Color as a determined communication

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Although it is possible that one viewer's perception of color may be very different from another's, experimental evidence suggests that the relationships between colors are, in many respects, universal, and thus relatively free from individual and cultural influences. The "experience of color" can be described objectively, so that predictable visual sensations can be elicited by adjusting the relationships among colors. A model of color experience is described that is based on the types of interactions among colors. The model adjusts formal compositional attributes such as hue, value, chroma, and their contrasts, as well as size and proportion. Components such as these can be utilized to build a general architecture for adding guidance to interactive systems.

There was gold paint, but Rembrandt didn't use it to paint a golden helmet.

—Wittgenstein

An engineer or scientist would use gold paint to paint a gold helmet. Why did Rembrandt choose not to use gold paint? The engineer's or scientist's quantitative understanding of color is far removed from an artist's qualitative understanding of color. The former considers color as something that is specified or measured in terms of metrics such as nanometers or just-noticeable-differences and speaks of color in terms of detection, discrimination, legibility, and contrast. However, for the artist or the poet, color is something to experience, not measure and quantify. Our current understanding of human color vision emanates from the traditions of both artists and scientists. Newton characterized light; Goethe contemplated its appearance.

In human visual experience, colors appear as interrelated sensations that cannot be predicted from the response generated from viewing colors in isolation. People can make *consistent* evaluations of the magnitude of any given experience of *colors* based on the type of interaction among colors. People respond to the relationships among colors.

Color experience is governed by well-defined objective principles that can be quantified. These principles are applicable to a wide variety of disciplines. For instance, in interface design, color can reinforce information by providing a visual "counterpoint." In image reproduction, "color matching" becomes a matter of "preserving" the experience of color. In graphic design, a wide variety of visual experiences can be established and "transposed." In multimedia applications, sensations produced by different modalities can be transcoded or integrated.

The common ground between the measurement of color and the application of color to design, the human *experience* of color, is found in the interaction between analytical and empirical data. In this paper, the search for a common ground begins with a *qualitative* description of color, followed by a review of *quantitative* descriptions of color. An experiment that models color expressiveness is described. The paper concludes with rules for creating a language of *color*

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Figure 1 From black and white to color (photograph of moon courtesy of NASA): (A) a lunar landscape composed from gray, (B) the elements used to create the landscape, (C) the addition of yellow, (D) the addition of more colors, and (E) the cacophony of too much color

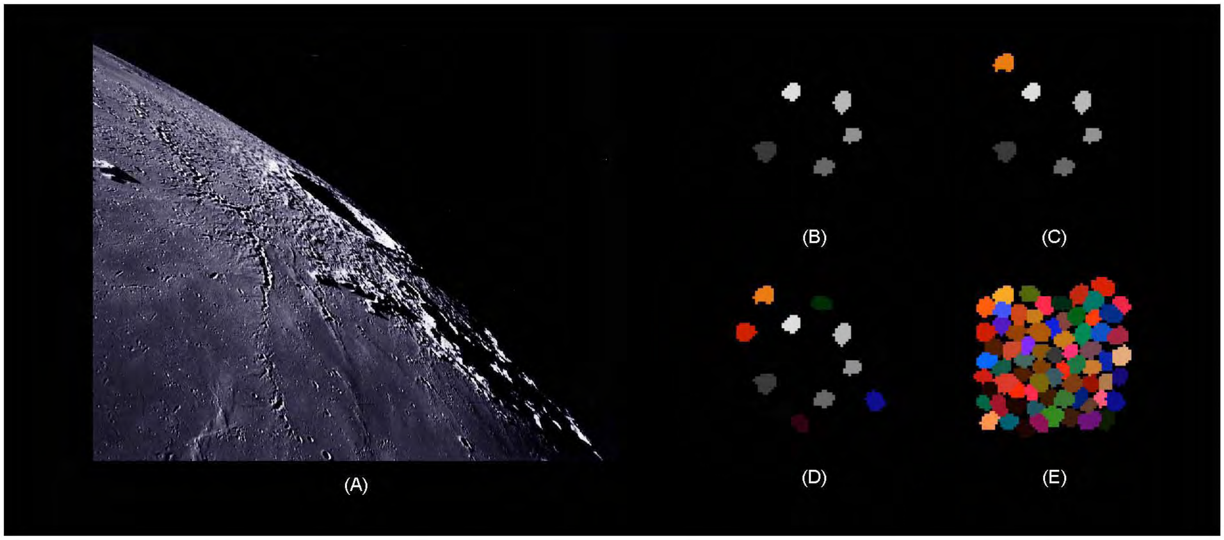
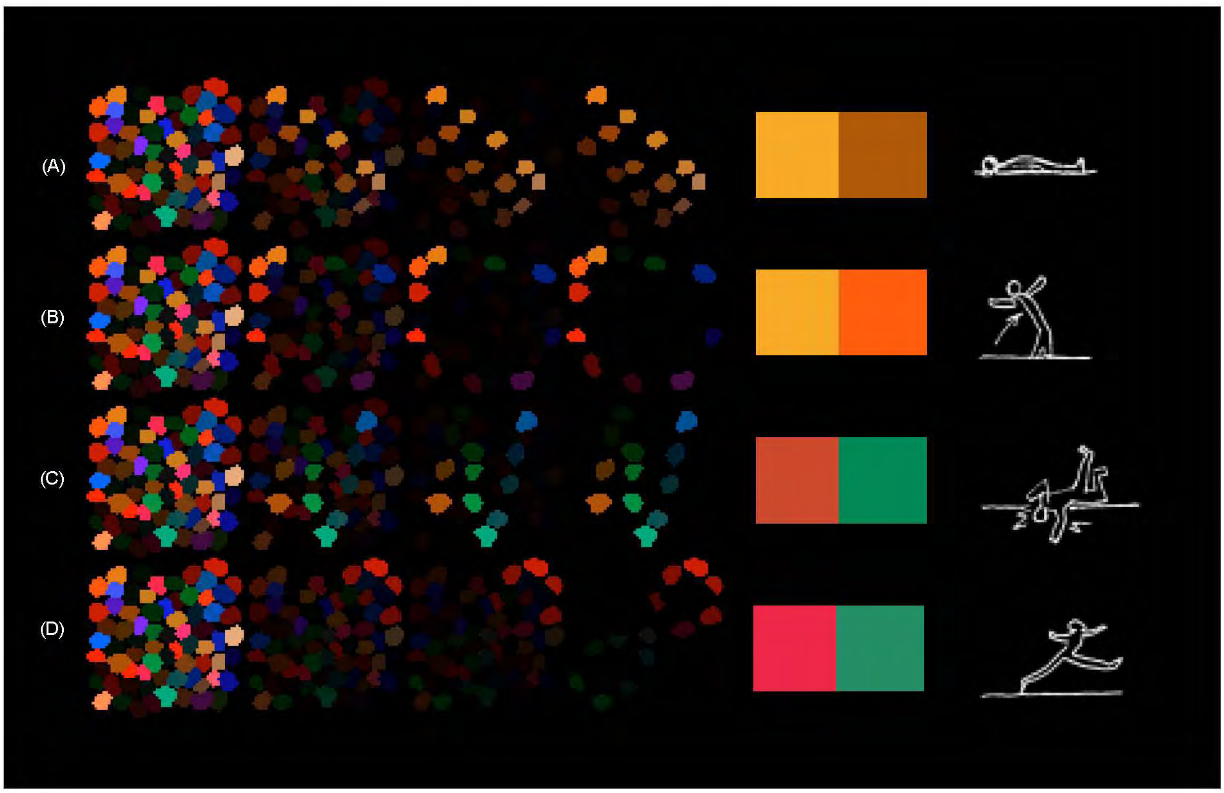


