well with previous estimates of short-range motion receptive field heights (Anderson & Burr, 1991, JOSA, 8, 1330), indicating similar underlying sensors for the initial stages of the long-range process. The TSH values in the aligned condition reveal (i) the insensitivity of the short-range process to spatial alignment, (ii) the division between short- and long-range processing around 50ms, and (iii) the effect of spatial form on the long-range process. There appear to be common early spatial constraints on both short- and long-range motion processing, at least for narrowband stimuli, and the long-range process is particularly sensitive to spatial form.

TU43 Perceptual categorization: Dynamical vs. Judgmental boundaries Lori Bukowski (loribfau@aol.com), Asta Huisman, Mireya Rivera, Howard S Jack; Department of Psychology, Florida Atlantic University, USA – Perceptual categorization was compared for two kinds of apparent motion stimuli. The first was a motion quartet for which pairs of elements in diagonally opposite corners of an imaginary rectangle were interchanged during successive frames; subjects reported whether a horizontal or vertical motion pattern was perceived. The second stimulus was composed of two spatially separate, single-element motions, one along a horizontal, the other along a vertical path; subjects reported whether the horizontal or vertical path looked longer. Whether the boundaries separating these perceptual categories were dynamical or judgmental was determined by gradually increasing and gradually decreasing the aspect ratio of the stimuli (the vertical divided by the horizontal path length). For the motion quartet, hysteresis effects of similar magnitude were obtained, regardless of whether subjects reported the loss of the initially perceived pattern or a change to the alternative pattern sometime during a trial; when the initial percept was lost, the new percept was immediately gained, the bistability indicating that the boundary separating these perceptual categories was dynamical. For the stimuli with spatially separated motion paths, hysteresis was obtained when subjects reported whether there was a change from the initial percept (e.g., the horizontal motion path looked longer) to the reverse percept (the vertical motion path looked longer) sometime during a trial. However, the hysteresis effect was sharply reduced or eliminated when subjects instead reported whether the initially perceived difference in path length no longer was perceivable sometime during the trial. This difference between when the initial percept was lost and when a new percept was gained indicated that there was a range of aspect ratios for which perception of relative path length was uncertain, evidence that the boundary separating these perceptual categories was judgmental.

TU44 Perception of curved apparent motion paths Megan L Meyer (MeganM22@aol.com), Thomas F Shipley; Temple University, USA – In two-frame apparent motion displays observers typically see motion along a straight path. Curved paths have been demonstrated for some specific stimulus configurations that may reflect knowledge of object motions; e.g., human limbs appear to move on curved paths when shown for long
The spatial properties of motion-defined contours?  Robert F Hess1 (robert.hess@mcgill.ca), Tim Ledgeway2, 1McGill Vision Research, McGill University, Montreal, Canada, 2Dept. Psychology, University of Nottingham, UK – Purpose. The visual system integrates local orientation information across space to define spatial contours (Field, et al. V.R. 33, 1993). More recently, it has been shown that a similar integration occurs for the direction of local motion signals in different parts of the field if they are aligned along a spatial contour (Ledgeway & Hess ARVO, 2001). Here we ask what are the spatial properties of this specialized type of motion integration. Methods Using a standard 2AFC task, observers were asked to choose which interval contained the elongated spatial contour (path) defined solely by motion. One interval chosen at random on each trial contained 158 micropatterns of random position and direction (background micropatterns) and in the other interval (path plus background) the motion directions of some (8) of the background micropatterns were arranged to lie along the invisible backbone of an elongated contour. The micropatterns contained 2-d, spatial noise that either had a spatial frequency bandwidth of 1 octave (Exp 1) or had an orientation bandwidth of 30 (Exp 2) and the centre frequencies/orientations of individual micropatterns could be varied. Results Motion-defined contours exhibit broad tuning for spatial frequency but narrow tuning for orientation. Conclusions Although motion-defined contours differ from orientation-defined counterparts in terms of their spatial frequency tuning they both exhibit narrow orientation tuning.

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TU44
Perceptual consequences when combining form and biological motion Helena M Paterson (helena@psy.gla.ac.uk), Frank E Pollick; University of Glasgow, UK – When presenting human derived stimuli, it is often the case that motion and form are investigated separately. As a consequence, it has rarely been possible to systematically study the interaction of form and motion in person perception. We present a possible solution to this problem for investigating perception of biological motion. Modern computer animation techniques were used to generate hierarchical humanoid models that, driven by digitally captured human movement and in two experiments we explored the interaction of form and motion. Firstly we combined affective human movement with static facial expressions in order to assess the contribution of facial expression and motion to perception of angry, sad and happy emotion. The results of this experiment suggested that although faces dominated the perception of emotion under normal conditions, it is movement that modulated the intensity of emotion. However, in cases where facial expression presented a low salient signal, movement dominated perception in the angry condition. The second experiment was motivated by findings in biological motion that suggests perturbation of phasic relationships amongst limbs have consequences in the perception of form. We used human movement motion capture data to investigate the phase relationships in limbs - for instance the relationship between wrist, elbow and shoulder. We found that in general there is a short phase shift amongst limb parts and used this to perturb the human movement in both point-light displays and dynamic humanoid models. We will discuss the consequences of sensitivity to phase noise for point-light displays compared with the causally connected hierarchical model. The findings from both experiments show that for high-level perception, there are multifaceted perceptual consequences of combining form and motion, suggesting the different integration of the two types of information.

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http://www.psy.gla.ac.uk/~helena/Publications.html

TU46
Motion from occlusion  David A Remus (remus@princeton.edu), Stephen A Engel; University of California, Los Angeles, USA – Prior research has shown that some depth cues, such as stereo and shadows, can generate strong perceptions of motion. Here we tested whether another cue, occlusion, can also generate perceived motion in depth. In our basic display, blue circles, outlined in black, appeared one at a time at random locations on a black background. Old circles remained in the image as new circles appeared. New circles opaquely covered portions of old circles where they overlapped: Regardless of their prior colors, image locations where the edge of a new circle fell were set to black, and image locations...
corresponding to the interior of a new circle were set to blue. Monocular viewing of this display generated a strong percept of motion in depth; the circles appeared to stack on top of each other, with new circles appearing closer to the viewer than older ones. The circles also appeared to grow in height, 4.5 eccentricity right/left side, monocularly, that moved either up or down (5.75Hz, 0.Scycle/ ) or were stationary. Relative salience in the stimulus was manipulated by varying the saturation of a greenish grating that was modulated isoluminantly in spatial antiphase with a 1.0 contrast red grating. For the low-, medium-, and high-green-saturation conditions, isoluminance was determined by motion photometry in each subject (n=6) immediately before each scanning session (6 per subject). By contrasting the salience-defined motion conditions with their stationary counterparts, we observed activations in bilateral MT+ and in the inferior parietal lobule (IPL). The functional profile of MT+ shows contralateral activity, whereas that of IPL reveals bilateral activity which is salience-specific. In the second experiment (n=12), we used the quartet apparent motion display (Temus,1938) consisting of two alternating frames (2 and 7Hz) each with two white dots (0.5 ) arrayed on the two diagonally opposed vertices of a 2 square (4 eccentricity left/right side, binocularly). This was contrasted to a control condition in which four dots were synchronously presented (7Hz). We observed activation in bilateral MT+ and other regions belonging to the lower-order motion pathway (Sunaert et al,1999), and also in IPL. Contrarily to the contralateral activity in MT+, IPL showed bilateral activity and specificity for the apparent motion condition. We conclude that there are two motion-processing systems in the human brain: an energy-driven, contralateral lower-order system including area V5/MT+, and an 'attention'-driven, bilateral higher-order system represented in IPL.

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**TU50**

**Extrapolation of motion paths behind an occluder** Erich Graf
Kris W Sauer (sauer@softhome.net), George J. Andersen, Assad Saidpour; University of California, Riverside – In previous work on collision detection (Andersen & Kim, 2001) involving objects following linear trajectories, it was found that the optical information specifying a collision was constant bearing and image expansion. This is not true for objects following nonlinear trajectories. In the present study, we used objects following trajectories of constant curvature, which project linearly changing bearings when they are on collision courses. Displays simulated a stationary observer with a spherical object approaching on a circular path at eyeheight from the horizon. We varied path curvature, the starting position of the collision object, and display duration, and maintained time-to-contact and object speed. Observers were asked to determine whether the object was on a path that would intersect the observer’s position, resulting in a collision. Observers...
were more accurate when the slope of the linear change in bearing was closer to zero. Collisions resulting in linear but rapidly changing bearing could also be discriminated, but observers were less accurate in these cases. These results indicate that the slope of the change in bearing is quite important for deciding if an object is on a collision path, despite the fact that the slope has no geometric relevance in this case.

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TU53

Attentional effects and motion-induced masking
Bettina Friedrich (bettina@psy.gla.ac.uk), Maria Hadjigeorgieva, Pascal Mamassian; University of Glasgow, UK – The position of a moving object can be perceived shifted in the direction of motion when its edge is equiluminous (Ramachandran & Antis, 1990; De Valois & De Valois, 1991; Whitney, 2002). Mamassian and Adams (VSS 2002) tested whether this would lead to a masking effect, i.e. if a target positioned directly in front of a moving object would be more difficult to detect as it is masked by the motion. This could not be shown consistently. We examine here whether this previous result can be explained by competing attentional effects to the front side of the moving object by using attentional cues in order to control the allocation of attention. Four grating motion fields modulated by stationary Gaussian envelopes (Gabor) were presented around a fixation cross. A target was presented next to one moving Gabor and observers had to report its polarity (dark vs. bright). Before the onset of the trial, the location of the target was hinted by a cue which was valid 75% of the time. As expected, the valid cues led to better discrimination of the stimulus than invalid cues did. After invalid cueing, targets were consistently better discriminated when they appeared behind rather than in front of the moving Gabor. Our results suggest that failures to find a masking effect can be due to more attention being allocated to the front of the moving object. When attention was drawn away from the moving object, a motion-induced masking effect appeared consistently.

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TU54

Properties of static and dynamic angle discrimination are different
Gunter Loffler (gloe@gcal.ac.uk), Graeme Kennedy, Harry S Orbach, Gael E Gordon; Glasgow Caledonian University – We have previously shown that human angle judgement is equally accurate whether angles are static or moving (up to moderate speeds). Are the computational strategies for static and dynamic conditions the same?

We investigated angle discrimination for static and rotating (angular speeds from 90 /s to 360 /s) triangles defined by three dots (8 cpd D4s). Good performance with moving dots triangles presented on a background of identical static dots argues against the possibility that static ‘snapshots’ are used to discriminate moving angles. If a single frame is not used, over what duration of a movie sequence does the visual system integrate information?

To investigate this, the display was modified so that only two of the three dots were visible on each frame. Blank periods were introduced as transitions between dot pairs. Angle discrimination thresholds show a strong dependence on blank duration when triangles rotate, with an additional dependence on speed of rotation, but are much more resistant to blanks when they are static. For moderate rotational speeds, thresholds double for a 50ms blank, while a 250ms blank is required before thresholds double for static triangles.

In a second experiment, the role of the information provided before and after a transition between dot pairs was investigated by changing pair lifetimes. Surprisingly, unlike static angles, increasing lifetimes (from 100 to 170ms) decreases performance. This implies that factors such as the total number of transitions, and the time between them are important.

In summary, high sensitivity on dynamic shape discrimination cannot be explained by static ‘snapshots’. Moreover, blank and lifetime experiments show two ways in which dynamic performance differs from static performance.

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TU55

Object motion from cortical form-motion interaction between V1, V2, MT and MST
Julia Benzuhanskaya (juliaber@cns.bu.edu), Stephen Grossberg, Ennio Mingolla; Department of Cognitive and Neural Systems, Boston University – To process object motion in cluttered environments, visual cortex has to solve multiple problems such as aperture ambiguity, integration across apertures, and motion segmentation. A cortical model of motion integration and segmentation suggests that form and motion processing streams must interact to generate coherent percepts of object motion from spatially distributed and ambiguous visual information. An earlier model (Chey et al, 1997, Grossberg et al, 2001) based on properties of V1, V2, MT and MST was used to solve both the motion aperture and correspondence problems and to explain motion capture, barberpole illusion, plaid motion and motion transparency. Here the model is further developed to explain more complex percepts, such as the motion of rotating shapes observed through apertures (Lorenceau and Alais, 2001), the chopsticks illusion (Anstis, 1990) and formation of illusory form boundaries from motion signals. First, form-based figure-ground properties, such as occlusion, influence which motion signals determine the percept. For invisible apertures, a line's intrinsic terminators create veridical but sparse feature tracking signals. These signals can be amplified before they propagate across position. For visible apertures, motion of extrinsic line terminators provides weak competition to ambiguous motion signals within line interiors. Spatially anisotropic directional grouping filters integrate motion signals over space and determine the global motion percept. The model hereby explains the Lorenceau and Alais results without appealing to a “veto” on motion integration. Second, top-down MT-to-V1 signals initiate the separation of ambiguous overlapping moving forms when static information required for separation in depth is not available. Finally, we suggest how mechanisms of motion segmentation can lead to kinetic boundary sensitivity in V2 but not MT (Marcar et al., 2000).

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TU57

Dichoptic motion within Panum’s fusional area? Martin Lages (m.lages@psy.gla.ac.uk), Alexander Dohia, Erich W Graf; Department of Psychology, University of Glasgow, Scotland UK – Purpose. Recent computational and neurophysiological findings suggest the existence of binocular complex cells that jointly encode motion and stereoscopic depth. Dichoptically presented gratings flickering in spatio-temporal quadrature can induce directional motion perception but the existence of an early binocular motion system is a debated issue. Here we investigated perception of dichoptic motion for stimuli defined on different depth planes.

Methods. Stimuli were presented to the left and right eye on a calibrated CRT display with a refresh rate of 120 Hz using a split-screen Wheatstone configuration. On each trial Ss verged on a fixation-cross flanked by nonius lines before two vertical sine-wave gratings of 1.1 c/deg were presented in dichoptic view. The gratings were displayed in a circular aperture for 200 msec flickering in temporal quadrature. After each presentation Ss indicated whether direction of motion was left or right. In three conditions disparity of the stimulus was set to -8, 0, or +8 arc min whereas spatial phase offset between gratings varied between pi/2 and 3pi/2 in randomly intermixed trials. Spatial and temporal phase of the gratings were randomised across trials.

Results. Although stimuli appeared on different depth planes psychometric functions shifted systematically with disparity. Discrimination of motion direction was best when phase offset together with horizontal disparity resulted in spatial quadrature. No reliable discrimination performance was obtained for stimuli with static pedestal, flicker frequencies beyond 4 Hz, and disparities outside Panum’s fusional area.

Conclusions. The present result does not support the notion of an early binocular motion system that can integrate dichoptic motion at different depth planes.

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TU58

Depth order perception in first- and second-order motion stimuli Gene R. Stoner (gene@salk.edu), Thomas D. Albright, Jay Hegde; The Salk Institute for Biological Studies – Dynamic cues for depth ordering of surfaces include (1) progressive uncovering and/or covering of the background texture by the foreground surface (‘accretion-deletion cue’) and (2) the fact that texture elements of a foreground surface should move at the same velocity as the boundary between foreground and background (‘boundary flow cue’).

We studied depth order perception using three first-order and three second-order motion stimuli. One first-order stimulus offered both depth cues and the other two first-order stimuli offered only the boundary flow cue. Two second-order stimuli (defined by either contrast modulation or ‘flicker’) offered only the accretion-deletion cue. The other second-order stimulus offered neither depth cue and was defined by both contrast modulation and flicker. Naive subjects (n=10) viewed stimuli and indicated perceived depth order by a key press. For stimuli with the accretion-deletion cue, all subjects reported the depth order that was consistent with that cue (p < 0.01), regardless of the presence of the boundary flow cue and whether the stimulus was first- or second-order. Accretion-deletion thus appears sufficient for depth order perception.

