OUTLINE

• 6:45 – 7:15 History of eye tracking (30 minutes)
  • This session will focus on the key foundational studies and methodologies in eye movement analysis. Topics covered in this section include:
  • Buswell’s investigation of image viewing
  • Yarbus’ demonstration that eye movements are indicators of attention and cognition
  • Fitts’ application of eye tracking to human factors and usability
  • Historical methods

1950

1st usability study with eye tracking (Fitts et al. 1950)
Airplane pilot instrument scanning
Primitive eye tracking technology
~30 published studies since
Wide variety of applications
Typically relatively large N compared to traditional usability study
Eye tracking in usability labs still not widespread due to perceived expense

OUTLINE

• 6:30 – 6:45 Introduction and Overview (15 minutes)
  • During the introduction and overview, participants will describe their experience conducting usability tests and what they usually learn from these tests. Then, the instructors will discuss the following topics:
  • Problems that are difficult to uncover and what might their characteristics be
  • How eye tracking can be applied to enhance usability testing
  • Eye tracking as a component of the usability testing process

AUDIENCE EXPERIENCE

Which usability problems are difficult to uncover?
What are their characteristics?
How can eye tracking be applied to enhance usability testing?

GOALS OF THE TUTORIAL

Understand fundamentals of eye movements and their relationship to cognition
Understand the variety of applications in which eye tracking may be applied
Specify how eye tracking could enhance problem understanding and solution discovery
Describe practical techniques for data analysis
Recommend how to effectively and efficiently include eye tracking into the usability testing process

WHY NOT USE EYE TRACKING?

• Technical issues with eye trackers
  Cost
  Time-consuming setup and use
  User discomfort
  Size and portability
  Unreliable
  Expertise needed

• Labor-intensive data extraction
  Large quantity of data captured
  Need to identify fixations and saccades
  Relationship of eye movements to the scene

WHY NOT USE EYE TRACKING?

• Data interpretation difficulties
  Based on cognitive theory?
  Based on design hypothesis?
  Based on data?
Vision is both ‘easy’ and complex.

Vision is easy, but it’s not simple - despite the seeming ease with which we see, vision is a complex process that unfolds over time.
Why make eye movements?

The visual world contains a vast amount of information:
- Limited sensor & wiring capacity
- Limited neural resources
- Limited bandwidth (1 kHz neural spike trains)

There were strong evolutionary pressures for both a wide field of view and high acuity.

Wide field of view is critical to the survival of prey (rabbit)
High acuity is critical to the survival of predator (hawk)

The Dual Retina

In humans the problem was solved by having two retinas:
Rods that offered wide field of view (and night vision)
Cones that provide high acuity (and color vision)

Acuity is highest at the fovea; a depression in the center of the retina where the high-acuity cones are concentrated.

The Foveal Compromise

... far more information can be captured in a biological system with relatively slow retinae. The problem was solved by having two retinas: rods that offer wide field of view and cones that provide high acuity.

The Foveal Compromise

Limiting acuity in the periphery addresses the bandwidth limitation, but it is only half of the compromise:

We also need a mechanism for moving the fovea to sample the environment.

Serial Execution

With each eye movement, the fovea 'slides under' a new portion of the retinal image.

A new portion of the image is sampled, but each new sample is foveated.
Eye Movement System

The extracocular muscles and complex control architecture provide a rich suite of actions to shift the point of gaze about the scene.

Three agonist/antagonist pairs:
- horizontal
- vertical
- torsion

Eye Movement Control

Eye Movement Control:

In the simplest case, when a stationary observer views a static image, there are only two actions:
- foveating an image region
- shifting the fovea to a different region

Saccadic eye movements

Shifting Gaze - Saccades

Saccades:
Rapid rotation of the eyes to reorient gaze to a new object or region.

Reflex saccades
Attentional saccades

Amplitude: < 1° → > 45°
Velocity: > 500°/second

"Backwards Masking"

Image Stabilization

Object in motion:

Smooth Pursuit
Retinal image motion caused by a moving target gives cue for rotation of the eyes to stabilize the retinal image.

Object in motion:

Smooth Pursuit – requires moving target

Observer in motion:

Vestibular Ocular Response (VOR)

Inner ear senses linear and rotational acceleration.
The eyes counter-rotate to stabilize the retinal image.

Vergence

Eyes counter-rotate to maintain corresponding points on the center of the two retinae.

Saccades as Attentional Markers

Vision is "easy"
- We collect a vast amount of data effortlessly, without conscious intervention

Vision is easy, but it’s not simple
- Despite the seeming ease with which we see, vision is a complex process that unfolds over time

We move our eyes >150,000 times per day
- These eye movements simplify vision by allowing perception that is "Just enough, just in time"
Saccades offer an externally observable marker of attention.

While covert shifts of attention are possible, they are evidently rare except as part of planning overt eye movements.

“Symptoms of perception” (Buswell, 1935)

“Signature patterns” (Yarbus, 1967)

We move our eyes >150,000 times per day.
These eye movements simplify vision by allowing perception that is “Just enough, just in time.”

Window into perception and performance
Watching the eye movements gives us a tool to monitor what, when, and how long people focus their attention as they perform a task or use an interface.