Figure 2 A sense of order: a succession of masks is applied to the cacophony of colors from Figure 1E in order to extract (A) monochrome, (B) analogous, (C) "beyond" analogous, and (D) complementary relationships



communication and how these rules may be applied to design systems.

The quality of color

How does color contribute to communication? In order to answer this question, first imagine a world without color, an achromatic world that consists of black, white, and shades of gray but no other colors. People lacking photopic vision live in such a world. Others, such as the man who is the subject of Dr. Oliver Sacks's essay entitled "The Case of the Color-Blind Painter,"[1] see the world without color because of a visual cortex injury (cerebral dyschromtopsia). Sacks's patient lost the ability to distinguish between hues but otherwise retained the ability to see. The patient saw objects, facial features, silhouettes, dynamics, and depth and focus, but could not see color. How was his visual message-processing system impaired by his inability to see color? How was his ability to communicate visually affected both quantitatively and qualitatively?

An examination of a monochrome image provides insight into the world of the color-blind artist. In Figure 1A, the moon is reproduced as a gray-scale image. Surface *texture* provides a sense of the lunar terrain. *Shape* and *volume* are evident from the shading or chiaroscuro. The relative *position* of the craters can be determined. Changes in the craters' *size* and *orientation* across the surface impart a sense that they are receding toward the horizon. And, *attention* is drawn to the crater Copernicus on the horizon, in part, because of the relatively large contrast of value between the sunlit sides and the shadow across its basin.

Some of the color elements used to create this reproduction of the moon have been extracted and are shown in Figure 1B. They are shown as patches of gray. Figure 1A is composed from these achromatic elements. Together these patches create an ordered progression from dark to light.

This black and white view of the world is similar to that experienced by the color-blind painter. Although rich in detail, it is void of color, and thus void of the expressive qualities of color. Consider what happens with the addition of color: Yellow has been added to Figure 1C; it changes the character of the message by adding another dimension to the composition. The addition of color stimulates and excites. As more color is added, attention is drawn away from the gray patches (Figure 1D), and a new sense of order emerges: a progression of hues.

However, with the addition of still more color, a point is reached where a consistent message can no longer be viewed in the image (Figure 1E). What began as an ordered progression has turned into a cacophony of colors. Whatever color relationships existed are masked by the complexity of the image. Attention is drawn to too many places at once because of incompatibilities in the ordering or segmentation of the image elements.

A sense of order. A middle ground can be found between the two extremes of no color and too much color. By application of masks designed to exploit

Expression is used to describe the human response to appearance.

selected dimensions of color appearance, order can be extracted from the chaos of Figure 1E. Figure 2A illustrates one such mask. All of the colors revealed share a common hue (in this case, yellow). Although yellow ranges in value from dark to light and in chroma from gray to highly saturated, the colors belong together, as part of a stable, ordered family. This organization of color is commonly referred to as *monochrome*.

Figure 2B illustrates another selection of colors brought out by the use of a different mask. A progression of *analogous* (or neighboring) hues following the order of the spectrum is extracted. The order found in this progression is familiar to all with "normal" color vision. Although more "lively" than the monochrome palette, it, too, is a stable arrangement.

A departure from the analogous ordering of hues is illustrated in Figure 2C. The mask reveals a progression from yellows to greens to blues. This ordering of colors is more stimulating but also more stressful and ambiguous. This arrangement, stretching *beyond analogous*, is less balanced than the monochrome or analogous selections.

Figure 2D illustrates yet another ordering. The mask exposes complementary colors (colors that intermix to gray). Although the complementary relationship is even further beyond analogous than the progression shown in Figure 2C, there is no visual tension or ambiguity generated from the colors. There is a sense of a dynamic energy associated with *complementary* pairings. Whereas the analogous progression of hues and the monochrome field are ordered and stable, the complementary progression invokes images of a "dance."