The efficacy of the boundary flow cue varied considerably across subjects, with some subjects showing no effect. No consistent depth order bias was evident when neither depth cue was available. In addition to highlighting the importance of the accretion-deletion cue relative to the boundary flow cue, our results show that second-order motion defined by either contrast modulation or flicker provides depth order information. Previous neurophysiological studies have found that some visual neurons respond to these types of second-order stimuli. This study suggests that such responses may encode information about depth order as well as motion.

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TU59

Different strategies for using motion in depth information in catching Randy Sieffert (randy.h.sieffert@intel.com), Rob Gray; Arizona State University East, USA – Relative to the large amount of research on temporal prediction, there have been very few studies that have examined spatial prediction (i.e., how to know where to move your hand to catch an approaching ball). Furthermore, previous studies in this area have had the limitation that the catcher was restricted to using only lateral movement of the hand. We investigated catching behavior in the more natural situation where hand movements were unconstrained. Movements of the index finger and thumb of the right hand were tracked as participants tried to ‘catch’ a simulated approaching ball. A sensation of motion in depth was created using combinations of changing image size and changing binocular disparity. Five different directions of motion in depth and five different values of ball time to contact (TTC) were randomly interleaved. Our participants used two distinct interception strategies: ‘Waiters’ (n=4) used only lateral movements of the hand and did not vary the interception point as a function of ball TTC while ‘Interceptors’ (n=4) used both forward and lateral hand movements. For the ‘Interceptors’ there was a significant negative correlation between the forward position of the hand and the ball TTC. These findings suggest that interception models based solely on lateral hand position (e.g., Peper et al, 1994) may not generalize to all catchers. In a separate experiment we mismatched the binocular and monocular cues to motion in depth. For both strategy groups, catching behavior suggested that the perceived direction and TTC of the ball was determined by a combination of disparity and size.

TU60

fMRI investigation of depth specificity in human posterior parietal cortex Derek J Quinlan (dquinlan@uwo.ca), Jody C Culham, Melvyn A Goodale; University of Western Ontario, Canada – Posterior parietal cortex in primates contains several functional areas associated with the visual control of body effectors such as the eye, arm, hand, and head. Thus, one might expect that different parietal regions would be maximally activated by visual stimuli within the depth range associated with the corresponding effector. For example, the ventral intraparietal area (VIP) in the monkey responds preferentially to moving stimuli near the head (Colby et al, 1993, J. Neurophys.). We used functional magnetic resonance imaging (fMRI) to examine how visually-driven activation in posterior parietal cortex varies as a function of stimulus distance from the head. Solid 3-D graspable objects were placed in near space (~ 17cm), grasping space (~ 43cm), or beyond normal grasping range (~ 95cm). At each of the three distances, the objects were either stationary or alternately loomed and receded. Visual angle and velocity were equilibrated across distances. Although the pattern of activation in putative area VIP showed inconsistent depth-specificity across subjects, an area in the superior parieto-occipital (SPO) sulcus did show depth-specificity. SPO activation was highest for objects near the head, moderate for objects within arm’s reach, and considerably lower for objects beyond grasping range. This preference for near and grasping space was observed for both moving and stationary objects. SPO may correspond to the human parietal reach region, perhaps including the homologue of monkey area V6A, an area which also responds best to objects presented in near space (Claudio Galletti, personal communication).

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http://defiant.ssc.uwo.ca/jody_web/presentations.htm
TU61
Brain activation during stereomotion perception: An fMRI study
Lora T Likova (lorat@ski.org), Christopher VY Tyler, Alex R Wade; The Smith-Kettlewell Eye Research Institute, USA – Purpose. Binocular disparity is one of the most powerful sources of depth information. Stereomotion (SM) is motion in depth generated by changing disparity over time. We ask whether SM is processed in (i) disparity-selective areas, (ii) motion-selective areas, (iii) in both disparity and motion areas, or (iv) in some specialized SM area?

Methods. The processing of SM in human visual cortex was studied with BOLD functional magnetic resonance imaging (fMRI). Dynamic autostereograms alternating between two disparity-determined depth planes produced the SM stimulation. SM was compared with: (1) stationary disparity planes, (2) lateral-motion at the horopter, (3) disparate lateral motion (MDM). The BOLD responses were collected on a GE Signa 3T scanner in 22 near-coronal slices spanning the posterior half of the brain. The test-null stimuli were alternated for 9s each in 8 blocks, totaling 144 s plus a fixation period.

Results. The main activity in all comparisons occupied regions inside MT/MST motion complex, with very little SM activation elsewhere. The posterior part of this complex could be subdivided into a region completely unresponsive to SM and an adjacent region responding preferentially to SM. The extension of the areas of differential activity sharply decreased from SM vs. disparity, through SM vs. lateral motion, to SM vs. DLM. In addition to V5+ response, an area purely responsive to SM vs. DLM was found in the temporal lobe anterior to the V5+ complex.

Conclusions. The results show a role of MT/MST complex in stereomotion processing. Within MT/MST, the data suggest segregated encoding of the direction of motion in the 3D space.

TU62
Perceptual offset between first- and second-order motion stimulus Kazuaki Maruya (maruyau@Liu-tokyo.ac.jp), Takao Satoh; Department of Psychology, University of Tokyo, Japan – Purpose: Motion- and luminance-defined motions (MDM/LDM) were perceived misaligned when they were presented physically with a same speed and in phase. MDM is motion of patterns defined by local motion direction. In this study, we examined the effects of global motion speed (physical and perceptual) of MDM and LDM on the amount of this offset to explore the origin of this phenomenon. Method: Stimuli were two types of square wave patterns. Each of them was consisted of 1024 random dots in the stimulus field of 120 x 300 pixels (4 x 10 deg). The square wave pattern was generated by modulating these dots’ motion direction (MDM) or luminance (LDM). MDM and LDM were generated by shifting these square waves once every 120 ms. These patterns were moved at the same speed, and the phase misalignment between the two stimuli was measured by finding the null point while varying the physical phase offset between LDM and MDM using the method of constant stimuli. The speed of global motion was varied in five steps between 1.7 and 6.9 deg/sec. Subjects’ task was to judge the offset direction of LDM with a 2-AFC method. Results and discussions: The null point for the apparent offset was calculated with a probit analysis. The calculated offset increased as the physical global motion speed increased. In contrast, no systematic change was found when the perceived speed of LDM or MDM was varied by manipulating the dots contrast or local motion speed. Theoretically, the spatial distance is the product of speed and time. So, the apparent spatial offset could be accounted for by the difference between perceived speed or processing time for LDM and MDM. The present results reject the former hypothesis. The offset phenomenon reported here, therefore, can be interpreted as the spatio-temporal conversions of differences in processing time for LDM and MDM.

Acknowledgment: HFSJ, JSPS

TU63
Contextual effects of binocular depth cues and shadow-based depth cues on motion interpretation Jay Hegde* (jay@salk.edu), Thomas D. Albright, Gene R. Stoner; The Salk Institute for Biological Studies, La Jolla, CA, USA – A horizontally moving grating viewed through a diamond-shaped aperture appears to move either upwards or downwards if binocular depth cues (disparity and monocular half-occlusions) are used to simulate partial occlusion of that grating (Duncan, Albright and Stoner, 2000, J. Neurosci. 20:5885). For these ‘barber diamond’ stimuli, the grating is perceived to move towards (and slide under) the occluding panels. We asked whether depth from shadows is as effective as binocular cues in biasing perceived direction. We created barber diamond movies in which the depth order of the surrounding panels was based on either binocular cues or shadows. In movies with shadows, all image features had zero disparity. Subjects (n=11) viewed all movies through anaglyph glasses and reported the perceived direction of the gratings by adjusting the orientation of a bar.

Reports in the direction of near panels significantly outnumbered those in the direction of the far panels (binomial proportions test, p < 0.05) for all subjects for both shadowed and binocularly cued movies. The directional bias for the two types of depth cues was indistinguishable for each subject (binomial proportions test, p < 0.05 in all cases). These results indicate that shadows can be at least as powerful as binocular cues in biasing perceived direction of motion. Since directional responses of area MT neurons have been shown to reflect the perceived direction for barber diamond stimuli with binocular depth cues, this raises the question of whether the effect of shadows is also present in that cortical area.

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TU64
Depth assignment in motion transparency Pascal Mamassian (pascal@psg.gla.ac.uk), Julian M Wallace; University of Glasgow, UK – Perception of motion transparency arises when two or more surfaces move over each other with different directions or different speeds. In all cases, a clear depth percept accompanies the segmentation and integration processes, even though depth is left ambiguous in the display. We are interested here in the way depth is assigned to each surface. Stimuli consisted of random dot kinematograms representing two surfaces moving at the same speed but in opposite directions. The stimuli were sparse (2% density), restricted to a circular aperture (8 deg diameter) and the common speed was set to 2 deg/sec. The orientation of the dot trajectories was randomly varied in 15 deg steps. One surface was arbitrarily displayed with black dots while the other one used white dots. Observers had to report the polarity (black vs. white) of the surface that appeared in front. While depth is completely ambiguous in the display, we found systematic biases in depth assignment. Observers consistently chose the front surface as the one that moved to the left and down. These results can be related to previous reports of a leftward bias for simple translation (Morikawa & McBeath, 1992, Vision Research, 6, 1137-1141). Our results suggest that such biases participate to depth ordering. We discuss the implication of this biased depth assignment for the mechanism underlying motion transparency.

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TU65
Reading quickly in the periphery Tracey D Berger (tdb205@nyu.edu), Marioluisa Martelli, Michael Su, Mauricio Aguayo, Denis G Pelli; New York University, USA – In the periphery, crowding obscures word content, yet somehow people still read quickly. To unravel this mystery, we measured reading rate, varying eccentricity, letter spacing, letter size, and word order. We find that when words are ordered, reading rate is independent of letter spacing; when words are unordered, reading rate falls at the small letter spacings at which crowding is expected. Word order compensates
for the impoverished word content caused by crowding, enabling fast peripheral reading.

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TU66

Harry Potter and the spatial spectra in English and Chinese
Frank Thorn (thornf@ne-optometry.edu), Sondra J Thorn, Ji-Chiang He; Myopia Research Center, New England College of Optometry, Boston, MA, USA – Purpose: Reading through ocular aberrations and defocus induced by an accommodative lag has been associated with the development of myopia. We wondered if the graphic nature of children’s text can contribute to the progression of myopia. Thus we have analyzed the spatial frequency spectra of English and Chinese text intended for children in the age range that myopia is most likely to progress. We then analyzed the effect of ocular aberrations and defocus on the spatial spectra of the text’s retinal images.

Methods: Harry Potter books have universal appeal to children between 7 and 13 years of age and have been translated into many languages. CT View (Sarver, Inc) was used to calculate the spatial frequency spectra of this text. The spatial spectra of its retinal image were then calculated based on different amounts of defocus and the ocular aberrations of individual children’s eyes. The children, whose retinal images were simulated, were between 10 and 17 years of age and were from Beijing or Boston (He et al., 2001).

Results: Typical small amounts of ocular aberrations and defocus had little effect on the clarity of retinal images at normal reading distances. Higher amounts of aberration and accommodative defocus, which is common among progressing myopes, degraded the text. Under these conditions, a child must read through significant contrast reduction and spatial phase shifts. Thus they may rely on overall letter, word, or character shape to read fast. Spatial spectra and their retinal images were similar for English and Chinese text despite their disparate appearance.

Conclusions: The various spatial frequencies in the retinal image of the text usually have high contrast for easy reading. Higher amounts of aberrations and accommodative defocus, which are common in young myopes, causes some children to routinely read through highly degraded images of a type that is hypothesized to induce myopia.

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TU67

What type of practice improves reading rates for nonstandard letter spacing: visual or text? Faith L Florer (florer@river.org), Teresa L Thompson, Christine V Jadeja; Marymount Manhattan College, USA – To examine the processes underlying the ability of graphic designers to read nonstandard letter spacing more quickly than normal readers (Hunter-Kahn & Florer, ARVO, 2000), we studied reading rates of four groups of readers -- artists (people employed at least three years primarily manipulating visual images as art); copyeditors (people employed at least three years primarily through manipulating text); dyslexic artists; and dyslexic (non-artist) readers. The spaces between letters varied from 0.5-12 M spaces. Print size was 1 deg. We found that copyeditors read most nonstandard letter spacing faster than all other groups: The critical letter spacing (the point at which reading rates fell using a two-limbed fit) was greater for copyeditors (3.25 M) than for graphic designers (1.8M), and more than three times the critical spacing of artists (1M) and dyslexic and normal readers (1M). When letter spacing was 3.25 M, copyeditors’ mean reading rate (154WPM) was significantly faster than normal readers (88WPM), t = 5.87, p < .05, and graphic designers (107WPM), t = 3.51, p < .05. In fact, the copyeditors read widely spaced text (3.25M) faster than normal readers read normally spaced text (148WPM). When letter spacing was wider than 3.25M, mean reading rate of copyeditors (39WPM) was no faster than normal readers (34WPM), and slower than graphic designers (mean of 80 WPM). The lowest reading rates for all groups were obtained at letter spacing of 12M, by artists (mean reading rate = 11WPM), and coincided with their verbal interest in the visual aspect of the text. The results, in sum, suggest that the ability to read wide spaced text is based on familiarity with words and letters, not in visual engagement with images. The verbal reports of the fastest-reading group (copyeditors) dismissed reading as unimportant to their reading rate because they ‘don’t need to read,’ but instead infer words’ based on few letters, experience, and context.

TU68

Font tuning differentiates experts and novices in letter recognition Alan Chun-Nang Wong1 (cn.wong@vanderbilt.edu), Isabel Gautieri2; 1Vanderbilt University, USA, 2Marymount Manhattan College, USA – Letter strings can generally be expected to appear in texts in a regular font (typeface). Previous studies (e.g., Sanocki, 1987, 88, 91) show that people are sensitive to this regularity, with better recognition performance for letters appearing in the same font than mixed fonts. We hypothesize that extensive reading experience equips one with the ability to pick up font regularity, which aids individual letter recognition. To test the relationship between reading experience and font tuning, we recruited Chinese-English bilinguals and English readers. They viewed 3 letters (Roman or Chinese) simultaneously presented side by side on the computer screen and responded to all of them by pressing their corresponding keys. The 3 letters appeared either in the same or mixed fonts, and fonts were manipulated in three different ways (1 – whether the middle part of the letter was high or low; 2 – whether the letters were solid or hollow; 3 – whether the letters were tilted to the left or right). We found that (a) In conditions where extensive reading experience was involved (bilinguals recognizing Roman and Chinese letters and English readers recognizing Roman letters), accuracy was higher when all 3 letters had high (or low) middle parts than when the middle-part positions were mixed, and (b) In conditions where little reading experience was involved (English readers recognizing Chinese letters), accuracy was higher when all 3 letters were solid (or hollow) than when they were mixed. Results show that both experts and novices were sensitive to font regularity but in different fashions. Experts may tune to font information that involves only parts of the letters (e.g., middle part position), whereas novices may be more sensitive to changes which apply to the whole letter (e.g., solidness / hollowness). The distinct types of font tuning suggest differences in the way experts and novices process individual letters.

