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**The Perception of Color as  
Espoused by Ralph M. Evans of  
the Eastman Kodak Company  
and its Extension to What is  
Known Now and What  
Remains to be Seen**

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# **The Perception of Color as Espoused by Ralph M Evans of The Eastman Kodak Company and Its Extension to What Is Known Now and What Remains to Be Seen**

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*Abstract: This paper is intended as an in depth review of Ralph Evans' book, The Perception of Color<sup>1</sup>, posthumously published in 1974, that focuses on what Evans noted as the central thesis of the book – that the perception of color in all but the most simple of contexts is the sum of not just the three fundamental perceptions of hue, lightness, and chroma, but five in total. The single thread that carries the development of this thesis throughout this book and Evans' work is his discovery, at least to him and his colleagues, of a new and unique perception of what he terms brilliance. Hence, the underlying thread of this paper is to relate, in hopefully a simple, easily understood manner, Evans' vivid descriptions of how brilliance is invoked and his analysis of its affect. Finally, Evans' central thesis is compared to what we know today about the appearance of color, and based on his work in brilliance, whether or not the study of brilliance can provide relevance to the understanding of vision.*

## INTRODUCTION

Gabriel Garcia Marquez in the first volume of his autobiography, Living to Tell the Tale, writes of when he, as an adolescent, disembarked from the town of Sucre on the Caribbean coast of Columbia that “... the entire region was a sea of gentle water that changed colors on account of the blankets of flowers that covered it according to the time, place, and our state of mind<sup>2</sup>.” Marquez was an avid reader, and while the visual experience he describes left an impression he was able to recall some sixty years later, it could be speculated that he may have read, at some point in his life, Ralph M. Evans’s book The Perception of Color<sup>5</sup> published in 1974.

The very essence of the notion of “changing colors ... according to time, place, and our state of mind” is the essence of Evans’ work. He notes in the book’s preface that the study of color over 150 years has developed into the science of colorimetry – that the physical attributes of the stimuli can be measured and specified in very simple terms and with precision approaching the sensitivity of the eye and that stimuli can be computed that exactly match one another. Yet, up to the time of Evans’ death, there had been little advancement in understanding what an observer such as Marquez actually saw in the blankets of flowers in the Columbian region of Sucre.

The way in which the eye’s sensitivities are used by an observer who is presented with more and more complex situations is a correspondingly complex mixture of the observer’s intentions, desires, and interests. In this context, Evans’ book begins with the simplest possible stimulus and eventually arrives at a treatment of the perception of color in everyday situations. In his development of the subject, he introduces the concept of

brilliance as a fundamental attribute of color perception – a concept that has, to this day, languished since its introduction.

## BACKGROUND

Ralph M. Evans principal work in color began in the early 1930's at the Eastman Kodak Company Research Labs and culminated in the period from 1945 to 1974, when he died, as Director of the Photographic Technology Division. His work was well recognized throughout the field of photography and color perception. This book, The Perception of Color, was published posthumously through the efforts of a colleague, Bonnie K. Swenholt.

In its introduction, an introspection into the history of color reveals the perspectives that influenced Evans' work beginning with Newton's demonstration of the spectral components of sunlight followed by the work of Young, Maxwell, and Grassmann. From these works, Hemholtz built the foundations of colorimetry based in the uniqueness of three perceptual variables and whose work, in the words of Evans, was hampered by " ... his [Hemholtz] somewhat too firm conviction of the uniqueness of the eye response to stimuli and by a theory that, while it explains much, is inadequate for a total explanation."<sup>1</sup> Yet, these three variables of color perception have become " ... such an article of faith with color workers that to question it at all is essentially heresy."<sup>1</sup>

In Evans' perspective, there are at least five attributes of perception that are reducible to three only under the simplest of conditions. These three irreducible attributes are said to be attributes of the stimulus itself, the other two arising from the context in which the stimulus is seen.

## ISOLATED STIMULUS

In the simplest context where color is seen, a single, isolated light stimulus, the physical specification of such a stimulus that produces the perception of color is completely described by its spectral energy distribution in the region where the eye is sensitive. Thus an infinite amount of colors are possible. However, because of the eye's discrimination, only a finite subset is possible as many of the combinations look alike. Hence, the concept of metamerism and the description of these discernible subsets of color using three psychophysical variables with basis in Hemholtz and the science of colorimetry. All possible color perceptions must arise from the effects of these three psychophysical variables.