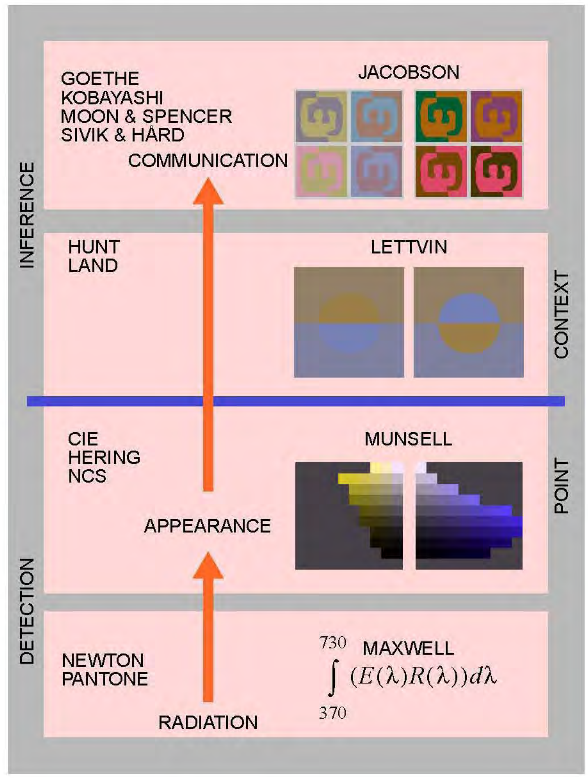
For those of us with normal color vision, the vocabulary of color communication is something both innate and intuitive. We do not rely on prescriptions of color semantics or rules of color harmony to determine a response to color. Our response to gravity and our sense of balance are based on an internal "plumbline," not Newton's equations. Similarly, our response to visual sensations and our sense of dynamics and stress are inherent. It is this internal "color plumbline" that Sacks's patient lost.

A hierarchy of color communication

Historically, color has been characterized by consideration of its application. Considerations have included the physics of color, the mechanisms of the human visual system (HVS), application to coding and reproduction, and application to design and interactivity. Color has been modeled as a physical, psychophysical, psychological, and metaphysical phenomenon. Evans's book, *An Introduction to Color*,[2] provides good background on the subject. Over the past forty years, through both clinical and neurophysiological studies, models of the HVS response to color have been developed, beginning with the detection of radiation in the retina and continuing as far as the visual cortex. Zeki[3] and Hubel[4] have written detailed descriptions of their hypotheses of the cortical processing of color.

The discussion of color in this paper is organized as a hierarchy (Figure 3). At the bottom level is the detection of points of electromagnetic radiation. At the next level is the appearance of radiation as an ensemble of points. At the top level are the inferences made from appearance. These inferences are the building blocks of color communication.

Figure 3 **A hierarchy of color communication is a progression from the detection of radiation, through the perception of appearance, to the inferences of communication.**



The HVS responds to electromagnetic energy between approximately 370 and 730 nanometers. The concept of visible radiation is used principally to describe energy external to our bodies and is defined, discussed, and applied using the language of physics. Radiation can be modeled as a collection of stimuli, each independent of its neighbor. A description of radiation is most often a description of points. Use of the word radiation is restricted to describing phenomena by wavelength, phase, and amplitude at singular points or across uniform fields. Examples of radiation models include that of Newton, who, by using prisms, established the principles of color mixing. Pantone**, a popular color atlas used by the printing industry, is a collection of radiation samples organized by the tints and shades of pigment.

A goal of color science is to model the transformation of radiation by the HVS into the sensation of color. Many models are designed to predict color appearance by scaling radiation based upon parameters found in human psychophysics. Examples include that of the Commission International de l'Eclairage (CIE), Munsell**[5,6] (Figure 4), and the Natural Color System (NCS)**[7] (Figure 5). These models vary in terms of their support for the independence of particular primary colors, mathematical complexity, and visual ordering. The latter is a particular strength of both the Munsell and NCS systems. Both of these systems are perceptually uniform and orthogonal (Figure 6). These models are useful for tasks such as comparing different color devices, predicting the results of color mixtures, and finding an approximate complement.

A limitation of these models is that they largely ignore visual context, i.e., they do not predict how the appearance of a color changes depending upon its proximally surrounding colors. This "visual context" can produce large shifts in the perception of a color that cannot be accounted for by colorimetric specifications of isolated points of color, since the appearance of color is the result of an interaction of *colors* (Figure 7).

The concept of color appearance is used to describe the retinal and cortical *responses* of the visual system to radiation. Color appearance is not an attribute of objects external to an individual's body. However, it is an attribute of representations within an individual's mind; hence, appearance is defined, discussed, and applied using the language of perception. Human response to radiation is derived from internal processing of the relationships between points of radiation. Examples of appearance models include those developed by Land,[9] Lettvin,[10] and Hunt.[11]

Color appearance models, just like colorimetric models, ultimately describe the phenomenology of a single color. That is, they describe the processes by which the appearance of a single color is affected by its surrounding colors, whether it is due to contrast effects, induction, assimilation, adaptation, or spatial or temporal configuration.

Wandell,[12] in *Foundations of Vision*, defines "seeing" as the process of deriving meaning from a "collection" of visual inferences about the world. Multiple inferences are reconciled to create a unified explanation of the stimuli. In keeping with Wandell's definition, seeing color involves more than just the sensation of isolated color appearances. It is the result of a plurality of colors taken as an ensemble, independent of how the appearance of the individual colors is

Figure 4 Munsell's *Book of Colors* is organized in terms of three perceptual attributes of color: hue, chroma (saturation), and value (lightness). (A table converting colors from Munsell to CIE can be found in Wyszecki and Stiles.[6])

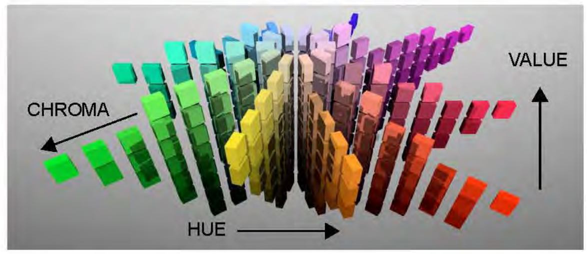
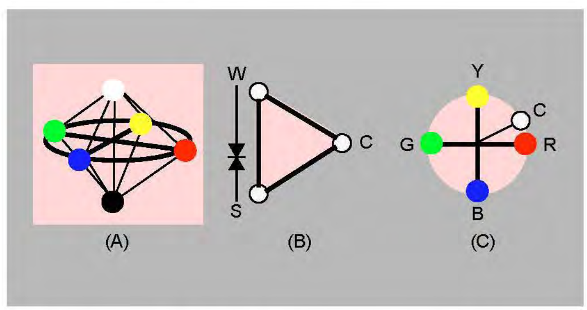