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http://www.psych.vanderbilt.edu/students/wong/academic/ VS08FontTuning.html

TU69

How well do we know our own visual limitations? Comparisons of estimated and actual visual abilities Johnell O. Brooks (jobrook@clenment.edu), Justin M. Owens, Ben R. Stephens, Richard A. Tyrrell; Clemson University, USA – In several aspects of nighttime driving our estimates of the visual abilities of ourselves and of others is important. Our decision to cross a street at night, for example, may be influenced by our estimate of the visual abilities of the approaching driver. Existing data reveal that pedestrians dramatically overestimate drivers’ visual abilities. This study explored the relationship between observers’ estimated and actual visual abilities in a lab setting. Young observers (N=34) briefly wore one of four different goggles containing ND filters (ND 3, 2, 1, or 0). They then removed the goggles and estimated their high contrast visual acuity (VA), low contrast VA, and contrast sensitivity (CS) at the previously seen luminance. To estimate their VA, observers sat 1 m from a monitor and matched the size of a high or low contrast E to their estimated threshold if they were viewing the E at 6 m. Similarly, observers used a Pelli-Robson chart to estimate their CS at the different luminances. Surprisingly, observers significantly underestimated their actual abilities. The
Visual perception is affected by motor experience: Evidence
TU71
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Graduate Transportation Fellowship

high luminance estimates of CS (r=.54) and by high luminance estimates of
contrast. Estimated pedestrian visibility distances were best predicted by
underestimated the importance of both luminance (beam setting) and
contrast. Estimated pedestrian visibility distances were best predicted by
underestimation decreased as luminance increased. Using photographs,
observers also estimated the maximum distance at which they could detect
a pedestrian walking in the middle of their lane when they drive along a
dark rural road at night. These visibility estimates were made for low and
high luminance and for different clothing conditions. Observers consistently
underestimated the importance of both luminance (beam setting) and
contrast. Estimated pedestrian visibility distances were best predicted by
high luminance estimates of CS (r=.54) and by high luminance estimates of
low contrast VA (r= -.47) but not by measures of actual visual ability.
Implications for nighttime traffic safety will be discussed.

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TU70
Spatial-frequency phase noise in central and peripheral vision
Noah Z. Schwartz1 (n.schwartz@usc.edu), Bogo S. Tjan1, Susana T.L. Chung2; 1University of Southern California, Los Angeles, CA, USA, 2University of
Houston, Houston, TX, USA – Common image features, such as edges, are
spatially broadband, comprising localized patterns at multiple scales and
in relative positions to one another. In order for the visual system to
perceive form, not only must it be sensitive to spatial patterns at different
scales, it must also be able to encode their relative positions, or phase, with
precision. It has been suggested that inaccuracy in phase encoding partly
accounts for the deficiency in form perception in the peripheral visual
fields. We showed that mathematically phase noise can be approximated as
a spatial-frequency-specific multiplicative noise, that is, a Gaussian
“pink” noise with a power spectrum that is a scaled version of the image.
We derived a double-noise masking paradigm to measure the effective
amount of phase noise in central and peripheral visual fields. Observers
identified Times-Roman letters of size 2.7 deg presented in the fovea and
at 10-deg eccentricity in the lower visual field. Four levels each of static
white and pink Gaussian noises were added to a letter target to obtain a
total of 16 contrast thresholds at 79% criteria at each eccentricity.
Threshold contrast energy as a function of the two noise spectral densities
could be approximated by a 2D plane. Average threshold elevation
between fovea and 10-deg eccentricity was about a factor of 4. Data were
fitted to an ideal-observer model, which incorporated both multiplicative
(phase) and additive noise sources. From fovea to 10-deg eccentricity,
internal phase noise increased by a factor of 3, accounting for about a
factor of 2.5 (out of 4) increase in threshold contrast energy. Our results
showed that inaccuracy in phase encoding is a major factor that
contributes to the deficiency in form perception in the periphery.

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TU71
Visual perception is affected by motor experience: Evidence from letter recognition
Karlin H James (karin.james@vanderbilt.edu), Shilpi P Roy, Isabel Gauthier; Vanderbilt University, USA – Motor sequences acquired through writing may be associated with letter representations,
resulting in the possibility that motor sequences are invoked when we
perceive a letter. Using an interference paradigm we investigated the
extent that motor and visual systems interact during letter identification.
Individuals identified letters presented in noise while simultaneously
writing letters or shapes. Written stimuli were either visually similar to the
viewed letter (high interference (HI) conditions) or visually dissimilar to
the viewed letter (low interference (LI) conditions). If seeing a letter
invokes a motor program associated with writing that specific letter, then
in the HI condition, letter identification would suffer relative to the LI
condition. Furthermore, if the motor sequences are letter specific, then less
interference, leading to better identification, should result from drawing
shapes while identifying letters than from writing letters. Results
supported our hypotheses-writing letters interfered with letter perception
more than drawing shapes. In addition, more interference resulted when
the written letters were more similar to the viewed letters, than when the
letters were dissimilar to the viewed letters. These data suggest that the
motor systems involved in writing letters interact with processes involved
in perceiving letters and that this interaction is shape specific. The idea
that stored motor programs of writing interact with letter perception
suggests that areas of the brain associated with motor sequencing may be
active whenever we perceive a letter. We present fMRI results that suggest
that, indeed, supplementary motor areas are active when we perceive
letters more than when we perceive shapes. Taken together, these studies
support the idea that stored information acquired through other sensory-
motor systems can have an effect on visual perception.

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http://www.psy.vanderbilt.edu/postdocs/jameskhl/

TU72
Channel for reading Najib J Majaj (majaj@cs.nyu.edu), Yang Xiang
Liang, Marialuisa Martelli, Tracey D Berger, Denis G Pelli; New York
University, USA – Letter identification is mediated by just one spatial
frequency channel (Solomon & Pelli, 1994). But what about reading? We
wondered whether larger features, e.g. words, at lower spatial frequencies
are used when reading text as opposed to just identifying letters. We
characterized the channel for reading by measuring reading rate as a
function of the spatial frequency of a narrow-band noise mask. We found
that reading text is mediated by the same 1.6 octave wide channel as that
used to identify letters. No channel tuned to words was revealed.

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TU73
Reduced contrast does not reduce visual crowding Elisabeth M.
Fine (fine@vision.eri.harvard.edu); SERI/Harvard Medical School; USA –
Background: Previous studies have reported reduced crowding for low
contrast stimuli (Kothe & Regan, 1990: Optom Vis Sci; Simmers et al., 1999:
Ophthal Physiol Opt). Both defined crowding as a change in acuity for
single vs. flanked letters, and used foveal viewing. This study sought to
confirm these findings using a more traditional crowding task (i.e.
comparison of single and flanked letter identification at different retinal
eccentricities). Methods: 10 observers (18-34 yo; VA 20/14) identified 0.34
deg letters and letters flanked by an ‘x’ on either side (xax) at fixation and
±1, 3, 5, and 7 letter spaces (±0.34, ±1.02, ±1.70, and ±2.38 deg) from fixation
on the horizontal meridian. All 25 letters (other than x) were presented at
each location; letter and position were randomly selected from trial-to-
trial. In separate blocks, the stimuli were ~100, 30, and 10% contrast.
Crowding was defined as the difference between single letter and flanked
letter performance. Results: There was little difference in crowding for the
three contrasts. Averaged across position, there was 14±0.3, 15±0.1, and
19±0.2% crowding for the 100, 30, and 10% contrasts, respectively [F(2, 18)
= 2.3, p = 0.127]. There was little change from 100% contrast for single or
flanked letters presented with 30% contrast, but with 10% contrast,
performance was significantly reduced for both stimulus types. Accuracy
was similar across positions for single letters presented with 10% contrast
and flanked letters presented with 100% contrast. Conclusions: Unlike
previous reports, these data show no change in crowding with reduced
contrast stimuli. It is possible that 10% is not sufficiently reduced for
crowding to disappear, but Kothe and Regan showed reduced crowding
for 11% contrast stimuli. The data suggest that the effect of flanking letters
may be to reduce the effective contrast of the target letters.
TU74
Precision of local signs for letters in central and peripheral vision
Susana T.L. Chung1 (schung@optometry.uh.edu), Gordon E. Legge2,
Alberto Ortiz2; 1University of Houston, USA, 2University of Minnesota, USA –
Previous studies have shown that people make letter-reversal errors in
identifying strings of letters in peripheral vision. These errors contribute to

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Letter identification latencies are predicted by an asymmetric contrast metric

Lauren F Scharff (lscharff@sfasu.edu), Albert J Ahumada, NASA Ames Research Center, USA.

Letter position judgment. When expressed in units of letter spaces, the derived SD of the position noise increases with eccentricity, and is independent of character size. Across observers and character sizes, the median SD is approximately 0.5 letter spaces in the fovea, and increases to approximately 0.96 letter spaces at 4 letter positions from fixation. We conclude that local signs for letters become increasingly imprecise in peripheral vision. This imprecision may account for errors in judging the order of letters in text, which may in turn, have an impact on reading.

Acknowledgment: Supported by NIH grants EY12810 (STLC) and EY02934 (GEL).

TU75

Letter identification latencies are predicted by an asymmetric contrast metric

Lauren F Scharff (lscharff@sfasu.edu), Albert J Ahumada, NASA Ames Research Center, USA.

Letter position judgment. When expressed in units of letter spaces, the derived SD of the position noise increases with eccentricity, and is independent of character size. Across observers and character sizes, the median SD is approximately 0.5 letter spaces in the fovea, and increases to approximately 0.96 letter spaces at 4 letter positions from fixation. We conclude that local signs for letters become increasingly imprecise in peripheral vision. This imprecision may account for errors in judging the order of letters in text, which may in turn, have an impact on reading.

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TU77

Spatial attention favors faces over non-face objects in an attentional cueing task

Karen Bornmann (karen@ego.psych.mcgill.ca), Isabelle Bouter, Avi Chaudhuri.

Many potentially significant social signals can serve as cues for guiding attention. Given that faces are an ecologically important stimulus for the visual system, an attentional advantage that could benefit rapid processing would be an important property. Here we present evidence for an automatic allocation of attention to faces. Subjects were simultaneously presented with photographic images of a face and a house on either side of fixation, followed either by a target and a distractor symbol or by two distractor symbols displayed in the locations previously occupied by the house or face. Target detection was faster for targets in locations previously occupied by faces than for targets in locations previously occupied by houses. These data suggest an attention capture by faces. When images were inverted, response times to target location were no longer influenced by whether the target was preceded by a face or house, suggesting that the attention capture of faces may be limited to upright faces. Attention allocated to an invalid face cue appears to linger in the attended location even after stimulus offset of the face, suggesting at least partial involvement of spatial attention.

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TU78

What causes the face inversion effect in a gender priming task?

Eric McCabe (eric.mccabe@umontreal.ca), Frédéric Goselin, Martin Arguin; Département de Psychologie, Université de Montréal, Canada.

In a seminal article, Yin (1969) reported that the recognition of face pictures was disproportionately affected by a 180° rotation in the image plane from the normal, upright viewing condition. This phenomenon is now commonly called the Face Inversion Effect (FIE). There is now agreement amongst most face recognition researchers that the FIE arises from a greater difficulty to perceptually encode inverted face information (e.g. Farah et al., 1998). Recent studies have therefore examined more closely these encoding differences. The exact nature of these differences remain so far largely unknown (e.g., Rossion & Gauthier, in press).
In order to throw some light on the FIE, we used Bubbles, a technique developed to reveal diagnostic visual information (Gosselin & Schyns, 2001), in the context of a face priming paradigm. Our stimulus set (prime and target) comprised 32 faces (8 individuals x 2 genders x 2 expressions). A trial consisted in the presentation of a «bubbled» face (i.e., a face sparsely sampled in spatial location space) for a duration of 100 ms (the prime) followed by the presentation of a white noise mask for a duration of 15 ms, and trailed by the re-presentation of the prime stimulus but unaltered this time (the target). On half the trials the prime was inverted; the target always appeared upright. Eight subjects viewed 2,560 trials (divided in 4 blocks). We computed separate multiple regressions of the bubble masks and response times for the upright and inverted conditions, and performed statistical analyses on the regression coefficients. When the prime was upright, the left eye, the mouth, and a region revealing a small part of the left border of the face produced a significantly larger priming effect than other regions; no region reached significance when the prime was inverted. We discuss the implications of these results for the configrual-but-not-featural-disruption explanation of the FIE.

TU79
Matching and searching for moving faces Karin Pilz (karin.pilz@tuebingen.mpg.de), Ian M Thornton, Heinrich H Bülthoff; Max-Planck-Institut für biologische Kybernetik, Tübingen, Germany – Human faces are dynamic objects. Recently, we have been using a number of novel tasks to explore the visual systems’ sensitivity to these complex, moving stimuli. For example, Thornton & Kourtzi (2002) used an immediate matching task to show that moving primes (video clips) were better cues to identity than static primes (still images); Knappmeyer, Thornton & Bülthoff (2002) used motion capture and computer animation techniques to demonstrate that incidentally learned patterns of characteristic motion could bias the perception of identity when spatial morphs were used to represent the saliency of form cues. Here, we present two sets of experiments which exploit a new database of high-quality digital video sequences captured from 5, temporally-synchronized cameras (Kleiner, Wallraven & Bülthoff, 2002). In the first series of experiments, we examined whether a dynamic matching advantage for identity decisions would generalize across viewpoint. We found that a) dynamic primes led to a small but reliable (24 ms) overall matching advantage compared to static primes; b) matching speed with dynamic primes was unaffected by view direction (left or right) or viewing angle (0, 22, 45 degrees) c) static primes were not only slower, but were also more dependent on view direction and viewing angle. These results suggest that the additional information provided by the dynamic primes is able to compensate to some extent for viewpoint mismatches. In the second series of experiments, we examined visual search for expression singletons using arrays of moving faces. Our initial results indicate that search for faces can be much more efficient (15 ms/ item) than previous studies using static images would suggest. Furthermore, as expression search using the same dynamic arrays turned upside down proved to be much harder (50 ms/item), it would appear that the observed upright performance is face related, rather than relying on low level static or dynamic cues.

TU80
Differential use of spatial frequency scales for face recognition in a person with Asperger’s syndrome Kin M Curb1 (kin.curb@vanderbilt.edu), Philippe G Schyns2, Frédéric Gosselin3, Isabel Gauthier1; 1Vanderbilt University, USA, 2University of Glasgow, Scotland, 3Université de Montréal, Canada – A previous fMRI study (Curby & Gauthier, 2002) found that RD, a patient with an Autistic spectrum disorder (ASD), lacks a fusiform face area (FFA) for unfiltered images, consistent with previous ASD research (Schultz et al., 2000), but surprisingly has face-selective activity in the fusiform gyrus for HSF (high spatial frequency) images (Curby & Gauthier, 2002). Using Gosselin and Schyns’ (2001) Bubbles technique, we measured RD’s relative use of information from different spatial scales in a face identification task. Bubbles randomly reveals limited information from different locations and SF bandwidths, allowing for the computation of an effective face stimulus, based on RD’s performance, depicting the information used for identification. Compared to 15 typical control participants from Schyns et al. (2002), RD not only uses much less information to identify the faces but also relies on a unique distribution of information from the different scales. Controls used relatively more information from mid-to-coarse scales (between 11 to 22 cycles per face) whereas RD appears to rely mostly on the fine scales (45 to 90 cycles per face). Using controls as a benchmark of information use, RD appeared to be more efficient with fine scale information (45 to 90 cycles per face). Efficiency progressively decreased with lower resolutions. RD’s effective face stimulus appeared to be atypical with a dominance of the right eye compared to controls in which both eyes were well defined. The nose was also poorly defined suggesting this feature plays little role in identification for RD. The results combined with RD’s IM activity pattern are consistent with recent work suggesting that the FFA operates on inputs that are segregated for different spatial scales (Gauthier et al., 2002; Eger et al., 2002). Further studies are required to establish if this bias for HSF information is characteristic of ASD as this may provide a new perspective on visual processing in this population.