In this simplest of contexts, the attributes of color perception are also three fold in hue, saturation, and brightness and these attributes are uniquely determined from the three psychophysical variables. Dominant wavelength mainly controls hue, the mixture of monochromatic and colorless light mainly controls saturation, and brightness mainly controlled by the luminance.

## RELATED STIMILI AND THE PERCEPTION OF BRILLIANCE

Evans' work with related stimuli grew out of his discovery in 1959 of a previously unreported visual threshold in the perception of grayness in colors. He admits that the results of this work are inconclusive, yet this work and its extension to chromatic stimuli clarified for him the necessity for five independent perceptual variables to represent the general case of all related colors. By way of illustration, he describes two specific cases of

related colors in achromatic surrounds that are paraphrased here as their descriptions are quite instructive.

### *Achromatic Relations and the Perception of Grayness and Lightness*

Evans considers an isolated  $10^\circ$  circular stimulus seen as achromatic and having a  $2^\circ$  stimulus at its center with identical chromaticity and variable in its luminance. The luminance of the outer stimulus is maintained at 100 milli-Lambert ( $318 \text{ cd/m}^2$ ) where the sensitivity of the eye is maintained.

Starting from the condition that the luminance of both stimuli are matched, the luminance of the central stimulus is reduced and a new perceptual variable is encountered – the perception of grayness. As the luminance of the central stimulus is decreased further, increased grayness is perceived along with increasing darkness until the central stimulus is perceived black of varying degree. Eventually, a point is reached where no further decrease in luminance will produce any perceptual change in the blackness or darkness of the stimulus.

In the isolated stimulus case, Evans notes that decreasing the luminance of the stimulus made it appear “dimmer” without introducing a new perceptual variable. In this context of related stimuli, “darker” describes the relationship of the two stimuli. It is a different perception than “dimmer” in the isolated stimulus case which is related to brightness. The words “darker” and “dimmer” are not synonymous.

This new perception in the semantic context of “darker” is denoted as lightness which Evans defines as “... the apparent relative reflectance or transmittance of a stimulus considered as a reflecting or transmitting object regardless of its physical nature.”<sup>1</sup> In

more current terms, lightness is defined as “ ... the ratio of the brightness of a stimulus to the brightness of a similarly illuminated white stimulus.”<sup>2</sup> While not as clearly stated, Evans’ definition is not inconsistent with the currently accepted definition.

### *Chromatic Stimuli with Achromatic Surround*

Evans considers the same isolated 10° circular stimulus seen as achromatic with luminous of 100 mL and having the same 2° stimulus at its center that is now monochromatic. He then describes a luminance series (1959) that he considered fundamental and defining of his further work.

Starting from a very low luminance relative to the surrounding stimulus where the central stimulus appears black, the luminance of the central stimulus is increased. The perception of blackness persists until hue becomes just perceptible. As the luminance of the stimulus is further increased, hue becomes stronger and blackness decreases.

Above this point, hue and lightness continue to increase and grayness decreases until a well-defined point is reached where grayness has disappeared. For Evans, this point where grayness disappears was denoted as the zero gray point  $G_0$ . At this point, the remaining perceptual variables are hue and lightness.

As the luminance is increased from  $G_0$ , lightness and hue continue to strengthen and a new perception appears in the central stimulus that “ ... can best be described ... as though it were fluorescent.”<sup>1</sup> This new perception along with lightness continues to increase until a luminance match between the two stimuli is achieved.

As the luminance of the central stimulus is increased above the match, lightness continues to increase. The appearance of fluorescence also continues to increase then rapidly decreases and disappears. Evans notes that the description of this change is difficult, and he proposes that it takes place as the appearance of the central stimulus changes from that of a surface [or object] color to that of a source of light - that the central stimulus now controls the sensitivity of the eye. Above this point up to the visual tolerance limit, the stimulus takes on the perceptual attributes of hue, saturation, and brightness.