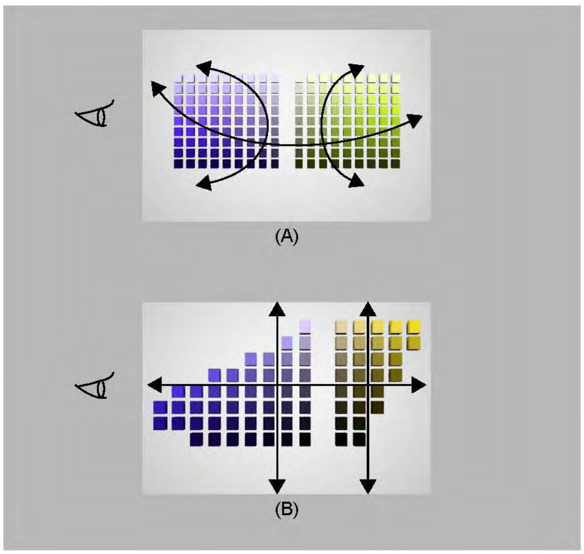
Figure 5 The Natural Color System is based upon Hering's Opponent Color Theory. (A) The system takes as its basic elements: black, white, red, green, blue, and yellow. These colors are taken as absolute "mental" references, from which all other colors are determined by their degree of resemblance. (B) Grays are described by the percentage of black and the percentage of white they contain. (C) Chromatic colors are described in terms of all six components.



established. It is only within the context of an ensemble of colors that color conveys semantic and symbolic information. Communication tasks such as naming, classifying, searching, quantifying, ordering, highlighting, and conveying expression or emotion are consistently determined by the use of a plurality of color appearances.

The word "expression" is used to describe the human response to an ensemble of color appearances. We have an internal psychophysical response that is initiated when viewing multiple external radiations. Although it is possible for one viewer's perception of color to be very different from another's, experimental evidence suggests that the relationships among internally generated colors are, in many respects, universal, and thus relatively free from individual and

Figure 6 A perceptually uniform and orthogonal ordering facilitates visual navigation: (A) when saturation extends to "100 percent" at all value levels, circuitous paths must be used to independently change value and saturation, but (B) when value and saturation increase in perceptually uniform increments, the paths are straight.

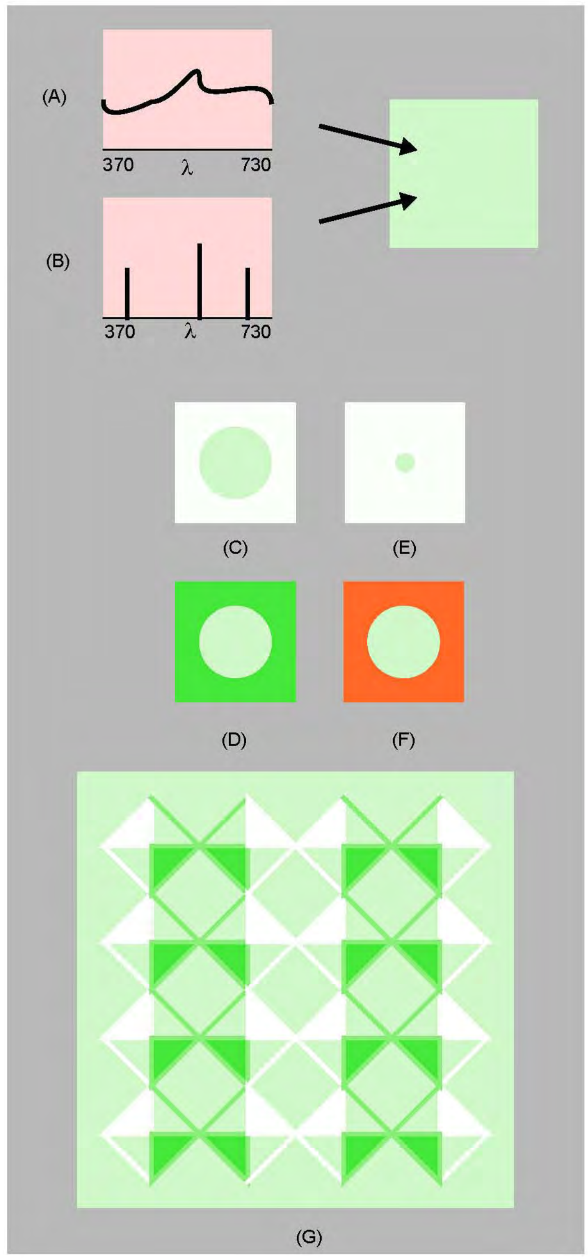


cultural influences. Examples of qualitative models of expression are Jacobson's Relative Harmony Quotient[13] and Kobayashi's Scale of Colors.[14] Examples of quantitative models are Moon and Spencer's Geometric Formulation of Harmony[15] and Sivik and Hård's Semantic Dimensions.[16]

Robust communication. In order to inform, persuade, and stimulate (or fatigue), messages to the visual system must have integrity, credibility, and excitement (or lack of excitement). Making the message available is sufficient for some applications, but for most, the message must be both available and easy to understand.

To design a message that is distinct, reliable, and draws the attention of the observer, one must evaluate the degree of visual prominence of the message. This means determining whether the message is able to be perceived and decoded. It also needs to have its proper place in the hierarchy of information so that it attracts the attention it deserves. Congruence among messages can make them easier to receive; incongruence can lead to the inhibition of communication, or miscommunication (Figure 8).

Figure 7 Colorimetric models can predict when different radiations, such as (A) and (B), will match, but not how they will appear. The same green appears different in (C), (D), (E), and (F) due to differing contexts. Appearance models can predict what colors in context will look like, but not what they communicate. (G) An interesting exception to appearance modeling is Adelson's illusion:[8] The diamond shapes in the "light" column in the center of the figure are the same as the diamond shapes in the "dark" columns on either side.



We need to grade the efficacy of various means of generating messages for the tasks we want to perform. Grading can lead to design methodologies for creating messages that are appropriate for our applications.