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TU81
Face perception and configural uncertainty in peripheral vision Carrie L Paras1 (paras@unr.nevada.edu), Jill A Yamashita1, Maria L Simas2, Michael A Webster3; 1University of Nevada, Reno, 2Federal University of Pernambuco – A face presented in the periphery can appear to change over time (the “multiple face effect,” Simas, Perception, 2000). We explored how this instability varies with retinal eccentricity and its relationship to threshold sensitivity for facial configurations. Observers judged the appearance of a frontal-view face image (approximately 4-deg in width) while fixating at eccentricities ranging from 0 to 32 deg (relative to the midpoint of the face). In one task, the static face image was shown for 4 min and subjects responded whenever it appeared to change. In a second task, a set of 3 faces were shown in succession (for 1 sec each) while observers responded which of the 3 was distorted (by a local expansion). The magnitude of the distortion was varied in a staircase to determine the discrimination threshold. Face images appeared stable for eccentricities up to 2 deg (over which fixation remained at a point on the face), but beyond this the frequency of perceived changes increased monotonically up to 16 deg. This pattern roughly paralleled the increases in configural thresholds with increasing eccentricity, suggesting that the instability reflects spatial uncertainty in the facial configuration. To explore why the changes appear as well-defined faces (rather than simply uncertain) we repeated the face change task for a triplet of Gabor patches (forming an eyes and nose configuration). With peripheral viewing these also changed in appearance over time and appeared more as a face-like configuration than when viewed directly. This suggests that face perception in the periphery may depend on a “perceptual completion” of impoverished and thus labile sensory information.

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TU82
Contrast reversals in faces and objects: The effect of albedo Jessie J Peissig (jessie.peissig@brown.edu), Quoc C Vuong, Marianne C Harrison, Michael J Tarr; Brown University, USA – Faces are more difficult to recognize than exemplars of other object categories, e.g., chairs, when viewed in reverse contrast (Subramaniam & Biederman, 1997). The visual mechanisms underlying this phenomenon, however, are not well understood. One possibility is that faces and objects rely on separate systems – one sensitive and the other insensitive to contrast reversal. Alternatively, the complex pigmentation patterns characteristic of faces may contribute to this phenomenon (Bruce & Langton, 1994; Liu et al., 1999; Kemp et al., 1996). To date there has not been a direct comparison of the same faces or objects with and without adbedo information (here,
defined as the reflectance map of a surface independent of shading/shadows). We tested observers in a same/different sequential-matching task using grayscale images of the same face models with or without albedo information. Observers were instructed to base their judgments on face identity, ignoring any changes in contrast. On trials in which faces were shown in different contrasts (e.g., positive-negative), observers responded more slowly and less accurately as compared to trials in which both faces were shown in the same contrast. This decrement in performance was significantly greater for faces with albedo than for faces without albedo. These results indicate that reported differences between faces and objects across contrast reversal may be attributed to the presence or absence of informative surface information and not to stimulus category. This hypothesis was tested further by comparing the effect of contrast reversal on non-face objects with and without albedo. We conclude that contrast reversal disrupts the recognition of both faces and objects to a greater degree in the presence of informative albedo. That is, another putative dissociation between face and object processing can be accounted for by factors other than the object category per se.

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TU83

The Effect of Information-Spread on Face Discrimination

Carl M Gaspar (gasparcm@mcmaster.ca), Jesse S Husk, Allison B Sekuler, Patrick J Bennett; McMaster University, Canada—Despite our extensive experience with faces, we are surprisingly inefficient at face identification. Previous research in our lab and others has suggested that we use only a small proportion of the available information in face identification tasks, and that this information is centered about the eyes and eyebrows. Interestingly, the eye and brow regions are the most informative for face identification in our stimuli. Here we consider the possibility that observers are simply unable to process information across the entire face, and focus on localized regions as the best way to cope with this limitation. Observers discriminated between two faces in each of two different conditions. In one condition, all of the pixels were presented in localized regions around the eyes and brows ("high information value"). In the other, the pixels were distributed broadly about the face but did not include the same eye/brow regions ("low information value"). A staircase varied the total amount of information available in each condition by varying the number of pixels presented. For example, 10% of the stimulus information is packed into a relatively small number of pixels around the eyes/brows in the "high information value" condition, whereas 10% of the stimulus information in the "low information value" condition is spread about a much larger number of pixels. Observers required a significantly higher percent of information in the "low" condition than in the "high", suggesting that the total amount of stimulus information is not as important as the spatial distribution of that information. Observers are much more efficient at discriminating faces based on the most informative regions, even when that information is contained in relatively few pixels. We are currently examining the effects of learning and stimulus context to determine the extent of flexibility in observers' face processing strategies.

TU84

Interaction between vision and speech in face recognition

Isabelle Bülthoff1 (isabelle.bueithoff@tuebingen.mpg.de), Fiona N Newell2; 1Max-Planck-Institut für biologische Kybernetik, Germany, 2Trinity College, Ireland—by characteristic auditory stimuli during learning (d-faces: different languages, intonations, accents, etc.). In the other set, all faces were accompanied by typical auditory stimuli during learning (s-faces: same words, same language). Face stimuli were counterbalanced across auditory conditions. We measured recognition performance in an old/new face/word identification task. Face recognition alone was tested. Our results show that participants were significantly better (t(12) = 3.89, p<0.005) at recognizing d-faces than s-faces in the test session. These results show that there is an interaction between different sensory inputs and that typicality of stimuli in one modality can be modified by concomitantly presented stimuli in other sensory modalities.

TU85

Face identification is dissociable from face imagery and generic face representation

Josef Rives1 (jrices@yorku.ca), Morris Moscovitch1; 1Psychology, Baycrest Centre for Geriatric Care, Toronto, Ontario, Canada, 2Psychology, York University, Toronto, Ontario, Canada—Last year, we introduced DC, a prosopagnosic man who has intact object and word recognition. The aim of the present study is to evaluate whether his face imagery and representation are spared despite his impaired face recognition. Although many have claimed that imagery and recognition depend on the same neural substrates (e.g. Kosslyn et al. 1995, 1999, and O’Craven & Kanwisher, 2000), object recognition can be dissociated from object imagery (Behrmann et al., 1992, 1994; and Servos & Goodale, 1995). DC, and five matched controls (including his brother) were assessed. Participants were asked to recognize 70 pictures of familiar individuals. DC could recognize only 37% of them, and controls, 91%. A face imagery test was designed in which face features and their relations had to be imagined and compared. Half of the faces to be imagined were those that DC could not recognized (set of 30), and the other half were those that he could (set of 30). DC’s face imagery performance was at 77% correct for both the faces that he previously recognized and those he did not. Controls obtained 77 and 74%, respectively. DC’s imagery ability at the Eddy & Glass (1981)’s sentence imagery test, and at the letter imagery test (Behrmann et al., 1994) was normal, and not different from those of controls. Further evaluation (using for example Arcimboldo faces, Mooney faces, and cartoons) show that DC’s face representation is intact. We conclude that face recognition can be dissociated from face imagery and representation.

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TU86

What types of configural face processing are impaired in prosopagnosia?

Richard Le Grand1 (legrand@mcmaster.ca), Daphne Maurer2, Catherine J Mondloch3, Bradley Duchaine2, Noam Sagiv3, Beatrice de Gelder4, 1McMaster University, Canada, 2Harvard University, USA, 3University of California, Berkeley, USA, 4Tilburg University, The Netherlands—Prosopagnosia is a severe impairment in identifying faces that has been associated with deficits in configural face processing—perceiving relations among facial features. Prosopagnosia can result from post-natal occipito-temporal damage (AP—acquired prosopagnosia), or occur with no apparent brain damage and be present from early in life (DP—developmental prosopagnosia).

Here we examined three types of configural face processing in eight adults with DP. The first task measured sensitivity to the first-order relations that define faces (i.e., two eyes above a nose and mouth); classifying Mooney stimuli as either face-like or not. The second task used the Composite Face Task (Hole 1994) to measure holistic processing (gluing the features into a gestalt). The third task measured sensitivity to second-order relations: discriminating faces that differ only in the spacing of features (Mondloch et al., 2002). For comparison we also tested LH, an adult with AP (de Gelder & Rouw, 2000). Prosopagnosics were compared to a normal control group that spanned the same age range (18-73 years).

LH was severely impaired on all three tasks and showed no evidence of any type of configural processing. A different pattern was found for DP.
All eight cases performed normally on classifying Mooney stimuli as faces, and all but one showed the composite face effect that indexes holistic processing. However, only one case showed normal processing of second-order relations. The others either showed deficits in distinguishing upright faces that differ in the spacing of the features, or failed to demonstrate the inversion effect for these faces. Although other tests with this cohort indicate that prosopagnosia is not restricted to configural processing of particular individuals. Given their behavioral deficits, we predicted that we would find a normal M100 but a reduced or absent M170. In keeping with this hypothesis, both subjects showed a higher M100 response to faces than to houses, but no difference in the M170 amplitude for faces and houses. Further testing in one subject revealed that in terms of face selectivity the sensors of interest defined in the previous experiment were within the normal range at the M100, but the face selectivity of his M170 was below that of normal subjects. Moreover, stimuli manipulated to contain only face parts or only face configurations elicited a normal pattern of response at both the M100 and the M170 in this subject, suggesting that his problem may be one of integration of these independent processing streams. In sum, our findings suggest that in some instances, MEG may prove a useful method for determining neural correlates of the behavioral impairments observed in developmental prosopagnosia.

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TU87

Trying your best to ignore a face does little to diminish the N170
Michelle R. Greene (michellg@usc.edu), Michael C. Mangini, Irene Birdman; University of Southern California, USA—Faces produce a significantly greater N170 response in the EEG waveform than objects. However, faces are interesting and invite attention. To what extent is the N170 response modulated by attention? In separate blocks of trials, subjects viewed images of faces alone, butterflies alone, and composites of faces and butterflies in which an image of a face and an image of a butterfly were superimposed. Subjects performed a 1-back task in which they had to judge whether the face or butterfly on the previous trial was identical to the face or butterfly that they were currently viewing. For the composite stimuli, this meant that subjects were sometimes attending to the faces on some blocks and to the butterflies on other blocks for the identical images. EEG was continuously recorded from two sites, T5 and T6. An N170 response was observed for the faces alone but not for the butterflies alone, consistent with previous accounts. Surprisingly, the largest N170 was found for face-attended composite images. This increase over baseline can be analyzed into two components, one associated with the mere presence of the face in the stimulus (whether by itself or in a composite with a butterfly, as these produced highly similar responses) and the other with whether the task required or deflected attention to the face. The largest component, 82.7% of the total, could be attributed to adding a face to the stimulus. Only 17.3% of the difference in the increase in the magnitude of the N170 when attending to a face in a composite over the butterfly alone condition was due to attention to the face. Thus, the N170 appears to be reflecting a face processing mechanism that is engaged automatically when one looks at a face, with only a modest increase in magnitude when that face is attended.


TU88

Characterizing face processing in developmental prosopagnosia using magnetoencephalography
Alison M Harris1 (aharris@fas.harvard.edu), Jia Liu2, Bradley C Duchaine3, Ken Nakayama1; 1Department of Psychology, Harvard University, 2Department of Brain and Cognitive Sciences, Massachusetts Institute of Technology – Magnetoencephalography (MEG) is a neurophysiological technique with high temporal resolution that has the potential to differentiate processing stages occurring tens of milliseconds apart. Recent research has characterized two early stages of face processing at 100 and 170 ms after stimulus onset, known respectively as the M100 and M170. While the M100 amplitude is correlated with successful categorization of a stimulus as a face, only the M170 amplitude is correlated with successful face identification (Liu et al., 2002). Here we examined the M100 and M170 responses in two developmental prosopagnosics, individuals who have a normal ability to categorize stimuli as faces but impaired identification of particular individuals. Given their behavioral deficits, we predicted that trying your best to ignore a face does little to diminish the N170.

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TU90

The effects of scene clutter on the M170 face response
Aaron S Andalman (andalman@mit.edu), Paixion Sinha; Department of Brain and Cognitive Sciences, MIT, USA—Objects in the real world are rarely seen in isolation. Generally they are seen embedded in complex backgrounds. This reality necessitates the ability of recognition mechanisms to disregard background information and selectively respond to objects of interest. Our goal in this study is to examine how putative object-specific neural responses are influenced by the presence of background clutter. We focus specifically on the domain of faces since a rich body of work has accumulated regarding neural correlates of face recognition. The recording technique we use is magneto-encephalography (MEG). The M170 response of the occipito-temporal region of the human brain has previously been implicated in face recognition. However it is unknown how this response changes when faces are viewed against complex natural backgrounds rather than in isolation. We measured the amplitude and latency of the M170 for color faces embedded either in natural scenes or in homogeneous backgrounds with luminance values representative of the natural scenes. The same face stimuli were also presented with thin white halos separating the face from the background to probe the effect of scene clutter.
A principled method to attribute function to brain signals  Marie L. Smith1, (marie@psy.gla.ac.uk), Ines Jentsch1, Frederic Gosselin2, Philippe G. Schyns1, 1University of Glasgow, Scotland, 2University of Montreal, Canada — A powerful methodology is required to resolve what is still one of the greatest methodological challenges in the cognitive neuroscience of vision: When dealing with complex visual stimuli, how can a brain response be attributed to a specific object category (e.g. a face), a specific feature (e.g. the eye) or a specific function (detecting an eye detector or responding to diagnostic face information)?

Here, we introduce a new principled approach (based on “Bubbles”) which uses face stimuli as their own control to determine the features driving a brain response (here, the N170 and P300). At a given latency (ms) the measured amplitude (mV) at particular electrode sites can be correlated with the stimulus giving rise to this amplitude. Our analyses on two observers resolving two different face categorization tasks (gender and expressive or not) reveal that the N170 responds to the eyes within a face irrespective of task demands and that the P300 responds to task specific information.

With this new technique it is possible to track the emergence of ERP components at each electrode site directly without performing an explicit search. Once identified an amplitude modulation is further explored to render how specific stimulus information modulates the amplitude. A dynamic rendering of the use of information over multiple electrode sites is then constructed, resulting in a model of the ERP response to stimulus information.

Such attribution of function suggests a new methodology to directly attribute function to different components of the neural system for perceiving complex stimuli.

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Adult perception of schematic faces that infants prefer  Angela W Ward1 (warda@clemson.edu), Benjamin R Stephens1, James L Dannemiller2, 1Clemson University, USA, 2University Wisconsin-Madison, USA — Mondloch et al (Psychological Science, 1999) report that newborns (but not 3-month-olds) prefer a simple schematic face with internal features in a normal orientation versus the same face with the internal features inverted. Older infants (but not newborns) prefer a more complex schematic face with normal phase versus the same face with a 180 phase shift. One interpretation of these results is that there are two qualitatively different mechanisms involved in face perception at birth versus 3-months of age. Adult’s identification of natural faces may be qualitatively similar across eccentricity (Makela et al, Vision Research, 2001). We evaluated whether adult processing of the schematic faces employed in the infant studies is similar across eccentricity. In the preliminary study, naive untrained adults (n=20) viewed pairs of schematic faces at 40 degrees eccentricity and indicated which face appeared most normal. In the main conditions, each pair differed only in orientation of the internal features. The upright internal orientation was judged “normal” significantly more often in complex schematic pairs compared to simple schematic pairs. (No differences were observed in subsequent foveal judgments.) To examine sensitivity to the orientation cue, two trained observers performed a two-alternative forced-choice discrimination task. Stimuli were low contrast pairs of identical simple or complex schematic faces with 0 versus 180 degree orientation of the internal orientation of the facial features. Pairs were presented at 0, 15, 31, and 38 degrees eccentricity. Orientation discrimination for complex faces was similar across conditions, but discrimination for simple faces was strongly reduced with eccentricity. These results suggest a different effect of eccentricity for faces that newborns differentiate compared to faces that older infants differentiate. Implications of this result for the development of face perception will be discussed.

