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Effects of Color on Emotions

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Emotional reactions to color hue, saturation, and brightness (Munsell color system and color chips) were investigated using the Pleasure–Arousal–Dominance emotion model. Saturation (S) and brightness (B) evidenced strong and consistent effects on emotions. Regression equations for standardized variables were: Pleasure = .69B + .22S, Arousal = −.31B + .60S, Dominance = −.76B + .32S. Brightness effects were nearly the same for chromatic and achromatic colors. Blue, blue–green, green, red–purple, purple, and purple–blue were the most pleasant hues, whereas yellow and green–yellow were the least pleasant. Green–yellow, blue–green, and green were the most arousing, whereas purple–blue and yellow–red were the least arousing. Green–yellow induced greater dominance than red–purple.

There is a large body of literature on the psychology of color. The research spans more than a century, covers a wide range of interests, and exhibits varying degrees of methodological rigor. The topics of investigation include: (a) color reactions as functions of personality and psychopathology, (b) physiological reactions to color, (c) color preferences, (d) color effects on emotions, (e) color effects on behavior, and (f) reactions to color concepts.

Methodological and Conceptual Issues

Color stimuli are characterized completely in terms of hue (i.e., wavelength), brightness or value (i.e., black-to-white quality) and saturation or chroma (i.e., purity or vividness, with lower saturation colors containing more grey). The following, more precise, definition of saturation is helpful: "Munsell chroma is often considered to be the approximate counterpart of perceived saturation. The Munsell chroma of a color sample is defined as the difference from a grey of the same lightness" (Agoston, 1979, p. 87).

As Gelineau (1981) noted, much of the research on color and affect is weak on several grounds. The methodological problems can be grouped in two broad categories. The first group includes studies that have failed to provide adequate specifications or controls of color stimuli (e.g., absence of controls for saturation and brightness while investigating effects of hue) and use of nonstandard or unspecified lighting conditions. The second group of studies failed to use sufficiently reliable, valid, or comprehensive measures of emotional responses to color stimuli. Thus, despite the substantial body of experimental work in this area, results have failed to provide a thorough and general characterization of relationships between color and affect.

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The following review of some of the best studies in the field includes comments, when appropriate, on specific methodological problems associated with each study. It is useful, nevertheless, to provide a broad overview of the types of methodological problems encountered in this literature. (Specific studies exhibiting each type of methodological problem were reviewed by Valdez, 1993.)

The first group of methodological problems relates to color stimuli. Many studies have simply reported vague verbal descriptions of the color samples displayed to subjects. Other researchers selected color stimuli that they *felt* best represented particular hues, such as red or green. Also, a number of studies did not use actual color stimuli but instead elicited subjects' responses to verbal labels of color (e.g., "red" or "black").

Other studies have failed to relate the color samples used to a standardized system of color notation (e.g., Munsell). Some of these specified one aspect (usually hue) but failed to specify the two additional characteristics of color necessary for a complete description of the color samples used. Other researchers who have provided an exact specification of each color sample (e.g., a Munsell blue with saturation value of 8 and brightness of 5) have tested differences in reactions to color samples that confounded hue, saturation, and brightness effects.

The second group of methodological problems relates to responses to color (i.e., the dependent measures) and is illustrated by studies that have used adjective checklists with dubious reliability and validity to assess emotional reactions to color. An even more problematic technique involved having subjects match verbal emotion labels to different color samples. Single-emotion terms that refer vaguely to discrete emotional states (e.g., "exciting" or "comfortable") have doubtful reliability for assessing emotional reactions. Furthermore, in the absence of a theoretical system that interrelates discrete emotional states, single-emotion terms do not provide a basis for characterizing similarities and differences in emotional reactions to various colors.

Other studies have used extremely rudimentary measurement techniques by, for instance, requesting that subjects rank the color samples on pleasantness. The single term "pleasantness" is apt to elicit different sets of associations from different subjects. Some people, for instance, may associate pleasantness with comfort and relaxation (i.e., pleasure plus low arousal), whereas others may associate it with excitement and elation (i.e., pleasure plus high arousal). Thus, whether used for characterizing color samples or for comparing (ranking) colors, single terms are likely to have doubtful reliability and validity in assessing emotions.

It also is difficult to abstract general patterns of findings from the color–emotion literature, because experimenters have used highly limited assessments of reactions to color (e.g., feelings of aggression) or have used different and nonoverlapping dimensions to assess emotional reactions to color (e.g., "happy" or "showy" in one study, as compared with "arousal" or "preference" in others). A comprehensive system for the description of emotions is needed to compare and contrast findings from studies that have used these nonoverlapping dependent measures.