These newly found perceptions of grayness and what Evans coined as perceived fluorance are mutually exclusive. They cannot be seen together. Hence, Evans considered them as different aspects of a single perceptual variable that he calls brilliance, and  $G_0$  is the threshold between perceived grayness and fluorance as the luminance of a chromatic stimulus is changed relative to its surround. The question for Evans then was to discover the relationship between the  $G_0$  threshold and the psychophysical variables of the stimulus and its surround.

### *The Relationship Between Wavelength and Purity*

Using interference filters at 31 dominant wavelengths in both spectral and extra-spectral regions as the central stimulus in a 100 mL surround, Evans was able to produce stimulus of color purity greater than 0.95 to characterize  $G_0$  as a function of wavelength. This work proceeded until his retirement as he notes, and it wasn't until the end of this work that "... we have come to appreciate its essentially revolutionary nature, involving as it does a new psychophysical function".<sup>1</sup>

The final results at maximum color purity of the central stimulus are shown in Figure I where the ordinate  $G_0$  is calibrated in density according to the wedges used to vary luminance of the central stimulus.

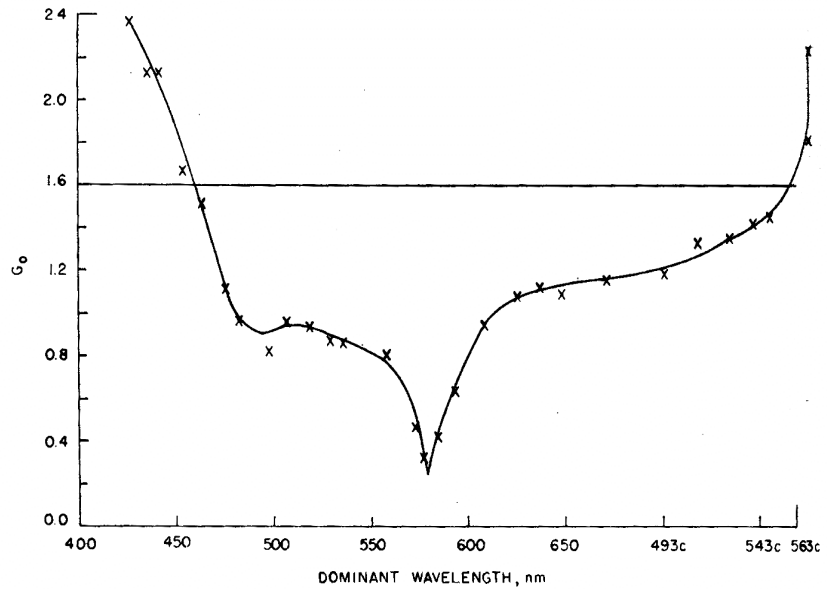


Figure I:  $G_0$  as a function of stimulus monochromatic wavelength with achromatic (C. 7000 K) surround at 100 mL (corrected for stimulus purities)<sup>1</sup>

Thus  $G_0$  is expressed in terms of the  $\log L_s/L_b$  where  $L_s$  is the luminance of the surround and  $L_b$  the luminance of the central stimulus.

From these data and in Evans' words, his fortunate choice of units assigned to  $G_0$ , he found that the curves for  $G_0$  and the colorimetric purity threshold  $p_c$  were parallel when plotted as  $\log 1/p_c$ <sup>ii</sup>. Hence, the two variables are related by a single multiplicative constant, and " ... both are indicative of what I shall call the varying "chromatic strengths" of the different wavelengths."<sup>1</sup>

<sup>ii</sup> The colorimetric purity threshold determines the relative amount of monochromatic light that must be added to white light to produce a perceptible hue.

## The Chromatic Threshold

While  $G_0$  and the colorimetric purity threshold  $p_c$  are connected, they are “... quite different perceptual phenomena because one is a threshold for color against white and the  $p_c$  threshold is for the color in a mixture *with* white.”<sup>1</sup> Evans characterized this later perception of a color in a mixture of white as saturation – the perception of the relative brilliance of monochromatic component and the white component in a mixture.

A series of studies by Evans to determine the relationship between the two revealed an additional fact, unknown in the literature, that when the luminance of the stimulus is reduced to the stimulus’s black point where hue disappears, the ratio of that luminance to its luminance at  $G_0$  also parallels the  $\log 1/p_c$  curve. Evans refers to this luminance setting where hue disappears as the chromatic threshold.