How to rob a bank and get away with it: Recognizing disguised faces  Yi D Cheng (Yi.Cheng@brown.edu), Michael J Tarr; Brown University, USA — Numerous studies have examined an observer’s ability to recognize faces across transformations (e.g., inversion, contrast reversal, configural and featural manipulations). However, few researchers have investigated how face recognition is affected by disguises. Here, we investigated observers’ ability to recognize disguised faces using an old/new recognition memory paradigm. Three levels of learning and three disguise types (hairstyle, facial hair, glasses) were manipulated. In Exp. 1, faces were disguised by changing a single existing feature, that is, changing the hairstyle, facial hair, or glasses from study to test. We found a main effect of disguise type, with hairstyle or facial hair producing a similar decrease in recognition accuracy, as compared to glasses, which produced a smaller decrease. Across learning conditions, performance resembled a U-shaped curve with lower recognition memory at intermediate levels of learning. This significant trend suggests that observers shift their strategy for remembering an individual face even over relatively moderate levels of experience. Our speculation is that there is a progression from feature-based representations to “holistic” representations that are less reliant on individual features, and consequently, are more robust to changes such as those that occur in disguises. In Exp. 2, faces were disguised by either adding or deleting a single feature. Here the effect of learning differed depending on whether a given face had a feature added or deleted. With increasing experience, recognition accuracy systematically improved for faces with a feature added, whereas recognition accuracy systematically decreased for faces with a feature deleted. In summary, a disguise per se, the type of disguise, and the direction of the disguise all interact with familiarity. Thus, the underlying representations used in face recognition are highly dynamic and may be more or less robust to disguise manipulations.

The effect of the dynamic property on the recognition of moving facial  Motoyasu Honma (mhonma@hej.rikkyo.ne.jp), Yoshihisa Osada; Rikkyo University, Tokyo — It is an open question how the dynamic property of a moving face affects the recognition of the facial expression. To solve this question, we compared moving and static morphed faces to static morphed faces through the use of four facial expressions (happy, sad, disgusted and angry). Method: Ten subjects took part in the experiment. A 4AFC task was employed to judge the facial expression. The degree of emotion of moving face images was set by morphing the original moving face on a scale of one to ten over the range from the neutral to the prototype face with a view to defining ten static face images for each emotion. The moving face images were randomly presented for all the emotions and the static face images were also presented at random. The durations of the static and moving face images were exactly the same for each morphing rate.

Results: Within the range from 30% to 50% of morphing rates of happy faces, the percentages of correct response increased for the moving faces as compared with the correct responses for the corresponding static faces. In the case of the sad face, too, the performance for the moving faces was higher than in the case of the corresponding static faces within the range
from 50% to 70% of morphing rates.

Conclusion: These results suggest that the dynamic property plays an important role in the recognition of facial expression even though the morphing rate is small. This implies that the dynamic property serves as a cue for the judgment on the facial expressions at an early stage of observation. Particularly, in the case of a happy face, the dynamic property may facilitate the utilization of the low spatial frequency component of the face and hence configural information on the face.

TU95

A psychophysical investigation of the other race effect in face recognition Xiaomin Yue (xyue@usc.edu), Michael C. Mangini, Irving Biederman; University of Southern California, USA – People are better at recognizing faces from one’s own race than individuals from other races. Is this effect perceptual or judgmental? A judgmental effect could be produced by adopting a lower criterion for judging individuals as being the “same” if they are from another race. Does the presumed deficit in individuating faces extend to distinguishing the gender or expression of people from other races? We address these questions with a novel perceptual-matching paradigm that eliminated such biases. Subjects, half of whom were Asians (recently arrived to the U.S.) and half Caucasian, performed a two alternative forced-choice task in which one sample was identical to the target face. Half of the faces were derived from a sample of Asian faces; the other half were derived from a sample of Caucasian faces. Each race sample was composed of half male and half female faces that were posed with different expressions. The distractor face differed from the matching face by linearly adding or subtracting a dimension that corresponded to gender, expression (happy vs. unhappy) or identity. The three types of discrimination were presented in a latin square sequence within blocks of trials. The subjects were not informed about the underlying dimensions by which a distractor could differ from the matching face. The distance from the midpoint of the matching and distractor faces was varied to determine the energy (mean squared difference in pixel luminance between the correct and distractor faces) required for a subject to achieve a threshold of 79% correct. Subjects required much more energy to achieve threshold for individuation than whether gender or expression, which had about equally low thresholds. This increase in threshold for individuation was approximately equal for faces whether they were of the same or different race from the subject. More data are required to determine if there is a reliable cost for performing this task with faces of different races.


TU96

News on facial views from humans and machine Adrian Schwaninger1 (adrian.schwaninger@tuebingen.mpg.de), Christian Wallraven1, Sandra Schubmacher2, Heinrich H Buellthoff2; 1Max Planck Institute for Biological Cybernetics, Germany, 2Dept. of Psychology, University of Zurich, Switzerland – Everyday experience suggests that faces can be recognized despite large changes of viewpoint. In this study we used the Inter-Extra-Ortho paradigm from Buellthoff and Edelman (1992) in order to investigate the underlying mechanisms of face recognition. We found systematic effects of viewpoint, which were consistent with computational approaches using interpolation of 2D views. Our results extend the findings from Buellthoff and Edelman on unfamiliar objects to the highly familiar class of faces thus confirming image-based recognition processes independent of class familiarity.

In addition, we found that human recognition performance was qualitatively similar to the performance of an extended version of the computational recognition scheme proposed by Wallraven and Buellthoff (2001) using the same faces as in the psychophysical experiments. This algorithm entails processing view-based features and their spatial relations in a dynamic context and is consistent with evidence from psychophysics suggesting separate representations for featural and configural information in face recognition (Schwaninger, Lobmaier, & Collishaw, 2002).

TU97

Keeping a straight face: configural processing and the aperture capture illusion Timothy Vickery (timothy.j.vickery@vanderbilt.edu), Isabel Gauthier; Vanderbilt University, USA – In the aperture capture illusion (ACI), a vertical bar moves horizontally with its top and bottom appearing sequentially through two vertically separated and horizontally offset apertures (Palmer & Kellman, VSS, 2001). Observers incorrectly perceive the bar as misaligned in the direction of the apertures, and the magnitude of the illusion grows with velocity. Palmer et al. (VSS, 2002) suggested that the visual system continues to represent object parts while occluded but that the velocity of occluded parts is underestimated. Faces (and other objects of expertise) are thought to be processed configurally, and subjects have difficulty selectively attending to half of a face composite, especially when it is aligned the other half (Young et al., 1987). Here, we ask whether such configural and holistic biases for upright faces would reduce the magnitude of the ACI. We compared the ACI for a moving upright face to each of a number of control stimuli matched in size, including a grey square, a textured square, a scrambled face and an inverted face. The stimuli moved behind a black occluder and appeared sequentially through offset apertures that were each 80% of the width of the stimuli. Observers compared the relative magnitude of the ACI for pairs of stimuli moving at the same velocity, in sequentially presented displays. The ACI was stronger for an upright face than for the control stimuli, for most observers tested. Because the ACI appears stronger with inverted than upright faces, it is possible that configural processing is responsible for the reduction in the illusion and thus, survives occlusion. Future work will explore whether the inversion effect on the ACI occurs for any object with a strong canonical orientation or is systematically related to the face inversion effect typically measured on static unoccluded displays.

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TU98

Face Detection using Half-Face Templates Yi Zhu (yz@indiana.edu), Florin Cuta; Computer Science Department, Indiana University, Bloomington, IN – Face detection is the first important step in many face image processing applications. Although a lot of work has been done on detecting frontal faces much less effort has been put into detecting faces with large image-plane or depth rotations. Most templates used in face detection are whole-face templates. However, such templates are ineffective for faces significantly rotated in depth. We propose to use half-face templates to detect faces with large depth rotations. Our experimental results show that half-face templates significantly outperform whole-face templates in detecting faces having large out-plane rotations and performs as well as whole-face templates in detecting frontal faces.

TU99

Bayesian combination of ambiguous shape cues Wendy J Adams (wendy@psy.gla.ac.uk), Pascal Mamassian; University of Glasgow, Scotland – Introduction: We are interested in how the visual system combines different visual cues to recover depth when one cue is ambiguous. Convex and concave surfaces produce similar texture projections, especially at large viewing distances. Our study considered disparity (an unambiguous cue) and its combination with ambiguous texture information. We investigated the amount of interaction between the two cues. Specifically, we asked whether disparity and texture were processed (a) separately, before linear combination of shape estimates, or (b) jointly, such that disparity effectively disambiguated the texture information.

Methods: Vertical ridges were presented stereoscopically to observers. There were four different texture patterns. Each was consistent (in terms of
maximum likelihood) with both a convex and a concave ridge of roughly the same amplitude. The lengths, orientations and distribution of the texture lines were consistent with 0, ±2.5, ±5 or ±7.5 cm ridges. Disparity was consistent with a -7.5, -5, -2.5, 0, 2.5, 5, or 7.5 cm ridge. Observers set a 2D cross-section to match the perceived amplitude. In a second experiment observers judged the profile of the stimuli defined solely by texture under monocular viewing.

Results & Conclusions: When texture was the only available shape cue (monocular presentation), observers consistently reported the convex interpretation. However, in stereoscopic stimuli, texture information modulated the shape from disparity in a way inconsistent with simple linear combination. For example, when disparity indicated a concave surface, a texture pattern which was perceived as highly convex when viewed monocularly caused the stimulus to appear more concave than a 'flat' texture pattern. Our data support the notion that different cues can disambiguate each other (e.g. modified weak fusion). The monocular data and the cue interactions are well modelled using a Bayesian approach that incorporates a prior for convexity.

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TU100
Perception of 3-D carved surfaces from monocular texture cues
Andrea Li (ali@sunyopt.edu), Qasim Zaidi; SUNY College of Optometry, New York, NY, USA - Surfaces carved out of patterned solid material are unlike folded developable surfaces in that the texture pattern on a carved solid varies on the surface as a function of the shape. Thus, unlike for developable surfaces, 3D shape extraction cannot be based on the assumption that textural changes in retinal images occur solely due to the projection. We first compared the perception of sinusoidally corrugated developable and carved surfaces, and then examined carved doubly-curved sinusoidal depth plasds that are inherently non-developable. We assumed the 2D patterns in parallel planes of the pre-carved solid to be identical. In all comparisons, the planar pattern of the carved surface matched the pattern on the developable surface. Vertical 3D shape perception of developable surfaces requires orientation modulations of critical components (Zaidi & Li, 2002). In perspective images of carved surfaces, similar critical orientation modulations arise from the same texture components, but spatial frequency modulations are greatly reduced. Frequency modulations in images of developable surfaces arise from changes in surface depth and slant, but for carved surfaces they arise almost entirely from changes in depth. As a result, concavities and convexities of isotropically textured developable surfaces are often perceptually confused due to similar slant-caused frequency modulations, but these confusions do not occur for carved surfaces. Perceived depth modulations along carved surfaces were much less and more gradual than along physically identical developable surfaces. Vertical perception of concavities, convexities, and saddles of depth plasds also require the visibility of critical orientation modulations about each of the two axes of depth modulation. However, isolated doubly-curved concavities often appear convex or flat. Despite differences in surface texture mapping between developable and carved surfaces, 3D shape percepts rely on similar orientation modulations.

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TU101
Combination of texture and object motion in slant discrimination
Pedro Rosas (pedro.rosas@psy.kuleuven.ac.be), Johan Wagemans; University of Leuven, Belgium - We have previously observed systematic differences in slant discrimination performance for different types of synthetic texture (Rosas et al., VSS-2002, abstract 300). These results allowed a rank-order of textures according to their "helpfulness" - that is, how easy the slant discrimination is when a particular texture is mapped on the surface. Textures composed of circles tended to allow the best slant discrimination performance, followed by a leopard-skin like pattern, then by a "coherent" noise, and finally a fractal noise inducing the worst performance. For large slants, 66 degrees or more, the discrimination was almost independent of the particular texture. In the present slant discrimination experiment these texture types were combined with two types of (rigid) motion: translation of the planes in the vertical direction (parallel to the viewing direction) and horizontal direction (orthogonal to the viewing direction).

In terms of cue combination, one subject showed a discrimination enhanced by the addition of motion in most conditions, consistent with an accumulation of both cues. However, for a second observer there was a significant fraction of observations with equal performance for both types of stimuli (texture with motion and texture only), and for a third subject equal performance was observed more often than discrimination enhanced by motion. This evidence discards a simple summation rule of independent cues in all conditions tested. A combination rule sensitive to the cue reliability could explain the lack of accumulation by nullifying the influence of motion for the more helpful textures. However, such a rule does not explain our data because the cues did not accumulate for the less helpful textures (noises) at low slants, that is, in situations when the texture cue was very unreliable for the task. These data provide a challenge to a simple cue combination model. Alternatively, they can indicate the dependence of the motion cue from texture type.

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TU102
Does a simple shading manipulation lead to size overestimation in 3-D volumes?
Lauren N. Hecht (lnh10@albion.edu), Michael D. Anes; Albion College, Albion, Michigan USA - In the 1850s, Helmholtz identified the Irradiation Effect, a phenomenon in which subjects identify a white square as larger than a same-size dark square. We investigated this effect by asking participants (N=36) to make same/different size judgments of two 3-D cubes, displayed briefly (167 ms) and masked in a centered vertical arrangement against a white background. Size differences were made by increasing line segment length by 10% from small to large cubes. Cube pairings (same/different), cube size (large/small), cube shading (one of the cubes was 0%, 25%, or 50% gray), and shading position (top/bottom) were manipulated. For same size cubes, accuracy in both large and small pairs was dependent on cube shading and shading position; increased shading of the bottom cube led to diminished same judgment accuracy. For different trials, accuracy improved in conditions pairing a small unshaded top cube and a large shaded bottom cube; accuracy increased parametrically with darker shading. The shading position effect can be understood in terms of differential attentional deployment to upper and lower visual fields and in light of the lower field advantage in figure-ground assignment (Vecera, Vogel & Woodman, 2002). The pattern of costs in same judgments and benefits in different judgments as a function of increased shading may be because darker shading resulted in size overestimation, an effect contrary to Helmholtz’s observations. Several additional experiments are in progress. If the relative salience of object to background is the mechanism behind overestimation, the pattern should be unchanged with a photonegative manipulation (Black background, with 100%, 75%, and 50% gray cubes). We also plan to investigate if the effect is reliant upon 2-D or 3-D representational format by using “flattened” cubes with the same line segments but that are not 3-D.