The Pleasure–Arousal–Dominance (PAD) Emotion Model

General characterization of the emotional effects of color requires a framework for the general description of emotional states. The rationale for the PAD emotion model, used in the present series of studies, is reviewed here, because we use the model below to describe and interrelate findings that used a variety of verbal-report, physiological, and behavioral measures bearing on emotions.

Osgood, Suci, and Tannenbaum (1957) identified Evaluation, Activity, and Potency as three basic dimensions of meaning. These factors, originally extracted from reactions to verbal concepts, were replicated in studies of reactions to highly diverse stimuli, such as sonar signals and paintings (Osgood et al., 1957; Snider & Osgood, 1969). Mehrabian (1972) noted that the same or similar factors were obtained also from factor-analytic studies of social cues, including postures, body positions, facial and vocal expressions, gestures, and movements. The considerable generality of the semantic differential factors suggests that they represent lowest common denominators of cognition and are thus associated strongly with affective responses. These low-level cognitive–affective responses in turn form the basis for metaphorical comparisons of objects and events in distinct areas of human experience (e.g., Osgood, 1969).

Mehrabian and Russell (1974) suggested that the dimensions of pleasure–displeasure (the emotional counterpart of Evaluation), arousal–nonarousal (the emotional correlate of stimulus Activity), and dominance–submissiveness (the converse of stimulus Potency) could provide a general description of emotions. Their preliminary measures of pleasure, arousal, and dominance accounted for 27, 23, and 14 percent of variance, respectively, of emotional reactions to highly varied everyday situations (Mehrabian & Russell, 1974, Ch. 2).

Russell and Mehrabian (1977) also showed that most of the reliable variance in 42 verbal-report scales could be accounted for in terms of the PAD (i.e., pleasure, arousal, and dominance) emotion scales. Shaver, Schwartz, Kirson, & O'Connor (1987) used multidimensional analyses to study 135 emotion terms, and their results corroborated the PAD Emotion Model. Although they obtained two-dimensional (Evaluation and Intensity) and three-dimensional (Evaluation, Potency, and Activity) solutions, they found the three-dimensional representation of affect to be more informative than the two-dimensional one (Shaver et al., 1987, p. 1071).

The generality of the PAD Emotion Model is illustrated by dichotomizing each of the dimensions: pleasure (+P) versus displeasure (−P), arousal (+A) versus non-arousal (−A), and dominance (+D) versus submissiveness (−D). The resulting 2P × 2A × 2D emotion categories are illustrated by the following groups, which are derived from ratings of 240 emotional states on the PAD scales (Mehrabian, 1978; Russell & Mehrabian, 1977):

+P+A+D:	admired, bold, creative, powerful, vigorous
+P+A−D:	amazed, awed, fascinated, impressed, infatuated
+P−A+D:	comfortable, leisurely, relaxed, satisfied, unperturbed
+P−A−D:	consoled, docile, protected, sleepy, tranquilized
−P+A+D:	antagonistic, belligerent, cruel, hateful, hostile
−P+A−D:	bewildered, distressed, humiliated, in pain, upset
−P−A+D:	disdainful, indifferent, selfish-uninterested, uncaring, unconcerned
−P−A−D:	bored, depressed, dull, lonely, sad.

Sample average ratings on pleasure, arousal, and dominance (scored from −1 to +1), respectively, were as follows for some of the emotions in the preceding groups: bold (.44, .61, .66), impressed (.41, .30, −.32), comfortable (.85, −.19, .13), protected (.60, −.22, −.42), hostile (−.42, .53, .30), distressed (−.61, .28, −.36), uncaring (−.32, −.12, .28), bored (−.65, −.62, −.33).

The preceding review of the PAD Emotion Model illustrates the model's considerable generality and potential versatility as a descriptive system for emotions. Accordingly, in the present study we used improved versions of the PAD emotion scales, provided by Mehrabian (1978), to assess emotional reactions to color.

Color Reactions as Functions of Personality and Psychopathology

Despite considerable interest in this area, it is difficult to draw any reliable conclusions from the available work. Much of the relevant research is methodologically weak and usually has relied on the Rorschach (1942) and the Luescher Color Test (Luescher & Scott, 1969). Both of the latter measures have problems with respect to validity (e.g., note

Cerbus & Nichols, 1963, and Frank, 1976, for reviews of the literature).

Physiological Reactions to Color

These studies have been motivated largely by the hypothesis that long-wavelength colors (e.g., red and yellow) are more arousing than short-wavelength colors (e.g., blue and green). Experimental studies that have used physiological measures (e.g., galvanic skin response [GSR], electroencephalograph) generally have shown that red and yellow were indeed more arousing than blue and green (e.g., Gerard, 1958; Jacobs & Hustmyer, 1974; Wilson, 1966). For example, Wilson's (1966) subjects were exposed to five red and five green slides, in alternating order. Results with two measures supported the hypothesis that red is more arousing than green, with the effect being particularly apparent in the GSR data. It should be noted, however, that neither color brightness nor saturation were controlled in the study. More generally, none of the studies dealing with physiological reactions to color have investigated these reactions in relation to color brightness and saturation levels.