Furthermore, if the stimulus’ monochromatic luminance remained constant at the chromatic threshold and white light was added, the mixture remained at the chromatic threshold. Stated conversely, for any mixture of white and monochromatic light where the monochromatic component is maintained at the chromatic threshold, the slightest increase the chromatic component made hue visible. Hence, “The relationship between black point and the “purity” threshold” is thus an identity, and “purity threshold” is a misnomer since the threshold is entirely independent of purity.”<sup>1</sup>

This study along with many others confirmed for Evans the belief that the chromatic and achromatic components of perception of a color stimulus are “...almost completely independent.”<sup>1</sup>

## Chromatic Strength and a Generalized Brilliance Equation

The conditions for a brilliance match between a monochromatic stimulus and its achromatic surround is that the luminance  $L_b$  of the central stimulus be below that of the surround  $L_s$  by a factor characteristic of the wavelength. Evans refers to this factor as chromatic strength  $S$  defined as the  $\log^{-1} G_0$ , and the condition where brilliance is neither perceived as gray nor fluorescent, the  $G_0$  point, is the condition where the luminance  $L_s$  of the surround is stated as  $S$  times the luminance  $L_b$  of a chromatic stimulus. In Evans' words "... must be thought of the state of excitation of the eye produced by the stimulus relative to that produced by the surround and  $S$  as a measure of this. It is just as susceptible to a change in the surround as in the stimulus."<sup>1</sup>

From Evans' previous findings of the perceptual independence between a stimulus' white component  $L_W$  and its chromatic component  $L_\lambda$ , a generalized brilliance equation for a brilliance match to the surround can be written as:

$$S_W L_S = S_W (L_W - L_{WT}) + S_\lambda (L_\lambda - L_{\lambda T}) + L_{WT} + L_{\lambda T}$$

where  $S_W$  is the chromatic strength of white component and  $S_\lambda$  the chromatic strength of the chromatic component. Because this relationship holds for a stimulus of purity less than 1, the terms  $L_{WT}$  and  $L_{\lambda T}$  are included as the luminance of the stimulus' white and chromatic components at the  $G_0$  threshold.

In words, the brilliance of a stimulus against that of a surround  $S_W L_S$  is given by the sum of its separate components,  $S_\lambda L_\lambda$  and  $S_W L_W$ . However, as the white component of the stimulus has the same chromaticity as the surround in this case, it is assumed that

$S_W$  is 1. Hence the relationship for a brilliance match to an achromatic surround reduces to:

$$L_S = L_\lambda + L_W + S_\lambda(L_\lambda - L_{\lambda T})$$

At this point, Evans considers a stimulus where both chromatic and achromatic components are present – a purity of less than 1 - and begins a luminance series below the chromatic threshold where black is seen. As the luminance is increased to just above the chromatic threshold, a hue is seen in the blackness and hue becomes stronger. To Evans, unlike his previous description, it was not clear whether the blackness perception is more appropriately described as grayness and this, he proposes, needs further investigation.

In any case, as luminance is further increased, grayness decreases as brilliance increases until the  $G_0$  point is reached where the perception of grayness or blackness disappears and fluorance begins. From the  $G_0$  point, fluorance steadily increases with increasing brilliance, and when the luminance becomes on the order of twice the surround, the perception of fluorance suddenly disappears.

Because the perception of blackness or grayness continues beyond the point where hue appears, both the white component  $L_W$  and the chromatic component  $L_\lambda$  of the stimulus determine  $G_0$ . To Evans, it was clear that the perception of grayness and blackness are associated with brilliance as the perception.

## Lightness

In the case of a stimulus in an achromatic surround, lightness appears to Evans as the perception of the relative luminance of the stimulus  $L_\lambda + L_W$  to that of the surround  $L_S$  and is independent of chromatic strength  $S_\lambda$ . For Evans, the perception of lightness is a directly perceived attribute.

## Saturation

Evans refers to the ambiguity of the term saturation in the literature up to his time and perhaps some of this ambiguity remains. In today's terms, saturation is considered as redundant, not ambiguous, as it can be expressed as the ratio of colorfulness to brightness<sup>3</sup> where colorfulness is thought of in the same sense as Evans' color purity  $p_c$ . In this sense, Evans' and current thinking are in accord.