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TU103 Perceived time order for the stimuli presented at different depth is event-dependent  Makoto Ichikawa (ichikawa@yamaguchi-u.ac.jp); Yamaguchi University, Japan – Recently (VSS 2002), I reported that, when two stimuli are suddenly presented at different depth positions, the nearer stimulus tended to be perceived as presented later than the presentation of the further stimulus. In this study, I investigate whether the perceptual delay for the nearer stimulus is common for any events that happen at different depth, or it is restricted to the perceived time order for sudden presented stimuli. In order to compare with the results for the sudden presented stimuli, I used the stimulus shift by 1.4 arc min on front-parallel planes. Pair of mirrors and displays were arranged as a haploscope to present binocular disparity. The viewing distance to the displays was about 45 cm. Two vertical line stimuli (20.8 x 1.4 arc min) were presented at the same level (56 arc min above a fixation point that was located on a display surface) but different depth position by using disparity of 5.8 arc min. There were three conditions for depth location of the stimuli: one of the stimuli was nearer to the fixation plane by a crossed disparity of 2.9 arc min, or both stimuli were nearer (further) than the fixation plane by crossed (uncrossed) disparities of 2.9 and 8.7 arc min. There were nine SOA conditions for the shift of the two stimuli, ranging from -64 msec to 64 msec by 16 msec step (positive SOA indicates that the shift of the nearer stimulus was earlier than that of the further one). Each condition was presented 40 times in random order. Observers judged which stimuli shifted later in each trial. The perception of the shift for the nearer stimulus was delayed only when both stimuli were further than the fixation point. This indicates that the perceptual delay for the nearer stimulus would depend on not only the location of the stimuli, but also the type of events in three-dimensional space. How the time order in visual perception of stimuli located in three-dimensional space is determined would be discussed.

TU104 Internal representation of gravity for visual prediction of an approaching 3D object  Hiroshi Ando (ando@atr.co.jp); ATR Human Information Science Laboratories / PRESTO, JST, Kyoto, Japan – Purpose: Internal knowledge of the physical world may play an important role in interpreting ambiguous sensory information. Computational vision models often impose physical constraints, such as surface smoothness or object rigidity, in order to achieve a stable interpretation. Gravity is a powerful physical constraint, since all objects receive 1 g on earth. Does the human visual system use any knowledge of gravity when predicting time-to-contact (TTC) and point-of-contact (POC) of an approaching object? The present study examines how gravitational acceleration affects the spatio-temporal prediction of an approaching object in a 3D environment. Methods. In the experiments, a computer-generated spherical object was displayed on a large binocular-stereo screen system and projected from a distant point toward a subject along a simulated parabolic trajectory. The subject tried to catch the virtual object, after the object disappeared at 2.4 m from the subject. The timing and location of each catch were recorded by a position sensor. To examine the effect of gravity on visual motion prediction, the value of the gravitational acceleration was varied. Results. The gravitational acceleration internally assumed by the visual system was estimated from the measured position and timing data. The results indicate that the estimated value of an internal gravitational acceleration did not change much even as the simulated gravity changed significantly. Conclusions. The results suggest that the human visual system does not directly estimate gravitational acceleration from retinal images, but uses an internal representation of gravity for visual motion prediction.

TU105 Actions of 9-month-old infants directed at real toys, photographed toys, and surfaces  Albert Yonas (yonas@umn.edu), University of Minnesota, USA – Deloache (1998) reported that infants do not fully understand the nature of pictures, and when viewing them with two eyes, “9-month-olds manually investigate pictures, touching and feeling depicted objects as if they were real objects and even trying to pick them up off the page.” It is possible that rubbing and scratching of a picture of a toy are actually explorations of the texture of the 2-dimensional surface rather than attempts to grasp a 3-dimensional object extending above the surface. Manual behaviors directed toward a toy, a photograph of that toy, and two pictures of a surface that did not include a graspable object were assessed in 21 9-month-olds. To attract the infants’ attention, both non-object control displays presented equal sized colored regions. One control display was untextured and the edges of its colored regions were sharp. The other had a hula-like texture and blurry edges on its colored regions. From video tape recordings, observers scored manual behaviors directed toward the displays while the infant was looking at the displays. In a pilot study, infants’ hands were significantly higher when approaching the real toy than the flat displays. In the present study, before the hand entered the region around the toy, the height of the infants’ index fingers clustered around the upper portion of the toy. This was not true for the picture of the toy or the colored surface displays. Infants brought fingers and thumbs closer together in a pincer motion (suggesting an attempt to grasp) on 85% of the real toy trials and on 2% of the trials in each of the 2-dimensional conditions. Scratching, patting, and rubbing occurred equally to the picture of the toy and to the control displays. Infants’ actions toward the displays suggest that they perceived the actual spatial layout of the objects. While the real toy produced grasping, the picture of the toy and the control displays evoked actions that explored the texture of the surface.

TU106 The dependence of slant perception on texture orientation statistics  Paul A. Warren (p.warren@psy.gla.ac.uk), Pascal Mantuassian; The University of Glasgow, UK – PURPOSE: Many studies have addressed the problem of extracting surface orientation from texture (e.g. Blake et al. 1993; Buckley et al. 1996; Knill, 1998; Li & Zaidi, 2001). Few, however, have looked specifically at the information available from the first and second moments of the orientation distribution of linear texels. There is evidence that observers are able to extract this information (Dakin & Watt, 1997) and use it to recover slant and tilt under orthographic projection (Witkin, 1981). Here we assess the extent to which human slant perception is biased by texture orientation statistics. METHODS: Observers briefly saw patches of texture through a circular aperture subtending approximately 20 degrees visual angle. The texture comprised of small line segments on a planar surface. Texel orientation on the surface followed either a uniform distribution (the reference) or a unimodal circular distribution with variable bias and spread parameters (the comparison). The plane was rotated about a horizontal axis and seen under perspective projection. In each trial observers saw a reference and comparison surface and were asked to indicate which had larger slant (top end away). Predictions were obtained by computing the closed form likelihood function describing the probability that a surface slant produces a particular image under perspective projection. RESULTS: Texture orientation statistics had a significant effect on perceived slant. Observers overestimated slant relative to the isotropic case when texel orientations were biased towards the horizontal, and inversely underestimated slant when they were biased vertically. CONCLUSIONS: Human observers rely on texture orientation statistics to recover surface orientation. Our data are consistent with a Bayesian model which uses the assumption of isotropy. This model has a uniform prior for surface orientation and a decision rule which selects the expected value of the posterior distribution.

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Disparity and texture gradients are combined in two ways. We have found (Hillis et al., Science, 298, 1627, 2002) that combining disparity and texture gradients improves the precision of slant estimation, but that single-cue information (disparity alone and texture alone) can be lost in the combination. However, different combinations of disparity and texture cues are relevant for different types of perceptual judgments. For judgments of slant, disparity and texture gradients should be combined in a weighted sum. For judgments of texture homogeneity (i.e., shape constancy), slants specified by disparity and texture should be compared and this can be accomplished by subtracting one from the other. We asked whether disparity and texture gradients are used in both of these judgments, by weighted summation for one and by weighted differencing for the other. We presented planes whose slants were defined by disparity and texture gradients. On each trial, three stimuli appeared sequentially. Two (or one) standard stimuli had a constant slant specified by both disparity and texture. One (or two) comparison stimuli had disparity and texture signals that indicated different slants from one another. Observers made three perceptual judgments (in separate sessions): (1) “Oddity,” in which they indicated on any basis the one that was different than the other two (as in Hillis et al.), (2) “Slant,” in which they indicated the one that had a different slant than the other two, and (3) “Homogeneity,” in which they indicated the one whose texture elements had a different distribution on the simulated surface than the other two. We found that the envelope of the slant and homogeneity thresholds predicted the oddity thresholds. Thus, disparity and texture cues are combined to allow precise judgments of slant and texture homogeneity. But in so doing, the nervous system loses access to perspective distortions of globally convex shapes that are not sufficient for regular symmetric shapes that can be visually partitioned.

fMRI correlates of visual cue combination

We have studied this illusion using smaller planar figures, based on symmetric pairs of regular shapes joined at a point (e.g. squares & diamonds), along an edge (e.g. octagons), as well as two circular disks joined by necks containing concave and convex contours. We found that while the peanut shape yields the strongest effect, the illusion persists for shapes based on straight lines and vertices, nor do painted axes of symmetry have an effect on the final percept. Two squares joined at their corners appear as an S-shaped form by an offset pair of identical rectangles. The common component among the shapes that best produce the illusion are necks formed by a pair of concavities opposite one another, which enable the shapes to be partitioned (Hoffman & Richards, 1985). In conclusion, perceptual priors that enable observers to correct for perspective distortions of globally convex shapes are not sufficient for regular symmetric shapes that can be visually partitioned.
TU111
Depth ordering in natural stereoscopic images: The role of monocular occlusion  
Laurie M Wilcox1 (lwilcox@yorku.ca), Rick Wildes2, Deepak Lakra1; 1Centre for Vision Research, Department of Psychology, York University, Toronto, Canada, 2Centre for Vision Research, Department of Computer Science, York University, Toronto, Canada – Rationale. There is convincing evidence that monocular occlusion regions aid stereoscopic vision (Gillam & Borsting, 1986) and this enhancement requires ecological arrangement of the stimuli (Nakayama & Shimojo, 1990; Grove & Gillam, 2001). Existing studies have, for good reason, used simple stimuli. Here we ask if the advantage provided by monocular occlusion information is generalizable to more complex images containing multiple cues to depth. Methods. Images of highly textured boxes were taken with a stereoscopic camera arrangement at three distances. The stimuli were positioned in front of a textured planar background, which was orthogonal to the parallel optical axes of the cameras. The images were digitally manipulated to create stereopairs in which occlusion regions were present or absent. All images were randomly presented as depth-correct or, by reversing the left and right eye images, as depth-reversed. A high-resolution 3D projector, with back projection and Stereographics shutter glasses were used to present the stimuli stereoscopically. The observers’ (n=12) task was to indicate as quickly and accurately as possible whether the depth ordering was correct or reversed. Results. In spite of the presence of multiple cues to depth (overlap, shading, texture and stereopsis) the presence of the monocular occlusion regions reduced the amount of time needed to discriminate the depth relationships in the scene. On the ‘depth-correct’ trials this advantage improved as the size of the occluded region increased; as expected, there was no such improvement in the ‘depth-reversed’ conditions. Conclusions. Monocular occlusion information has a substantial effect on the perception of depth in natural images. The fact that this advantage persists in the presence of multiple depth cues suggests that such monocular regions play an important role in the interpretation of depth ordering at object boundaries. 
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TU112
Effects of viewing distance and experience on the integration process of disparity and perspective for the slant perception  
Yuichi Sakano (sakano@isl.titech.ac.jp), Kazumichi Matsumiya, Hirokiro Kaneko; Imaging Science and Engineering Laboratory, Tokyo Institute of Technology, Japan – The human visual system has been assumed to integrate the information from several cues for depth perception. Landy et al. (1995) proposed a model for the process of depth cue integration, which stated that perceived depth depends on the weighted sum of the depths specified by the cues. According to the model, the weight of a particular cue depends on the estimated reliability of that cue relative to those of the other cues, and the reliabilities of cues depend on the scene contents. This model, however, has difficulty in accounting for the individual differences in the depth cue weight (Johnston et al., 1993; Sakano et al., 2002). We hypothesized that the individual differences in depth cue weight are due to the individual differences in the past experience combining with the dependency of the depth cue reliability on the experience to particular scene contents. If this hypothesis is valid, the weight of disparity would be large for the person whose viewing distance has been biased to near distances, because the reliability of disparity would be high at near viewing distances taking the geometrical characteristics of disparity into account. To test this hypothesis, we measured the relative weights of disparity and perspective at several viewing distances and compared them with some indices of the viewing distance bias in the past experience. We used ocular refraction and normal viewing distance when performing some tasks as the indices. The results showed that the weight of disparity decreased as the viewing distance increased for many subjects, which is consistent with the previous reports, and that the individual weight of disparity negatively correlated with the viewing distance bias in the past experience indicated by the measured indices. These results suggest that the weight of disparity in the process of depth cue integration depends on the viewing distance bias in the past experience of each person as well as the viewing distance of the moment. 

TU113
Increasing the range of self-generated motion parallax increases its effectiveness  
Elton H. Matsushina1 (tolitoli@uol.com.br), Nilson P. Ribeiro-Filho2, José A. Da Silva1, 1Department of Psychology and Education, University of São Paulo at Ribeirão Preto, Brazil, 2Institute of Psychology, Federal University of Rio de Janeiro, Brazil – Motion parallax is an effective source of depth information, even for large outdoors environments. Its definition as a differential of angular velocities could be transformed to a differential of angular displacements, since time interval were the same for every stimuli seen in a natural scene. The present experiment investigated this transformed definition of motion parallax. Experimental environment was a spatial layout composed by two exocentric intervals, horizontal and depth, each one defined by two stimuli (cylindrical stakes) and with a expansion center located 15m away observer, built on a large outdoors grassy and plan field (30m x 30m). Observers (N=60), under objective instructions, verbally judge six exocentric distances (1.5, 2.4, 3.84, 6.14, 9.83, 15.73m) in random order, in two series of estimates, respective to a one-meter modulus. Three head movement apparatus were designed to control self-generated motion parallax: restrained, 15cm translational, and 35cm translational head movements. Two viewing conditions were also designed to scrutinize for binocular cue interactions: induced monocular and binocular viewing. Observers produced head movements in an 1Hz rate during judgments. Despite the fact that we found strong spatial anisotropy (undershot depth, accurate horizontal), linear regression fits indicated that large head movements improved accuracy in depth estimates. Overall differential of angular size (or displacement) of exocentric intervals were calculated for head movements conditions and plotted as a function of logarithm of perceived distance. Strong covariation between angular size variation and judged distance provided us with evidence of a possible explanation on increased accuracy in depth estimates for large head movements. This was not the case for maximum angular size which produced no differences at all for the two head movements. 
Acknowledgment: Supported by Grants from CNPq/CAPES/FAPERJ.

TU114
Differential motion parallax as a monocular depth cue?  
Laura Jimenez-Ortega (laura.jimenez-ortega@rub.de), Nikolaus F Troje; Ruhr-University-Bochum, Germany – Computing the distance of an object from motion parallax involves the comparison of the displacement or velocity of the observer’s eye with the hereby induced displacement or velocity of the object on the retina. Motion parallax computation therefore requires knowledge about the relative speed between the observer and the object. In many situations this information is not available to the observer – either because the observer or the object moves with an unknown velocity. Theoretically, one could still determine distance by moving with two different speeds and employing only knowledge about the difference between them. We refer to this mechanism as “differential motion parallax” and we assume that many birds use this mechanism to monocularly measure distance in the lateral visual field. Here, we examine whether humans are capable of using differential motion parallax. Observers had to indicate whether a central, horizontal array of small squares was before or behind a plane represented by two flanking horizontal arrays. We measured depth discrimination thresholds for the monocularly viewed patterns with and without adding a constant, but from trial to trial unpredictibly varying motion component to the stimulus. Since motion parallax was the only cue, subjects had to make lateral translational movements with their upper body in order to solve the task. If the stimulus did not move, subjects demonstrated a high accuracy (in average 0.2 % of the viewing distance). Adding a constant speed of the
same magnitude to both the central pattern and the flanking arrays did only slightly impair this performance. However, when adding constant, randomly chosen speeds independently to both patterns, the threshold increased dramatically, suggesting that the human visual system is not able to adapt to this type of spatial frequency contrast.