Color Preferences

Much of the earlier work dealing with color preferences has failed to control for the three dimensions of color—hue, saturation, brightness—and thus is methodologically flawed (e.g., Birren, 1952; Dashiell, 1917; Eysenck, 1941). Guilford (1934) and Guilford and Smith (1959), however, conducted some of the most systematic work in this area. Their studies yielded the following rank-ordering of hues, from most to least preferred: blue, green, purple, violet, red, orange, yellow. Also, Guilford and Smith (1959) found that brighter and more saturated colors elicited greater pleasure, with the relationships tending to be curvilinear.

Color Effects on Emotions

Experimenters used a variety of affect inventories and semantic measures in these studies. Jacobs and Suess (1975) investigated the effects of four primary colors (red, yellow, green, blue), projected onto a large screen. Scores on Spielberger, Gorsuch, and Lushene's (1970) State–Anxiety Inventory served as the dependent variable. Brightness and saturation levels of the colors were not controlled. Nevertheless, it is noteworthy that higher state-anxiety scores were associated with red and yellow than with blue and green. Because anxiety involves displeasure and high arousal, the latter findings were consistent with results from studies of physiological reactions to color (demonstrating that red and yellow were more arousing than blue and green) and with studies of color preferences (showing that red and yellow were less pleasant than blue and green).

Wexner's (1954) study dealt more generally with associations between color samples and words that describe feelings. The color red was associated with "exciting" and "stimulating," both of which imply pleasure and high arousal. Blue was associated with "secure/comfortable" and "tender/soothing," which imply pleasure and low arousal. Orange was associated with "disturbing/distressed/upset," implying displeasure and high arousal. Black was associated with "powerful/strong/masterful," implying high dominance. Although Wexner neither used standard specifications for her color samples nor controlled for brightness or saturation, her findings were generally in accord with those already reviewed.

Profusek and Rainey (1987) investigated the effects of rooms painted in red versus Baker–Miller pink on state anxiety. As hypothesized, pink elicited less anxiety than red.

Weller and Livingston (1988) investigated the effects of the color of paper (blue, pink, white) on which text was presented to subjects. Subjects read about rape and murder incidents and reported their emotional reactions to these events. The same events were less upsetting when described on pink paper than when described on blue or white paper. Brightness and saturation were not controlled in the study, although, pink generally tends to be of high brightness and low saturation, whereas white is of high brightness and is achromatic.

Subjects in Wright and Rainwater's (1962) study rated color chips on six connotative dimensions. "Showiness" (assumed here to be indicative of the arousing quality of a color) correlated positively with saturation and brightness. Furthermore, "calmness" (assumed to be indicative of the nonarousing quality of a color) correlated negatively with brightness. Together, these results suggest that arousal is a positive correlate of color saturation and brightness.

Color Effects on Behavior

A few studies have investigated effects of colors on distinct, and unrelated, behaviors. Garrett and Brooks (1987) found that ballot color (green vs. pink) affected voting behavior. When a candidate's sex was unspecified, men showed greater preference for candidates whose positions were printed on green ballots than for those whose positions were printed on pink ballots. Female subjects showed the reverse preferences. However, ballot color had no effect when candidate sex was specified: men tended to vote for men and women tended to vote for women, regardless of ballot color.

Damhorst and Reed (1986) investigated the effects on male raters of female job applicants' dark versus light clothing and facial expressions. Men rated models who wore dark jackets as more powerful and competent than models who wore light jackets. Also, brightness of clothing was more important than facial expressions in determining judgments of potency. Finally, Frank and Gilovich (1988) investigated the effects of black versus nonblack uniforms of professional football and hockey teams on aggressive behavior. They found that black uniforms, compared with nonblack uniforms, not only were associated with greater degrees of perceived aggression but also led to higher levels of player aggressiveness.

Reactions to Color Concepts

Unlike the preceding studies, which investigated emotional and behavioral reactions to specific color stimuli, the final study noted here dealt with emotional reactions to color concepts. Adams and Osgood (1973) conducted a very comprehensive cross-cultural study in which subjects from 23 different cultures rated color concepts (e.g., the words, "blue," "green," "yellow") using the semantic-differential factors (Osgood et al., 1957).

The following effects of hue were evident across the 23 samples as a group: Blue and green were good; yellow was weak and bad; red was strong and active; black was bad, strong, and inactive; grey was bad, weak, and inactive; white was good and weak; and color was good and active. In addition, evaluation correlated strongly and positively with brightness, potency correlated positively with darkness, and activity was associated strongly with color (vs. no color).