However, Evans goes on to say that two colors of different wavelength but the same purity can have differing degrees of admixture with white and correspondingly wide differences in saturation. Further, that no white component is perceived in spectral colors, except perhaps yellow. Hence, Evans extends the concept to say that monochromatic stimuli differing in chromatic strength, i.e. brilliance, " ... accords with what is actually seen."<sup>1</sup> That saturation is the perception of the brilliance of the chromatic component in relation to its total brilliance. Saturation is zero when no chromatic component is perceived and one when no white component is seen based on his premise that the white and chromatic components are separately perceptible.

## Hue

In Evans' opinion, hue is obviously an attribute of perception, yet it is " ... most unsatisfactory as a variable [attribute] of perception because there is no obvious way in which it can be quantified."<sup>1</sup> Further, he notes that hue is an unstable attribute dependent on the conditions in which it is investigated. Investigations up to his time have almost exclusively relied on simultaneous comparison of stimuli, yet Evans notes that it is likely that the appearance of one would influence the appearance of the other. Further, that methods relying on memory matching are known to be systematically poor. Alternatively, he suggests inter-eye comparisons.

In this regard and relative to a statement he made in the preface of his book, he states that " ... a systematic study of perceived hue ... would unravel most of the mysteries of color perception. My certainty comes from my very strong feeling that only a complete understanding of hue and brilliance as variables will tell us what kind of phenomenon it is for which we are trying to postulate a mechanism."<sup>1</sup> It is interesting to note that today, hue is considered certainly a fundamental attribute of perception that is very stable when considered in the context of the opponent colors of vision. This current, yet relatively long standing status, is achieved perhaps due to its basis in opponency as the mechanism that Evans refers to, and perhaps this was not fully understood in his time.

## CHROMATIC SURROUNDS

Summarizing up to this point, the appearance of an achromatic stimulus having the same chromaticities as its surround is fully described by three perceptions – the brightness of the field, the lightness of the stimulus relative to its surround, and brilliance in the form

of the appearance of grayness in the stimulus for luminances lower than that of the surround.  $G_0$  for this case occurred at a luminance match with the surround where chromatic strength  $S = 1$ . For chromatic stimuli, the perceptions of hue and saturation appeared in addition, and  $G_0$  became dependent on the dominant wavelength and purity of the stimulus. Evans next considers the situation where the chromaticity of the surround is changed.

### Chromatic Surround

As part a first experiment to develop an instrument capable of introducing monochromatic luminance in the surround to characterize its effect on the  $G_0$  threshold, some crucial results were obtained. First, Evans found that if any hue introduced in the surround was disregarded, the setting for the  $G_0$  threshold occurred at the luminance match point with the surround independent of the wavelength and that the surround can always be assumed to have a chromatic strength of unity once adaptation occurs. In this context, the appearance of the central stimulus was “... even more surprising to us ...”<sup>1</sup>. The induced hues in the central stimulus by the surround split into two independent components of adjacent unique hue [opponent] pairs.

A second experiment was to determine the relationship given previously in this paper of  $G_0$  as a function the wavelength of the central stimulus and, in this case, the surround. The above noted effects along with the problem of setting the brightness of the surround made this second experiment difficult. These effects were minimized by concentrating on the surround and limiting the time looking directly at the central stimulus presumably to maintain a stable level of adaptation. On this basis, Evans proceeded to characterize  $G_0$  at three surround wavelengths as he realized that a complete study for all

wavelengths and purities of stimuli would be an enormous undertaking. However, the results for the second experiment, limited as they are, gave Evans even more of a sense that brilliance as a perceptual variable is independent of lightness.

The resulting  $G_0$  for three high purity surrounds are shown in Figure II<sup>1</sup>. Comparing these results with those for an achromatic surround discussed previously, maximum brilliance relative to the surround is produced by a high purity stimulus in an achromatic surround.