Acknowledgment: This work was funded by the German Research Foundation (DFG)

TU115
Investigating perception of motion in depth using monocular motion aftereffect Satoshi Shiiori (shioiri@iname.tl.chiba-u.ac.jp), Daisuke Kakahi, Tomoyoshi Tashiro, Hirohisa Yaguchi; Chiba University, Japan – [Purpose] Two binocular mechanisms to see motion in depth are known. One is that based on disparity change in time and the other is based on inter-ocular velocity differences (IOVDs). To investigate the spatial frequency properties of the IOVD mechanism, we developed a technique to isolate the mechanism from the other.

[Experiment] In the technique developed, one eye is exposed to horizontal motion (adaptation phase), following which a static stimulus is presented binocularly (test phase). Monocular MAE in the adapted eye should generate IOVDs in the static stimulus presented binocularly. If the observer perceives motion in depth there, the perception should be attributed to a motion sensitive mechanism. After confirming that motion in depth was seen in this procedure, we measured MAE duration to investigate spatial frequency properties of the IOVD mechanism. The MAE contained horizontal motion (2D MAE) and depth motion (3D MAE) components and the duration of 3D MAE as well as that of 2D MAE was measured using sinusoidal gratings with various spatial frequencies both in adaptation and test phases

[Results and Discussions] The results showed that 3D MAE duration was about a half of 2D MAE duration. Dependently on which eye had been adapted, either approaching or receding motion was seen with leftward (or rightward) motion at the beginning, while the depth motion component disappeared earlier than the horizontal motion component.

The longest 2D MAE duration was found when the spatial frequency was the same for the adaptation and test gratings, as predicted from spatial frequency channels in the motion analysis. In contrast, 3D MAE duration was approximately constant for all test spatial frequencies, suggesting the broad spatial frequency tuning of the IOVD mechanism. These results can be explained as signals from monocular motion detectors with different spatial frequency tunings are combined before comparing the motion signals between the two eyes.

TU116
Spatial scale of stereomotion processing from changing disparity signals Kevin R Brooks (kbrooks@mail.arc.nasa.gov), Leland S Stone; NASA Ames Research Center, USA – To examine the spatial scale of the mechanism supporting the perception of motion-in-depth defined by binocular disparity cues, we measured stereomotion speed discrimination thresholds as a function of stimulus width using a 2IFC paradigm. Dynamic random dot stereogram bars, wherein new but perfectly binocularly correlated dot arrays are presented interleaved at a rate of 120Hz per eye, were displayed using ferro-electric shutter glasses on a 240Hz fast-phosphor monitor. Frame-by-frame manipulation of disparity simulated receding motion (standard retinal speed: 0.62 deg/s). We jittered the disparity starting point (±0.1 deg) and the stimulus duration (500-700 ms) to render the use of static disparity and total displacement cues ineffective. Stimuli ranged in vertical extent from 0.02 to 0.66 deg, but had a constant width of 7.3 deg to minimise and hold constant any effect of monocular half-occlusion artifacts. A background of static random dots allowed us to avoid visibility issues as the stimulus passed through zero relative disparity. Multiple interleaved staircases were used to measure speed-discrimination performance for each size condition, with thresholds computed using Probit analysis. For all three (two naïve) observers tested, Weber fractions were strongly related to stimulus width. For the largest width, they were 19, 25, and 26% for the 3 observers. Performance decreased for smaller widths, becoming nearly random for widths below 0.08 deg. However, for standard random dot stimuli, which contain monocular motion cues as well as changing disparity cues, speed discrimination remained robust, even at the smallest width tested. The spatial resolution of the changing disparity mechanism supporting the perception of motion-in-depth is much more coarse than any monocularly based motion-in-depth mechanism.

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TU117
Effect of background motion on perceived object shape Huining Zhang (hzhong@ucr.edu), Myron L Braunstein; University of California, Irvine, USA – A three-dimensional scene often contains several moving objects and perceived shape may depend on interactions between the motions of these objects. In the present study we address the question of how the speed of a background surface influences shape judgments for a moving object. The stimulus displays were perspective projections of a horizontally-oriented concave dihedral angle (20 or 40 ) shown against a frontal-parallel plane. The dihedral angles translated horizontally. The projected speed of the dihedral edge was 2 /sec and the projected speeds of the front edges were either 2.25 /sec or 2.5 /sec. The background plane was either stationary or translated horizontally at 1, 2, 2.25, 2.5, 4, 6, or 8 /sec. The subject’s task was to judge the magnitude of the dihedral angle by adjusting a cross-section of the angle on a separate monitor. We found a significant effect of background speed on dihedral angle magnitude judgments. For each simulated angle magnitude, judged angle magnitude first decreased as the background speed approached the speed of the angle’s front edge and then began to increase rapidly after the two speeds were equal. Judged angle magnitude continued to increase with background speed and then leveled off. Similar results, but with greater individual variability, were obtained with vertical dihedral angles and vertical translation of both the angles and background plane. A possible explanation of the results is that the motion of the angles is perceived as having both a translation and a rotation component, with the relative effects of the two components on judged angle magnitude determined by both the angle speed and background speed. A mathematical model of the interaction of background speed and object speed in determining perceived object shape was formulated based on this account of the results.

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TU118
Perceived direction of binocular 3-D motion when tracking a moving object Philip J Dean (p.j.dean@ncl.ac.uk), Val L Tuck, Julie M Harris; University of Newcastle-Upon-Tyne, UK – Previous research has shown that perception of binocular 3-D object motion can be highly inaccurate (Harris, ECVP 2000, 2001). In these studies, observers were asked to maintain fixation on a stationary point. However, when viewing moving objects in real world situations, the moving object is often followed with the eyes. Are observers able to use information about their eye movements to help determine 3-D object motion? In this study we compared a condition in which observers fixated on a stationary reference point whilst judging 3-D motion direction, with one where they followed the moving object with their eyes. The display always consisted of a pair of stereoscopically presented points (each subtending 8.3 min arc). Observers viewed trajectories ranging from 20 deg to the left of straight ahead, to 20 deg to the right. The perceived trajectory of the moving point was recorded by the observer, for each trial, by moving a pointer to reproduce the angle. The average perceived trajectory angle for each observer, for each angle, was measured. Pooled results from 14 observers showed that very similar angles were perceived for each condition. Performance was highly inaccurate, as we found previously (e.g. angles of 20 deg are perceived, on
average as 39 deg). We also tested whether the observer’s precision was similar in the two conditions. We found that observers had a tendency to be more precise for the fixation condition rather than the eye movement condition.

The results suggest that there is no advantage to looking at either the fixation point or the moving point. The inaccuracies of trajectory perception shown in previous research cannot be improved on (or indeed are not impaired further) by the addition of eye movement information.

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TU119 The Duncker illusion affects the perception of targets moving in depth Eric Gamph1, Paul Gamblin2, Cognitive Science-UB, Birmingham, AL, USA, 2VSR-UB, Birmingham, AL, USA – The trajectory of a target moving across a wide-field, coherent motion stimulus is incorrectly perceived as including a direction component opposite to that of the background flow field (Duncker, 1929). This induced motion illusion has been shown to perturb both saccades and hand movements to remembered targets (Zivotofsky et al., 1996; Soechting et al., 2001), and to affect the perceived initial position of a target (Sheth and Shimojo, 2000).

Since, to our knowledge, all previous studies had investigated the Duncker illusion for stimuli during frontoparallel motion, we investigated the effect of this illusion on targets moving in depth.

Experiments were conducted to quantify the illusion strength, and to determine the effect of flow field speed. Using stereo shutter glasses five subjects viewed dichoptic images on a monitor. A vertically moving flow field was presented in the plane of the screen while targets moved in depth over a range of ±2 of disparity, with a vertical component that ranged between ±10 . Control trials consisted of either no flow field motion or non-coherent motion. Flow field direction reversed half way through each trial. Subjects reported the perceived tilt of the target trajectory as up or down. Responses at the different trajectories and flow field speeds were graphed, and the strength of the illusion was determined by comparing the offsets between curves obtained under experimental and control conditions.

The results demonstrate that the Duncker illusion influences target motion-in-depth. The illusion created a significant shift in perceived target trajectory ranging from 2.5 to 12.5 of vertical tilt for the subjects. Speed of the flow field affected the strength of illusion in a non-linear fashion, with reduced influence at both low and high speeds.

We conclude that the trajectory of a target moving in depth can be influenced by background flow field motion.

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TU120 Detecting changes in spatial frequency: Exploring the interaction of object- and space-based visual processing James M. Brown (jmbrwn@arches.uga.edu), Jennifer L. Solberg: University of Georgia, USA – Purpose. Object- and space-based visual processing involves two dynamically interactive systems. Both object- and space-based system activation results from complex interactions of top-down and bottom-up inputs The present study explores the interaction of these systems as processing shifts from one stimulus to another in a bottom-up driven manner dependent on the spatial frequency (SF) of the stimuli.

Methods. Participants responded to the onset of a single SF and to the onset of the second of two SFS presented in succession in separate blocks of trials. Stimuli were Gabor patches of 0.5, 1, 0, 4.0, and 12.0 cdp always presented at fixation. In the single-patch condition, one of the four SFS was randomly presented each trial. In the two-patch condition, one of the SFs appeared briefly (either 200 or 500 ms) followed by a target SF. The SF of the first and second patches was always different. All possible combinations of first patch SF and duration and second patch SF were randomly presented. Single-patch RTs were used as a baseline and subtracted from the RTs in the two-patch conditions. These difference scores allowed us to examine the influence preceding SFS had on the response to the target SFs.

Results. Analyses of the differences scores for each target SF were conducted as a function of the first patch SF. The patterns of differences scores as a function of first patch SF were significantly different for 1.0, 4.0, and 12.0 cdp targets but not for the 0.5 cdp target. The results cannot be based on SF discriminability and indicate differences in the SF tuning of the object- and space-based systems.

Conclusions. Object- and space-based visual processing systems may be activated differently depending on the spatial frequency content of stimuli. These differences may allow us to examine the interaction of these systems as processing shifts from one stimulus to another in a bottom-up driven fashion.

TU121 Contrast sensitivity is enhanced at cued and impaired at uncued locations Franco Pestilli (fop302@nyu.edu), Marisa Carrasco; New York University, USA – Spatial covert attention can be voluntarily and involuntarily allocated to select information in a specific area of the visual field in the absence of eye movements. We know that covert attention increases contrast sensitivity at the cued location. What we do not know is how contrast sensitivity is affected at the unattended locations. Generally the fate of stimulus processing outside the focus of attention has been explored using concurrent tasks. In this study, we explored whether a transient peripheral cue affects contrast sensitivity at both cued and uncued locations, in the absence of a concurrent task. Five observers performed a 2AFC orientation discrimination task (target tilted 4 to the left or to the right). An adaptive staircase procedure (QUEST) was used to assess contrast thresholds. In the neutral trials a cue announced the display onset but not the target location. In the experimental trials, a dot appeared briefly above one of two Gabor patches (with spatial frequency of 1, 2, 4 or 8 cdp), which were simultaneously presented for 100 ms on opposite sides of the horizontal meridian at 4 of eccentricity. A post-stimulus arrow was presented to the observer for 300 ms to indicate the Gabor patch to be discriminated. When the cue and the post-stimulus response arrow locations matched, a contrast threshold was computed for the cued location (valid trial); when they did not match the contrast threshold was computed for the uncued location (invalid trial). For all observers, directing covert attention enhanced contrast sensitivity at the cued location compared to the neutral trials; interestingly, contrast sensitivity was impaired by a similar magnitude at the opposite, uncued location.

TU122 Intra- and cross-modal cuing of visual spatial attention: The hyper-effective simultaneous auditory peripheral cues Zhong-Lin Lu (zhonglin@usc.edu), Hennis Chi-Hang Tse, Barbara A Dosher, Luis A Lesmes, Christian Posner, Wilson Chui; Laboratory of Brain Processes (LOBES), University of Southern California, USA, 2Memory, Attention and Perception (MAP) Laboratory, University of California, Irvine, USA – We report a new phenomenon in cross-modal cuing of visual spatial attention. Simultaneous auditory peripheral cues are “hyper-effective” – more effective than auditory peripheral cues that preceded the target stimulus with ample time for preparatory orienting. Observers were cued at several alerting times (cue-target onset asynchronies, CTOAs) to identify the orientation of one of four briefly presented Gabor stimuli, which were embedded in varied amounts of external noise (1). For visual central cues (VC), pre-cuing improved performance only in high external noise conditions, with performance monotonically improving with increased orienting intervals. For visual peripheral cues (VP), longer pre-cuing intervals improved performance, in this case in both the presence and absence of external noise. Surprisingly, for auditory peripheral cross-modal cues (AP), the performance for simultaneous cues exceeded even that for pre-cues with the largest orienting interval (CTOA = 240 ms).
Although possibly related to reported perceptual advantages for simultaneous auditory and visual stimuli (2,3), to our knowledge, the “hyper-effectiveness” of simultaneous auditory peripheral cues for visual processing is novel and may have major practical implications. The combined results suggest two separate processes: an orienting or alerting process that increases its effectiveness with additional lead time to the target with identical temporal dynamics but different magnitudes for the three cue types, and a cross-modal marking process that provides privileged access to simultaneous targets based on cross-modal interaction. As in earlier reports (4, 5), visual central pre-cuing was associated with pure external noise exclusion, while peripheral auditory or visual pre-cuing yielded a mixture of stimulus enhancement and external noise exclusion. 1. Lu & Dosher, VR’98. 2. Stein et al, J Cog Neurosci’96. 3. Vroomen & Gelder, JEPHPP’00. 4. Dosher & Lu, Psych Sci’00. 5. Lu & Dosher, JEPHPP’00.

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TU123

Effects of attention and contrast on motion processing Amy A Rezec1, Bart Krekelberg2, Karen R Dobkins1, 1UC San Diego, 2Salk Institute for Biological Studies, La Jolla, CA USA – PURPOSE: Directing attention toward a stimulus has been shown to enhance processing for various types of stimuli, including motion stimuli. It has been suggested that attention may act to change the strength of a stimulus by increasing its ‘effective contrast’ (Treue & Trujillo, 1999). This predicts that attention should shift the contrast response functions of underlying neural mechanisms horizontally, enhancing processing for stimuli of intermediate luminance contrast the most. Alternatively, if the effects of attention operate separately from the encoding of stimulus contrast, the magnitude of attentional modulation is predicted to be independent of stimulus contrast. To test these two alternative hypotheses, we measured the effect of attention on the strength of motion processing, assessed by the duration of the motion aftereffect (MAE), as a function of contrast. METHODS: Stimuli were achromatic sine wave gratings presented at 11 different contrasts (4-80%). For each stimulus contrast, MAE duration was obtained for two conditions: 1) Full Attention- subjects were instructed to attend to the adapting motion stimulus, and 2) Poor Attention- subjects were instructed to perform an attentionally demanding vowel counting task in the center of gaze while the adapting motion stimulus was presented. Thus, subjects’ attention to the adapting stimulus was greatly diminished in condition #2. In both conditions, a static test stimulus was presented after 30 seconds of adaptation. Subjects responded with a key press to indicate when the MAE was no longer perceived. RESULTS & CONCLUSIONS: The effect of attention on MAE duration was relatively constant (~ 2-fold) over a wide range of stimulus contrasts, even those for which MAE duration had saturated (at roughly 33 - 80% contrast). These results are consistent with the notion that attention and stimulus contrast influence motion processing independently.