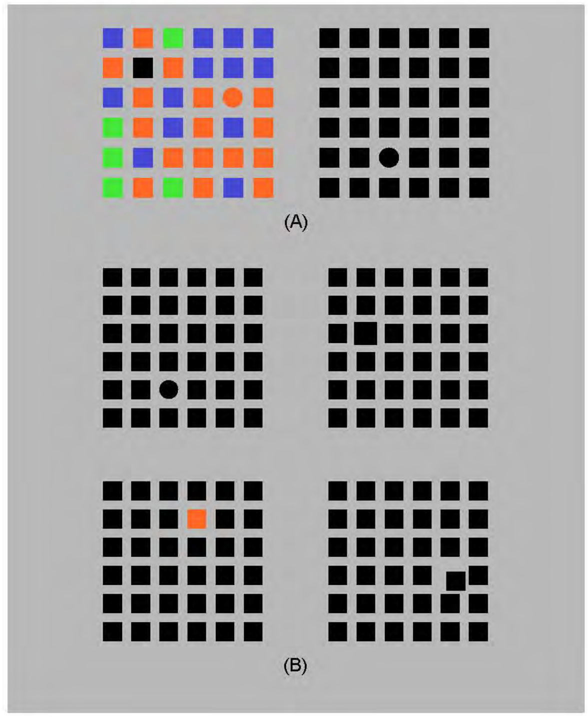
Experience of color. In visual communication, a wide variety of color experiences can be established. Patterns of color combinations constitute experiences of color, each with its own unique "character." However, even among varied experiences, it is possible to identify features that are common among color experiences: some experiences are energetic and others are weak.

Humans make consistent evaluations as to where any given color experience, produced by interactions between two colors in patterns encompassing a wide field of view, lies in a range of magnitude. We have an ability to make judgments about the magnitude of the interaction of colors based on how colors relate to one another. Features of the colors, such as chromatic composition and spatial configuration, determine the magnitude of the interactions. These features constitute the dimensions of color experience.[17]

A study by Feldman, Jacobson, and Bender[18] found that when evaluating the experience of color, agreement among people is strong; that is, judgments of the magnitude of experience constitute an invariant aspect of human response to color. Beyond such invariant responses lies a more personal and subjective issue of judgment, such as whether an experience is "pleasing." The problem with assessing personal preferences is that there is no consensus among people, even less among different cultures, as to which colors are "beautiful" or "ugly" together. Therefore, subjective evaluation of color is deliberately avoided. A complementary study by Green-Armytage[19] evaluates the role of personal preferences on the color experience.

Architectures for interaction. Today's application and development environments, although increasingly capable of providing the user with the ability to interactively select colors (as well as fonts and other graphical elements), do not offer the user guidance when making these selections. Consequently, though the capacity for creating powerful visual communications with color exists, it is often not realized since the user is free to produce illegible and jarring results. Any architecture for interaction with color must consider radiation, appearance, and expression.

Figure 8 **Color can hinder or help search: (A) color interferes with the task of finding the circle, and (B) color, as well as shape, size, and position, aids in the task of finding nominal changes.**



The remainder of this paper discusses how color experiences are established, described, quantified, and finally, may be utilized in an interactive system.

Dimensions of color experience

Color is colors, plural.

—J. Albers

The experience of color is described with the directly observable features of the colors such as the chromatic dimensions of hue, value, chroma, and their contrasts, as well as the spatial dimensions of size and proportion. Other features not considered here include facial features, silhouettes, dynamics, and depth and focus. The interactions between the dimensions were uncovered through a series of experiments, which are reviewed briefly in this paper and detailed in Feldman, Jacobson, and Bender.[18] Semantic differential scales, as defined by Osgood et al.,[20] were used to evaluate systematic variations in the relationships

Table 1 Seven dimensions of color experience and their effect on response along semantic differential scales

Dimension	Effect on Response	To *Increase* Response
Reference hue	No	–
Hue contrast	Yes	Increase hue contrast
Reference value	Yes	Raise value
Value contrast	Yes	Increase value contrast
Chroma	Yes	Increase chroma
Block size	Yes	Decrease block size
Area ratio	No	–

between the colors. Two of the scales of Osgood et al. were used: activity (tame-wild, still-vibrant) and potency (quiet-loud). Their evaluation scale (pleasant-unpleasant) was not used since a nonjudgmental evaluation was sought. It was found that distinct color experiences can be described with a single scale of magnitude so that seemingly disparate visual sensations can be made commensurate with each other. It was also found in Jacobson, Bender, and Burling that within each isobar of magnitude—low, medium, and high—distinct qualities of expression are evoked, which vary from stressful to harmonic.[21] Experience of color is determined by several factors: the number of colors, the brightness, the intensity, the size and shape of colored regions, etc. Thus, when evaluating a color experience, it is not any one factor that is taken into consideration but rather the experience of the interaction between factors that is recorded. Therefore, to describe the experience of color, several factors need to be considered, as well as their interactions.

Chang and Carroll[22] used multidimensional scaling (MDS) to analyze data obtained from a color "similarity" experiment. Their analysis suggested that in addition to Hering's three color dimensions, lightness, red-green, and yellow-blue, there are "folded" dimensions. These folded dimensions approximate value contrast and hue contrast (as described below). Chang and Carroll also found an additional dimension, "split yellow," which they attribute to anomalies in some of their subjects. A more likely explanation of this artifact is the choice of sample points used in their experiment.

The dimensions of color experience are grouped into two categories: chromatic and spatial. The dimensions used in the experiment designed by Feldman, Jacobson, and Bender were:

Figure 9 Seven dimensions of color experience

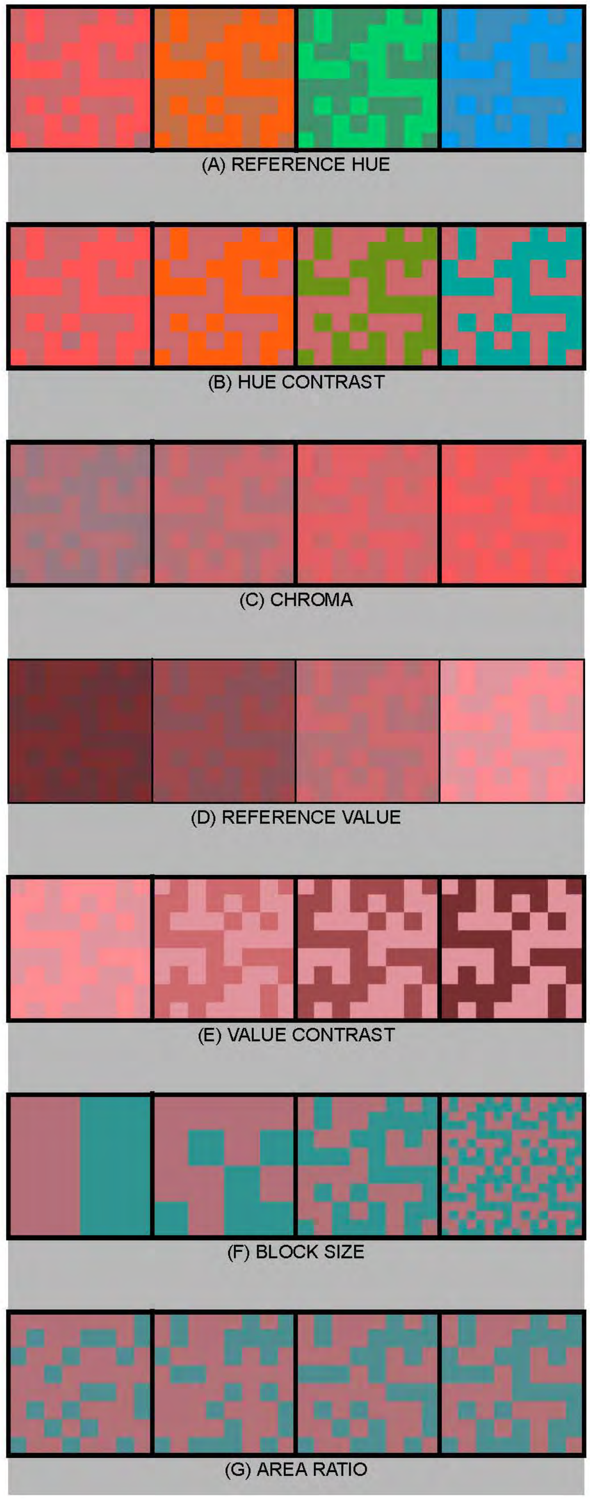


Figure 10 Interaction between hue contrast and chroma: chroma increases from bottom to top and hue contrast increases from left to right. The interaction increases moving up and to the right. The region of maximum interaction is in the upper right.

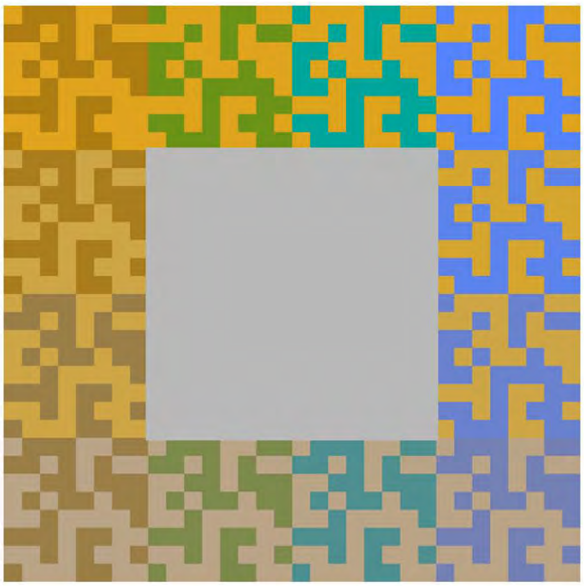


Figure 12 Interaction between hue contrast and value contrast: value contrast increases from bottom to top and hue contrast increases from left to right. While the interaction increases moving up and to the right, the region of maximum interaction is indistinct.

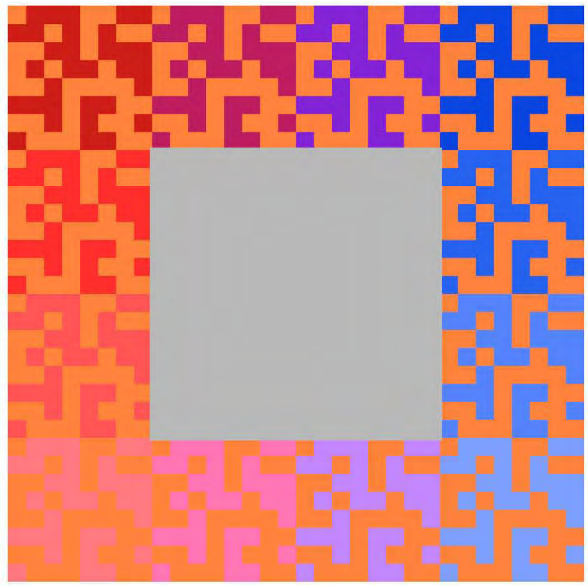


Figure 11 The measured response of the interaction between hue contrast and chroma