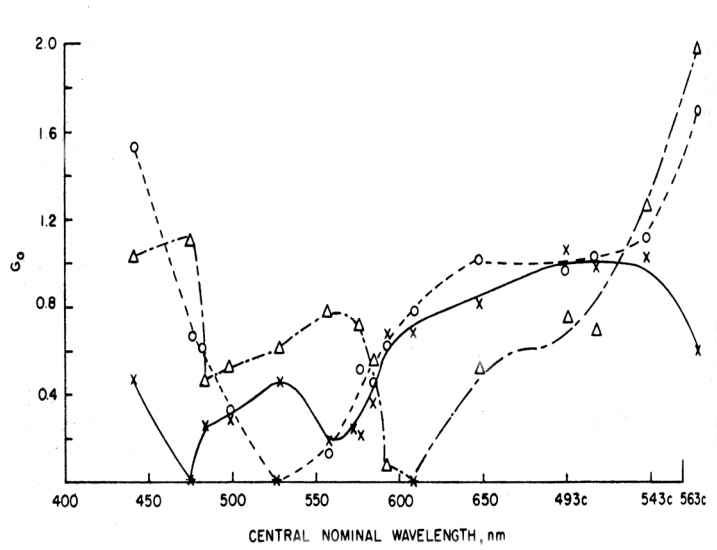


Figure II:  $G_0$  as a function of nominal wavelength for three high purity surrounds (X-X-X) 475 nm; (O-O-O) 528 nm; (D-D-D) 608 nm

However, the “... most striking ...”<sup>1</sup> feature of these data is that minimum brilliance occurs at the wavelength of the surround which Evans notes makes perfect sense as they are metameric at a luminance match ( $G_0 = 0$  and  $S = 1$ ). Hence, chromatic strength is not an inherent characteristic of the wavelength, but is a relationship between the stimulus and its surround which is a function of wavelength. As Evans notes, the concept of adaptation as an adjustment in the gain of the eyes receptors may be “... too naïve.”<sup>1</sup>

The results for three high purity central stimuli at seventeen different monochromatic, high purity surrounds shown in Figure III<sup>1</sup> are a direct demonstration of brilliance as a perceptual variable independent of lightness – that  $G_0$  can be varied not only by

changing the chromaticity of the central stimulus, but also by changing the chromaticity of the surround. At each point on the curves shown, brilliance of the central stimulus is seen as equal to that of the surround, yet lightness is determined by its luminance with respect to the surround.

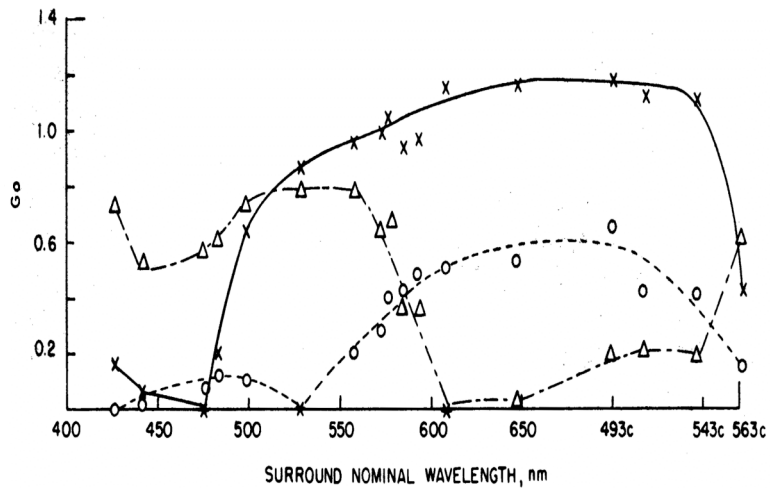


Figure III:  $G_0$  as a function of surround nominal wavelength for three high purity central stimuli (X-X-X), 475 nm; (O-O-O), 528 nm; (D-D-D), 608 nm

In summary, stimuli at a relative luminance above  $G_0$  appear fluorant against their surround, and further, any stimulus with a dominant wavelength different from the surround will be fluorant at the luminance of the surround. In effect, brilliance increases with increasing hue difference, and stimuli having a similar luminance as the surround will appear more brilliant than the surround. This effect will magnify in increasing hue difference. Stimuli of a similar hue will appear gray if their lightness is slightly less than the surround.