TU124

Object-based cross-attribute attentional effects in bivectorial motion Won-leung Sohn1 (wons@rci.rutgers.edu), Thomas V Papathomas2, Erik Blaser1, Zoltán Vidnyánszky3; 1Laboratory of Vision Research, Rutgers University, USA, 2Human Vision Laboratory, University of Massachusetts, Boston, USA, 3Vision Research Laboratory, Neurobiology Research Group, Hungarian Academy of Sciences, Hungary – Cross-attribute attentional effects – i.e., attentional modulation of task-irrelevant attributes of an object when one of its attributes is attended – have been interpreted as supporting object-based attentional mechanisms. Alternatively, these effects can be explained by mechanisms that bind spatiotemporally collocated attributes, before object formation. We showed cross-attribute attentional effects between luminance and motion, and found that these effects indeed occur at the stage of object representation. During adaptation, observers viewed two populations of random dots. Half of the dots (“effectors”) moved along 0°. The other half (“distractors”) alternated direction every 4 s between +90° and -90°. The two groups of dots were also colored differently, red or green. Observers’ task was to detect occasional brief luminance increases of either red or green dots, thereby directing attention to the luminance of effectors or distractors. In the ‘transparent’ condition, dots were randomly located, so observers perceived two transparent surfaces moving orthogonally. In the non-transparent condition, each effector dot was locally paired with a distractor dot at close proximity [Qian et al. 1994], so observers perceived one bi-colored surface moving along the vector average of the two motion vectors. We measured the duration of the MAE using a group of static dots. We found strong cross-attribute attentional effects, but only when dots were perceptually segregated into two surfaces: In the transparent condition, the MAE duration after attending to the luminance of effectors was longer than after attending to that of distractors. By contrast, in the non-transparent condition, the two MAE durations were not significantly different. These results imply that cross-attribute attentional modulation is based on object-level properties of the stimuli; it appears that there is no direct attentional modulation between visual attributes at a local pre-object processing stage.

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TU125

A dimensional switching model of early visual orienting in human infants James L. Dannemiller (dannemiller@waisman.wisc.edu); University of Wisconsin, Madison, USA – Visual orienting by human infants to a singleton bar oscillating in a field of similar static bars is influenced by non-motion related characteristics of the static bars such as their colors and contrast polarities implying natural variation across trials in the stimulus dimension controlling orienting (Dannemiller, 1998; 2001). With a sample of 207 infants in six experiments (7- to 11- or 17- to 21-week-olds), two possible models for understanding how different stimulus dimensions (e.g., color, motion) interact to determine a directional orienting response were compared. Model 1: all stimulus dimensions are reduced to a single salience dimension with the location of the highest salience element controlling orienting (winner-take-all, WTA). Model 2: on a given trial one dimension (e.g., motion) dominates the orienting response while others (e.g., color) have no influence, with the dominant dimension switching across trials (dimensional switching, DS). A set size manipulation (range 2 to 28 bars) in which static bars are added equally to both sides of the visual field can distinguish the models. The WTA model predicts a decrease in orienting to the singleton moving bar because with internal noise, the likelihood that one of the static bars will produce the maximum response increases as more bars are added to the field. The DS model predicts no set size effect because trials on which orienting is dominated by non-motion related stimulus dimensions (e.g., color) will lead to chance orienting with respect to the location of the oscillating bar independently of the number of static bars added to the visual field. The DS model captured the behavior of older infants better than the WTA model with motion pop-out evident at this older age, while the WTA model better captured the behavior of the younger infants. A quantitative version of the DS model that captures this variation in stimulus-related orienting behavior will be presented. [Supported by NICHD R01 HD32927.]

TU126

Comparison of two methods for equating the salience of first- and second-order motion Anne-Sophie Del Vecchio (ddevecchio@vax2.concordia.ca), Michael W. von Grünau; Department of Psychology, Concordia University, Montreal, Que, Canada – Purpose. An important issue for studies comparing attentional selection of first- and second-order motion stimuli is how to equate both components. Methods. One way is to present a series of counterphase gratings (mixture of 1st- and 2nd order), with variable luminance contrast for the 1st-order stimulus, and to derive
the contrast that corresponds to the 50% threshold for perceived direction of the overall stimulus. Another method is to present a transparent plaid made-up of a mixture of a 1st- and a 2nd-order grating for a discrete time and ask the participant to continuously monitor which grating appears in front. The contrast of the 1st-order stimulus is varied to obtain the 50% threshold corresponding to equal cumulative time for both components. In the present study, both methods for equating 1st- and 2nd-order motion were compared. Since the 2nd-order grating consisted of texture modulation, random noise can be added to the 1st-order component in order to increase the similarity of the components. This effect of random noise was also investigated. Results. When noise was included in the 1st-order component, the 50% thresholds between 1st- and 2nd-order components were not statistically different for the plaid and the grating methods. The grating method without the noise in the 1st-order component was also equivalent. Only the plaid method without noise in the 1st-order component required significantly higher luminance contrast for the 1st-order component to match the 2nd-order component. Conclusions. Both methods are acceptable in order to equate 1st- and 2nd-order components as long as noise is included in the 1st-order component. Supported by NSERC and FCAR (MvG).

TU127
Dissociating neural correlates of attentional tracking and attention to visual motion  Adriane E Seiffert (seiffert@princeton.edu); Princeton University, USA—People can track the motion of objects with focused attention to different object positions over time. Do the brain regions engaged in this task reflect a specific position-tracking mechanism or just visual attention to motion? This fMRI experiment measured brain activity during an attentional tracking task and a comparable motion discrimination task to dissociate between brain areas responsive to tracking and attention to motion. All displays showed superimposed high-contrast color and low-contrast luminance radial gratings moving in opposite directions. Observers see motion in the direction of the luminance grating, unless they attentionally track the components of the color grating (Cavanagh, 1992, Science. 257:1563-5). Four observers discriminated the speed change of either the color or luminance grating, alternating gratings between 15-second blocks. Task difficulty was counter-balanced such that either the color or luminance task was more difficult in alternate sessions with the same subjects. Standard GLM analyses with two predictors corresponding to the two tasks were performed on individual subject data. Greater activity specific to the color tracking task (independently of task difficulty) was found in all subjects bilaterally in the superior parietal lobule, posterior intraparietal sulcus and the frontal eye fields. No area was consistently active specifically to the luminance task across the difficulty manipulation and in all observers. The response of the motion-sensitive center, MT+/V5 (localized with separate scans), did not show significant differential activity between color and luminance tasks in most cases. Similar results were found when subjects tracked a texture grating instead of color (N=2). Taken together, these results suggest that posterior parietal structures are intimately involved in attentional tracking changes in object positions beyond the role they might play in attending to visual motion.

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TU128
Attentional sensitization to specific colors  Chia-Huei Tseng (chaby@troland.hipl.uci.edu), Joetta L. Gobell, George Sperling; Department of Cognitive Sciences, University of California, Irvine, CA USA—The perceived direction of motion (e.g., up/down) in an ambiguous third-order motion stimulus can be changed by instructions to attend to a particular color (Blaser et al., 1999) or by prior practice in a color-search task (Tseng et al., 2000). In these experiments, subjects performed thousands of consecutive trials attending to only one color. Tseng found that sensitization to that color survived for a month. Is there attentional sensitization when observers shift attention between colors every N trials, N = [1, 200].

Procedure. In our third-order ambiguous-motion paradigm, even frames contain red/green isoluminant gratings, odd frames contain high/low contrast texture gratings. Apparent motion is determined by figure-ground, i.e., the movement of salient areas. Salience is determined by the difference from the gray background—areas of high contrast or of high color saturation have greater salience. Attention to a color produces a change in motion-direction perception that is equivalent to an increase in saturation, i.e., an increase in salience. Three different attend cues for each trial were used: letters, color patches, and spoken color names. After observers attended to red stripes, attention was switched to green every N trials, and vs. The results were compared to the no-instruction condition.

Results. Most observers failed to perceive motion above 8 Hz. Below 4 Hz, all modes of instruction and all values of N produced shifts in observers’ psychometric functions equivalent to increasing the saturation of the attended color by 10-20%. This effect of “fast,” voluntary attention, while highly significant, is half of what we measured with prolonged attention to the same color.

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TU129
Relationship between response blocking and task switching  Yoko Hibi (hibi@L.u-tokyo.ac.jp), Kazuhiko Yokosawa; University of Tokyo, Japan—We investigated the factors to select the stimulus and response properties, especially links between object and action. Riddoch, Humphreys, and Edward (2000) reported data from a patient with cortical basal degeneration, suggested the inhibition effect of the distractor varied dependent on the stimulus-response association when the distractor was attended, that is, response blocking effect. The mechanisms of this response blocking are considered to be caused by object-action assemblies, which are longer lasting links between object and action. Monsell, Yeung and Azuma (2000) suggested that task repeating or switching was related with stimulus and response association. In order to clarify the factors to select object and action, we measured the inhibition effect, the compatibility effect, and the task switching. Healthy participants viewed two arrows or one arrow and one bar in a horizontal position. Before this display, an endogenous cue was presented in order to indicate the dimension to be selected and responded the direction of the target arrow or the location while ignoring the distractor. Each effect is defined by the relationship between the target and distractor stimulus (the inhibition effect), the target stimulus and -associated response (the compatibility effect), and the task repeating and changing (the task switching). The response blocking effect is manifested by the inhibition effect dependent on the compatibility. As a result, the response blocking effect was observed even by healthy participants. And the occurrence of this effect depended on task switching or not. Furthermore, our result in the task switching implies that a task set contains not only an instruction task set in inter-trial but also the presence of the task switching context in inter-experiment. These results suggest that the temporal links between object and action as task switching, other than object-action assemblies, decide the object and action selection.

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TU130
Saccadic eye-movements reduce but do not eliminate the line-motion illusion  Sheila G Creethers1 (s.creether@latrobe.edu.au), David P Creethers2, Stephanie E Cook2, 1Psychological Science, La Trobe University, Australia, 2Brain Sciences Institute, Swinburne University of Technology, Australia—a Burr et al (1994) have proposed a selective suppression of the M-pathway during voluntary saccades. An alternative explanation is that transient attention is selectively suppressed. To test this idea, the strength of line-motion attention (Hikosaka et al 1993) was measured within and between saccadic eye movements. The strength of the illusion was

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measured by a nulling technique under 4 conditions: cue presented during or after a voluntary saccade and no-cue trials with similar during/after saccade presentation. Saccadic eye movements were detected using a Skalar infra-red eye movement detector which triggered cue presentation immediately (within 8 msec) or with an extra 85 msec delay (i.e. after the saccade was complete). Logistic fitting of the response of 6 subjects (each completing over 350 trials) showed that with achromatic stimuli, the cue effect (as measured by the shift in the psychometric function) was reduced from 34 msec to 17 msec relative to trials with no cue. A non-zero line-motion illusion when the cue is presented during a saccade suggests the cue-line facilitation occurs in in body-space rather than in retinotopic coordinates. Together with visual evoked potential (VEP) data showing that saccades do not systematically alter the M-pathway early cortical response, the reduced cue effect on the line-motion illusion under the saccadic state could be interpreted as hypothesised, namely, as being due to a reduction in the transient neural facilitation (attention) that would normally occur in the neighbourhood of the cue.


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TU131

Attention helps one acquire novel color/shape combinations

Adam J Reeves1 (reeves@neu.edu), Heather Fuller2, Elisabeth M Fine1; 1Department of Psychology, Northeastern University, Boston MA, USA; 2Scheppens Eye Research Institute, Harvard Medical School, Boston MA, USA – We investigated whether attention is useful for binding shape to color by studying the acquisition of novel shape/color combinations.

Methods. We created pictures of 60 familiar objects depicted in novel colors, such as a green dog, a blue frog, etc. Each picture had a strong outlined shape and a vivid color (red, green, yellow, blue, or purple) which was fixed for each picture. Two such pictures were flashed simultaneously, left and right of fixation, on each trial. On half the trials the pictures were the same, and on half they were different. On every trial, all the subjects reported 'same' or 'different', an easy task requiring little attention. Half the subjects also named the pictures, while the other half of the subjects identified a masked letter at fixation. Both of these tasks were attention-demanding. After each block of 30 trials, all subjects received a Yes/No recognition test for the shapes of ten of the pictures portrayed in monochrome and then reported the color of any recognized shapes.

Results. For subjects who were required to name the pictures on each trial, and who presumably attended them closely, recognition of both shapes and shape/color combinations improved rapidly and was highly accurate within 4 blocks (120 trials). For the remaining subjects, who were required to attend to the masked letters, shape recognition increased at the same rapid rate, but shape/color combinations were still reported poorly after 6 blocks.

Conclusion. Attention benefits the perceptual acquisition of novel shape/color combinations in the periphery, even when the shapes themselves do not benefit from attention.

TU132

Temporal tuning characteristics of perceptual templates

Simon Jeon (seongtaj@usc.edu), Zhong-lin Lu, Barbara A Dosher; University of Southern California, USA – External noise presented in temporal contiguity with a target impairs perceptual performance, reflecting the temporal tuning of the perceptual template. Deriving the temporal weights of the perceptual template, however, requires an observer model that segregates the impact of non-linearities and intrinsic inefficiencies of the observer in order to account for the impact of external noise in various temporal configurations. We showed that the perceptual template model successfully accounts for temporal masking functions measured with a wide range of temporal configurations of external noise, and estimates the temporal characteristics of the perceptual template. This was first demonstrated in estimating the temporal tuning characteristics of the perceptual template in a foveal Gabor orientation identification task. The same procedure was then used to compare the temporal tuning characteristics of the perceptual template in pre- and simultaneous cuing of spatial attention in a peripheral Gabor orientation identification task. In both experiments, four non-overlapping temporal regions of external noise, each occurring at different temporal intervals from the target display, were combined in 10 different temporal configurations. Psychometric functions were measured in the 10 external noise temporal configurations along with a zero noise condition. The PTM model provides a full account of all the psychometric functions. The estimated full width of the perceptual template at half-height is about 80 ms in experiment 1, 67 ms in the pre-cuing condition and about 90 ms in the simultaneous cuing condition in experiment 2. Manipulations of the temporal configurations of the external noise coupled with the PTM thus provide a method to characterize the temporal tuning properties of perceptual templates with an intrinsically coherent structure.

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TU133

Selective attention during adaptation weakens negative afterimages

Marcia Grabowecky (grabowecky@northwestern.edu), Satoru Suzuki; Department of Psychology, Northwestern University, Evanston, IL, USA – We previously reported that when observers voluntarily directed their attention to one of two overlapping outline triangles, they reported that the subsequent afterimage of the attended triangle was weaker than that of the unattended triangle (Psychonomics, 2000). We extended this result by using RSVP tasks to control the allocation of attention. Attention was directed at either the inducer triangle or a central digit stream (Exp. 1), or at either the inducer triangle or an overlapped brightness-balanced non-inducer circle that did not produce afterimages (Exp. 2). Occurrences of a target color or digit were counted. The afterimage of the attended inducer triangle was delayed in onset relative to when the triangle was ignored. Finally, in order to examine the attention effects using a criterion-independent measure, we adapted a dot-integration paradigm so that a gap in a circular array of discs could be found only when complete afterimages were visible. On each trial 6 of 12 locations on a circle were randomly chosen to contain inducer discs that rapidly changed colors, as did a single central ring. Observers either counted the number of times all inducer discs became the same color (to ensure attention to all discs) or counted the number of times that the central ring turned yellow. Following adaptation, test discs that were not perceptibly different than the afterimage discs briefly appeared in 5 of the 6 remaining locations, followed by a mask. Observers reported the location of the missing disc. Gap detection accuracy was reduced 33% when the inducer discs were attended relative to when they were ignored. Across experiments, the fact that attention during adaptation weakened or delayed afterimages suggests that selective attention primarily facilitates the adaptation of polarity-independent processes that modulate the visibility of afterimages rather than facilitating the adaptation of polarity-selective processes that mediate the formation of afterimages.

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