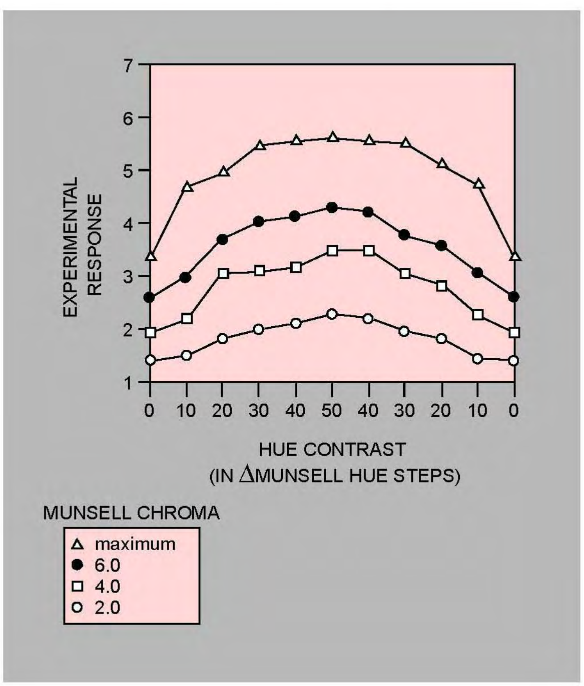
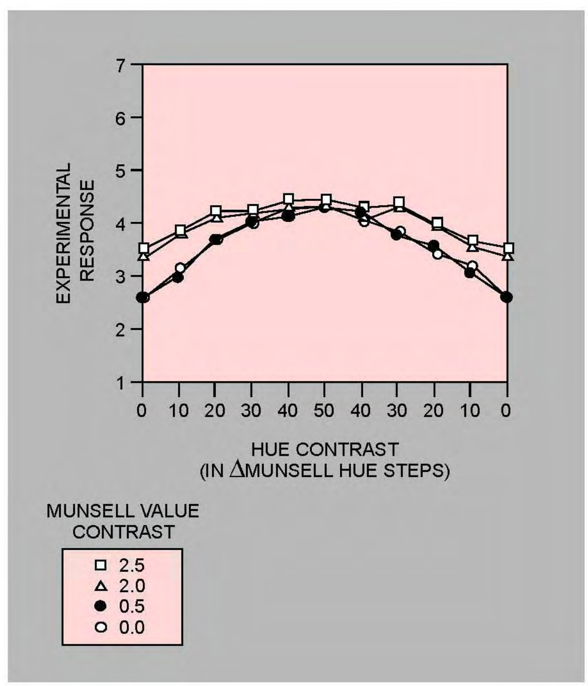


Figure 13 The measured response of the interaction between hue contrast and value contrast



- Reference hue: When comparing two hues, one of the hues is designated as the reference hue, the other as the related hue. In this investigation, the ten basic Munsell hues were selected as the reference hues (Figure 9A).
- Hue contrast: Hue contrast corresponds to the alignment between hues. It is defined as the distance in hue angle between any two colors, i.e., the amount of change in Munsell hue units between two hues. Hue contrast is a measure that indicates relative angular distance from a reference hue, independent of the reference hue (Figure 9B).
- Chroma: Chroma indicates the degree of departure of a color from a neutral of the same value. Chroma corresponds to the distance from the achromatic core. In Munsell notation, neutrals are defined as having chroma equal to zero. The chroma of a color increases up to a maximum number that varies, depending on the hue and value of the color (Figure 9C).
- Reference value: The Munsell color system can be visualized as consisting of planes of samples of equal value that are stacked perpendicular to a central achromatic core. When comparing two colors, the value of one color is designated as the reference value. With respect to the reference value, the related color may be of either "equal," "higher," or "lower" value (Figure 9D).
- Value contrast: Value contrast indicates the difference in lightness between colors. It is computed by measuring the distance in value between colors. In Munsell notation, value contrast is a number ranging between zero and ten units (Figure 9E).
- Block size: Colors may be assembled in any size and configuration. For simplicity, in this investigation colors were confined to two-dimensional square waves whose characteristic frequencies varied in octave increments. These waves were arranged in a matrix configuration. The characteristic wave-length is measured in degrees of visual angle. The size of the blocks was large enough to be well beyond the range of optical mixing that occurs for sizes less than 0.25 degrees. The blocks spanned angles of greater than 0.5 degrees. The block size was inversely proportional to the border (or shoreline) shared by the colors in the stimulus (Figure 9F).
- Area ratio: The number of blocks assigned to each color within the stimulus varied. The ratio of the area of the colors varied between 1:1 and 5:1 (Figure 9G).

The experiment measured the interaction of these seven dimensions of color experience. The magnitude of response along the semantic differential scales to hue contrast is used as a reference in the analysis of the data. The measured responses are bilaterally symmetric around the reference hue.

The lowest values existed at the endpoints that corresponded to monochrome, and the peak values corresponded to complementary colors. Figures 10 and 11 illustrate the interaction between hue contrast and chroma. Both the mean response and the spread between minimum and maximum response are

Figure 14 Plot of Equation 1 showing (A) holding h1=Y, and (B) holding h1=BP

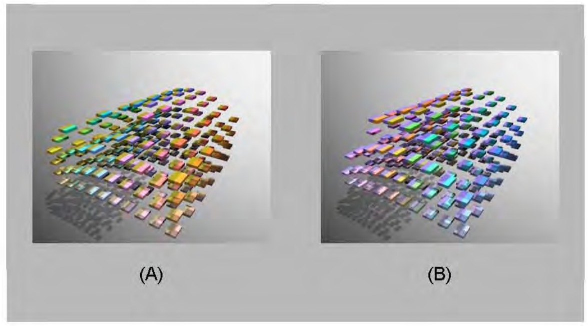


Figure 15 Rules of relative contrast are used to prescribe (A) quiet and (B) loud colors.

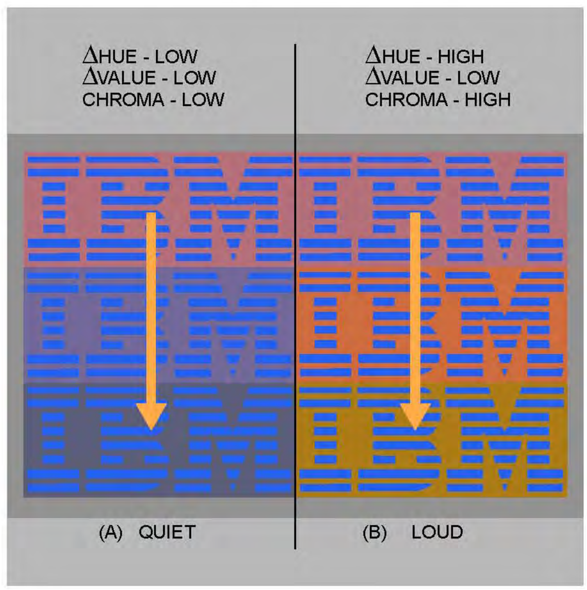


Figure 16 **The same reference hue, pink in this example, can carry two very different messages: (A) "baby colors" are a result of decreasing hue and value contrast, and (B) "soccer colors" are a result of increasing hue and value contrast.**