### The Independence of Brilliance and Lightness

Under the guise of a discussion of the “... general problem of lightness and brilliance”<sup>1</sup>, Evans sums up the central thesis of his book. The fact that all colors can be matched by mixtures of three others and the establishment of three psychophysical attributes for such a match, the assumption since the time of Hemholtz has been that there must only be

three perceptual attributes of color. In Evans' own words, " ... the three-dimensional requirement for perception is logical *only if* it is *also* assumed that the appearance of the stimulus is controlled entirely by the stimulus itself. And this is true only when the stimulus is itself the only thing affecting the eye, that is, the isolated stimulus case."<sup>1</sup>

While the grayness of an object appears to be a property of the object itself in isolation, this is not the case even though it appears so. The lightness or darkness of an object, while physically a part of it, is simply light or dark compared to other colors in the field. As long as these perceptions are thought to emulate from the properties of the stimulus alone, it is logical to restrict perception to three attributes. However, as Evans has demonstrated, these perceptions are produced by the " ... presence of surroundings ... [and] lightness and brilliance are produced by the appearance of a second stimulus [i.e. the surround] and are in addition to the three perceptual attributes produced by an isolated stimulus"<sup>1</sup> In which case, the perceptions are described by six psychophysical variables – three in the surround and three in the object itself [In fact, Evans later states that it is really nine psychophysical variables required in general case].

In real objects uniformly illuminated by light seen as achromatic," ... while the perception of brightness can be assigned to the illumination, we are left with four independent perceptions to describe the appearance of individual objects."<sup>1</sup> As such, in situations dealing with more than one stimulus, perception is in five dimensions. The dimensions are reduced to four if perceived differences are at issue and to three if the surround is constant and controls the sensitivity of the eye. "The general case can thus be artifi-

cially reduced to four, but it cannot be reduced to three without danger of misunderstandings and a limited view of the whole. This is, essentially, the thesis of this whole book.”<sup>1</sup>

#### WHAT IS KNOWN NOW AND WHAT REMAINS TO BE SEEN

Perhaps the first realization of the perceptual attributes of color occurred through Munsell’s representation of color perception in hue, value, and chroma, and it wasn’t until the definition CIE 1931 Standard Observer was defined that these three perceptual attributes could begin to be expressed in terms of the physical parameters of color as the science of colorimetry developed. In 1976, the CIELAB/CIELUV opponent spaces were standardized as perhaps a step closer to color perception at least in the Munsell sense of representing equal perceptual differences, yet directly derived from the measured, physical parameters of color. Furthermore, the three fundamental perceptual attributes of hue, chroma, and lightness could also be directly derived. But, as Evans notes, these attributes could only be applied in the limited case of a fixed background where the appearance of the stimulus is controlled exclusively by the stimulus itself.

Based in these fundamentals, work in color perception shifted to the color appearance of related stimuli, principally through the study and modeling of chromatic adaptation. In 1991, Hunt published a model of color vision for predicting color appearance<sup>4</sup> that was first outlined in the early 1980s. In this model, Hunt recognized five different visual fields – a uniform color patch of about  $2^0$  subtense, a proximal field, the background, the surround, and the adapting field. Further, Hunt’s model required 16 independent input variables to fully describe these fields including three for reference white. In this context, Hunt described certainly more than three perceptual [appearance] attrib-

utes – hue and colorfulness; saturation, relative yellowness-blueness, and relative redness-greenness; brightness and lightness; chroma; and whiteness-blackness. Of course, they are not mutually exclusive, and in the evaluation of his model, observers scaled hue, lightness, colorfulness, and chroma.

In a similar effort, parallel with Hunt's work, Nayatani<sup>5</sup> describes his color appearance model of a uniform color stimulus in achromatic backgrounds. His model requires specification of eight physical parameters of the viewing field accounting for background, illuminant, and test stimulus, and it predicts directly the perceptual attributes of hue, brightness, lightness, saturation, chroma derived from saturation and lightness, and colorfulness.

By today's standards<sup>6</sup>, exemplified in CIECAM97s/CIECAM02, five perceptual attributes are believed to be required for a complete specification of color appearance – brightness, lightness, colorfulness, chroma, and hue. Saturation is redundant as it is derived from either colorfulness and brightness or chroma and lightness, and while it could be argued on this basis that brightness-colorfulness and lightness-chroma would seem redundant, they are in fact distinct in different viewing environments. Then, it is by these standards that Evans would be pleased in that his “central thesis” has been realized and accepted. Furthermore, the latest work in color appearance, iCAM<sup>6</sup>, extends the capabilities of color appearance to that of image appearance and the provision of complex viewing environments – a logical extension of Evans' work that he fully recognized and certainly would have pursued had he lived.