OUTLINE

• 7:15 – 7:25  Exercises: Visual perception and eye movements (10 minutes)
  - There will be several brief exercises designed to demonstrate the major types of eye movements. Working in pairs, participants will use stimuli that will evoke different eye movements: saccades, smooth pursuit, VOR, vergence, and optokinetic movements.
  - Participants will explore the limits of peripheral vision using stimuli that vary in size, motion, color, etc. In addition to the limits imposed by the optics and structure of the eye, vision is constrained by central limitations as well. Participants will perform exercises that illustrate the limits of internal representation and visual memory.
  - Do peripheral stimuli and change blindness

Types of Eye Movements

Saccades
- two points
- different speeds

Smooth Pursuit
- follow one point
- try two points
- different speeds

VOR
- different distances

Vergence
- different distances
- combine with saccades
- combine with smooth pursuit

Peripheral Vision

High-level Limitations

If a clear, stable internal image is built up over multiple fixations, it should be easy to detect changes in an image.

Change Blindness
OUTLINE

- 7:25 – 8:00  Types of eye trackers and theory of operation (35 minutes)
- In this session the various types of eye tracking hardware and their use will be described. Some representative eye tracker designs include:
  - Video-based
    - Head-mounted, Remote, Portable, Wearable
  - Analog/optical
  - Limbus
  - Magnetic search coil
  - Dual Purkinje

A. Yarbus

G. Buswell

Types of Eye Trackers

Video-based Eye Trackers

Pupil and Corneal Reflection
OUTLINE

• 8:00 – 8:30 BREAK

• 8:30-8:45 Demonstration of an eye tracker and sample video clips (15 minutes)
  • In this session a portable head-mounted eye tracker will be demonstrated, with audience participation.
  • Several sample videos of various types of usability testing applications will be shown. These include:
    1. Digital camera use
    2. Interaction with multimedia software
    3. Assembly of mechanical components
    4. Image quality judgments
    5. Image editing
    6. Driving

Hardware

ASL Headband (bright pupil)

Lightweight (dark pupil)
OUTLINE

• 8:45-8:55  Case Study: Introduction (10 minutes)
  • The case study used in this session will be a usability test in which eye tracking was used on a subset of participants. The study tested three multimedia interfaces designed to support the completion of a complex task – the set-up of an inkjet printer. The focus of the study was to explore the temporal relationship between text and animated graphics.

Typical Usability Study

Goal = usability problem identification
Subjects attempt prescribed tasks
Small sample size
Think aloud protocol
Direct observation & analysis of audio / video recordings

Current Usability Metrics

Sometimes performance quantified at task-level
  Time to complete task
  Percentage succeeding
  Error type & frequency

Eye Tracking Value Added

More detailed understanding of human behavior to inform design decisions

Did users...
overlook the control?
become distracted by another element?
see control, but fail to comprehend meaning?
Unbiased report of performance
Unlike think-aloud or debrief protocols, monitoring participants' eye movements gives a performance measure that is not biased by unnatural reports.

Introspection is unreliable
Often results in biased and/or incorrect evaluation
Eye movements reveal unconscious strategies that participants can't accurately report

Case Study
- Test bed:
  Setting up an ink jet printer
  Aided by an electronic performance support system
  Multimedia application with text and animated graphics

Questions
- Design
  • Which are the most effective temporal relationships for text and animations?
- Eye tracking
  • Is eye tracking a few subjects valuable in usability testing of complex tasks?
  • Can eye tracking identify different classes of problems than traditional usability testing?

Performance Support
- Instructional media (paper - text & images)
- Electronic Performance Support (text, images and animations)
- Reading text and viewing images well understood
- Little study of simultaneous presentation of text and images / animation

Methods
- Complex divided attention task: inkjet printer assembly
- Eye tracked subjects: 4
- Traditional usability testing: 20
- Eye tracker:
  Applied Science Laboratory
  Model 501, video-based
  Video @ 60 Hz, free head
- Video record
  Display:
  Pioneer 5032HD
  57” plasma display
  1280 x 768
## Methods

**Over-the-shoulder camera**
- Coarse grain; what action?

**Video eye tracker record**
- Fine grain; where is attention?
  - Animation, Text, Controls, TOC, …

## OUTLINE

- **8:55-9:15 Exercise:** Group analysis of over-the-shoulder and eye tracking clips (20 minutes)
  - Groups of four participants will first view over-the-shoulder clips then eye tracking clips of the same task for this case study. Instructors will work with groups to help them discover differences and to illustrate how eye tracking enhances understanding of observed usability problems. Instructors will summarize group findings.

## Discussion

**OUTLINE**

- **9:15-9:30 Case Study:** Findings and discussion and wrap-up (15 minutes)
  - Instructors will present research findings for this study, particularly those from the eye tracking analysis. Data analysis methods will be described and illustrated. The topics will include:
    - Defining areas of interest
    - Data encoding
    - Qualitative and quantitative data analysis
    - Discount methods – keeping eye tracking affordable and manageable

## Eye Tracking Data Analysis

- Focused on 2 tasks exhibiting most usability problems
  - Paper tray installation
  - Ink cartridge loading
- Encoded gaze start / end points
  - Looking at areas of interest in the environment and electronic performance support
  - Time-saving technique
- Quantitative and qualitative
Project Findings

Users relied heavily on the still image at the end of the animation

Users searched for confirmation regarding task completion

Project Findings

Users missed significant portions of the animation

Due to simultaneous presentation of text and animation

During performance of complex tasks

When there is no movement at the beginning of the animation

Design Considerations

Divided attention can cause users to miss animation

• Consider running animation in continuous loop
• Break animation into smaller chunks
• When animation starts, present action immediately

Users rely heavily on still image

• Ensure high quality information content of still image

Recommendations

Conduct traditional usability test first

Run small sample with eye tracking

Encode gazes / dwells

Conclusions

Qualitative findings from a small number of participants are valuable.

Eye tracking enables discovery of different types of usability problems.

Eye tracking allows the generation of more relevant design recommendations.

Eye tracking can enhance the discount usability toolbox.