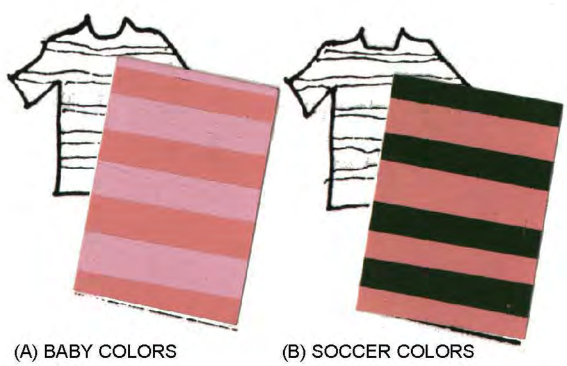
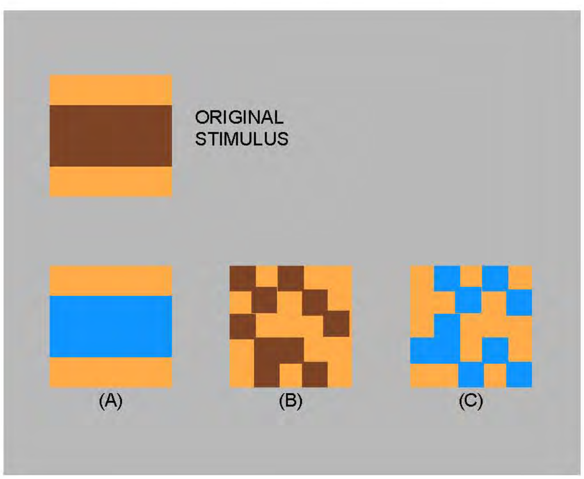


Figure 17 **There are multiple means to affect experience: changing (A) chromatic attributes, (B) spatial attributes, or (C) both.**



directly proportional to chroma. Figures 12 and 13 illustrate the interaction between hue contrast and value contrast. The mean response is directly proportional to the value contrast. The spread is *inversely* proportional to value contrast. As value contrast varies, mean and spread vary in opposite directions. Graphically, as value contrast increases, the ends of the curves move up, resulting in a "flatter" response.

As value contrast increases, the flat response indicates that the effect of hue alignment is weakened because of diminished spread. This suggests a strong interaction between value contrast and hue alignment.

The seven dimensions listed earlier are sufficient to describe the phenomenology of color experience for simple color configurations. However, additional dimensions, such as separation between colors, enclosure of colors, and temporal effects, can be added. The results of numerous repetitions of the experiments indicated that five of the seven dimensions had a statistically significant effect on experience. They are hue contrast, value contrast, reference value, chroma, and block size. The remaining two dimensions, area ratio and reference hue, had no significant effect. The overall results are summarized in Table 1.

The experimental data can be modeled by Equation 1:

$$f(v, w, x, y, z) = ac(0.5 - x)^2 + bc \qquad (1)$$

where v is the average value $((value_1 + value_2)/2)$, w is the normalized block size in terms of a reference frequency $((\log_2(\text{frequency/reference}))$, x is the normalized hue contrast $((|hue_1 - hue_2|)/100)$, y is the value contrast $(|value_1 - value_2|)$, z is the average chroma $((chroma_1 + chroma_2)/2)$, $a = (y - z)$, $b = (v/5 + z/2)$, and $c = 1.3^w$.

Hue contrast (x), value contrast and average chroma (a), and block size (c) account for the most rapid transitions in the model.

The dimensions of color experience can be visualized as spanning the multidimensional space described by $f(v,w,x,y,z)$ in which all experiences are represented. Experiences comprise a response "space" that indicates the magnitude of the responses for a given combination of dimensions. The space spanned by the dimensions of experience provides the framework for establishing any color experience because it indicates how experiences relate to one another. Establishing color experience amounts to a "navigation" in the space. For instance, traversing the space along a region of constant responses results in experiences that are equivalent to one another. Navigation is performed by adjusting the contributions of each dimension to the overall experience, and varying the position in the space.

A plot of Equation 1 is shown in Figure 14. Examples of rules for adjusting relative position in the space are shown in Figure 15. Figures 16 and 17 illustrate example applications of the model.

An intelligent tool for selecting colors

Color, when once reduced to certain definite rules, can be taught like music.

—G. Seurat

People who think and create on an abstract level tend to experience difficulties when they cannot readily translate their abstract thoughts into tangible details, e.g., the nonartist's dilemma in attempting to draw a sad, frustrated, or understanding face. Most of us do not have the skills necessary to translate these simple abstract notions into a concrete drawing.

Most people are color-inarticulate as well. Few of us are able to create consistent and robust messages with color. However, through the use of an expressive model, within a system of constraints, a person might improve his or her ability to compose a visual message that conveys his or her abstract thoughts.

The rules that govern color appearance, context, and expression can be used as the basis for interactive grammars. These grammars can be used to perform high-level tasks, which are the foundation for communicating with color messages, such as detection, legibility, and categorization, as well as expression.

One example of an intelligent tool for selecting colors is the Color Rule and Font Tool (CRAFT),[23-25] which is being developed by Rogowitz et al. as a general architecture for adding guidance to interactive systems that have been extended to the domain of user interface design. The CRAFT system constrains choices for each operation (e.g., selection of background color and text color) based upon perceptual[26] "rules." CRAFT shares many design goals with other automated or guided design systems, such as those described by Mackinlay,[27] Feiner and McKeown,[28] Roth and Mattis,[29] Weitzman and Wittenberg,[30] and Ishizaki.[31] CRAFT's particular emphasis is on the legibility and aesthetics of typography.

In the CRAFT architecture, all operations are linked; every time the user makes a selection, the impact of that choice is reflected in the selections for other operations. For example, if the user selects a color for a window background, that information is fed back to the operation responsible for selecting text color, where legibility rules constrain choices to ensure sufficient luminance contrast for good legibility. Adding rules for expression to the CRAFT architecture would be a way to ensure that the visual messages generated from an interactive system are effective.

Conclusion

Color demands a response.

—N. Jacobson

A future direction for this work is a study of how the experience of color is related to emotion. The dimensions of color experience constitute the internal context in which a message is received. Burling and Bender[32] argue that this context establishes a sense-of-order or expectation. The violation of expectation and the subsequent resolution of discrepancy is an emotion mechanism of the type described by Mandler.[33]

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