Yet, in all this, the central thread of Evans' work, clearly its motivation and his passion, has seemingly languished over all these years. It was this central thread of brilliance as a unique and fundamental attribute of our perception of color that led him to extend the fundamental perceptions of color to more complex stimuli and the additional perceptions they invoke. To him, brilliance could not be directly derived from the known physical characteristics of the stimuli and the CIE 1931 Observer as can brightness, lightness, colorfulness, chroma, and hue nor is it assignable to any known physiological characteristic of visual sensation.

#### Hunt on brilliance

In a paper published in 1982 [Hunt,1982], Hunt deals decisively with Evans' findings on brilliance. Hunt first acknowledges Evans' work by stating that "The illuminance of a colour relative to that of its surround greatly effects its appearance: when it is higher, the colour usually appears luminous, looking like a light source or a fluorescing surface; when it is much lower, the colour usually has apparent grey content." Hunt notes that "various explanations for this function have been suggested ..."<sup>3</sup> and concludes that the relative luminance " ... corresponding to optimal colors [MacAdam Limits] ... agrees quite well with the zero gray content ...." Hunt asserts, " ... zero gray content does not correspond to some physiological response level but to the observer's estimate of the upper limit of lightness for normal surface colors in practice."<sup>3</sup>

#### Nayatani on brilliance

The most resounding acknowledgement of Evans' work on brilliance came in a paper, *Relation on Helmholtz – Kohlrausch Effect, Purity Discrimination, and  $G_0$  the Function*<sup>3</sup>,

where Nayatani related that “the authors now believe that the function  $[G_0]$  is a fundamental quantity in the color appearance of object and luminous colors. The importance of the studies by Evans should be recognized in the color community.” Furthermore, Nayatani showed that Evans’  $G_0$ , the variation of Munsell Value with hue at maximum chroma, purity discrimination, the Helmholtz-Kohlrausch (H-K) Effect, and the determination of perceived hues are all a result of the chromatic of color stimuli. In essence, the chromatic strength of colors is the ability to induce brightness or lightness in a color stimulus.

In a more recent series of papers<sup>5,6,7</sup>, Nayatani brings together the concepts of chromatic strength and the perception of grayness into almost a unified theory of color appearance. He notes that “... the chroma perception in the chromatic color series is always assessed only by considering its chromatic component ..., but neglecting its grayness ... although the perception of grayness always exists ....” Furthermore, in opponent color theory, grayness is also “... important for whiteness-blackness perception.” Nayatani then proposes that the achromatic perception of whiteness-blackness is analogous to chroma in redness-greenness and blueness-yellowness and, further, that the Hunt Effect and the Stevens and Jameson-Hurvich Effect “... belong to the same category in opponent color theory.”<sup>6</sup>

summary

Through the work of Hunt, Nayatani, and others not cited here, Evans’ concept of brilliance has not at all languished since its introduction and has certainly been given cre-

dence. Yet, what Evans refers to as fluorance as a precept of brilliance has languished, perhaps as it is not a part of the gamut of our normal, everyday experience.

The perception of fluorance gives an almost newfound power in the effect of surround on object color perception, and its effect is visually quite striking. With the current growth of digital media technologies, much more is possible in achieving brighter and more vibrant colors, colors that transcend the gamut our experience. It is the greater promise of this technology to take us beyond our experience – an experience well within our ability to perceive and an experience offered by expanding the gamut of this technology in the perceptual sense.

Brilliance is a difficult perception to invoke as its realm is not a part of our everyday experience. As noted before, few objects with chromatic surface reflectances of 2 and 1/2 percent or more can reach a lightness at which the brilliance is equal to the surround and most reflected colors in our experience include the perception of relatively large amounts of grayness. Hence, in the sense of brilliance as a perception mediated in the higher orders of cognition, it is difficult to speculate that brilliance is a learned effect from experience. Instead, perhaps it arises as an artifact or anomalous result of our learning – an effect occurring as a result of our experience yet outside it. As such, it is reasonable to ask what value there is in its study, yet it is sometimes through such effects that the nature of vision can be more fully understood.

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