The preceding review shows that, despite considerable interest and work in the field, studies have yet to provide a thorough and general characterization of the relationships between color and emotions. The present series of studies was designed to address various methodological and conceptual issues by (a) using a wide range of color samples, (b) referencing the color samples in terms of a standardized system (Munsell), (c) using experimental controls in investigating the effects of color hue, saturation, and brightness, (d) using standardized background and lighting conditions, and (e) using a comprehensive system of measures to assess emotional reactions.

Hypotheses

Hypotheses were abstracted from the review noted above and are summarized as follows. Pleasure is a positive correlate of brightness and saturation. Short-wavelength hues (e.g., blue, green) are more pleasant than long-wavelength hues (e.g., yellow, orange). Because, however, findings on the pleasantness of red were contradictory, red was hypothesized to be neutral on pleasantness. Long-wavelength hues are more arousing than short-wavelength hues. Arousal is a positive correlate of brightness and saturation. Dominance is a negative correlate of brightness.

Plan of the Studies

We conducted three studies and addressed the following three questions, respectively: How are emotions affected by (a) brightness and saturation of colors, (b) hue, and (c) brightness of achromatic colors? A within-subject design could not be used to investigate all of the preceding effects in a single study, because there were too many color samples requiring judgment. Accordingly, the color samples were organized into the three categories noted above, thus allowing the use of a within-subject design in the investigation of each question.

Study 1

Study 1 was designed to investigate the emotional impact of color saturation and brightness. In the study, saturation and brightness were within-subject factors, and hue, along with subjects, provided replications.

Method

Subjects

Two hundred and fifty University of California undergraduates (103 men, 147 women) served as subjects, in partial fulfillment of a course requirement.

Materials and Setting

Color samples. Color samples were taken from the Munsell Color System (available from the Macbeth division of Kollmorgen Corporation) and were on 3-in. × 5-in. (7.6-cm × 12.7-cm) cards. The following 10 hue groups from the Munsell Color System were used: red, yellow, green, blue, purple; and the five intermediate hues, yellow–red, green–yellow, blue–green, purple–blue, and red–purple.

A minimum of 7 color samples was chosen from each hue level so as to provide representative variations of brightness and saturation for each hue. As much as possible, selections within each hue represented combinations of high and low saturation with high and low brightness. In all, 76 color stimuli were selected for testing.

Display of color samples. The color stimuli were placed in the window of an 8.5-in. × 11.0-in. (22-cm × 28-cm) middle grey (Munsell value = 5) background.

Test setting. The room where subjects were tested contained no windows and was illuminated with eight fluorescent tubes (Sylvania GTE, Design 50, at 40 W) with a color temperature at 5,000° K, which approximates daylight. The choice of lighting was important, because data from Munsell color samples have been derived from the CIE data for illuminant "C," which represents daylight conditions. Angles of illumination and observation were in accordance with Commission Internationale de L'Eclairage (CIE) recommendations (Judd & Wyszecki, 1975). Color stimuli were positioned such that the top of the display page was leaning away from the subject at a 45° angle from the vertical position (to allow a 45° illumination angle). Stimuli were approximately 24 in. (61 cm) from subjects.

Measures of emotional state. We used Mehrabian's (1978) verbal-report Pleasure–displeasure, Arousal–nonarousal, and Dominance–submissiveness (PAD) scales to assess emotional responses to color.

Items of the PAD scales were in semantic-differential format. To ensure unconfounded assessment of each of the three basic emotion factors, Mehrabian (1978) selected precalibrated emotion terms for each pair. The 2 words in each pair had been rated almost equally on two emotion factors and differed greatly on the third remaining emotion factor. For instance, the 24 pairs (items) of the Pleasure–displeasure Scale were exemplified by "happy–cruel" and "affectionate–nasty." "Happy" and "cruel" had been rated almost equally with respect to connotations of arousal and dominance but differed with respect to pleasure. Similarly, "affectionate" and "nasty" fulfilled the requirement of differing on pleasure but being nearly equal on arousal and dominance.

For each pair, subjects placed a check mark in one of nine spaces separating the pair to show how they felt. The Arousal–nonarousal Scale contained 8 items exemplified by "troubled–dull" and "frustrated–sad." These pairs differed with respect to arousal but were almost equal on pleasure and dominance. The Dominance–submissiveness scale contained 15 items exemplified by "masterful–fascinated" and "violent–fearful."

Half the items in each of the Pleasure and Arousal scales and 7 of the 15 Dominance items were inverted to control for response bias. Items from all three scales were intermixed to achieve an opaque (nonobvious) assessment of the various emotions.

Procedure

Subjects were run in groups of 2. Each subject rated seven to nine different color samples within the same hue. The color samples were presented to subjects one at a time. The order of presentation of color samples was designed to avoid extreme (or minimal) changes in brightness and saturation in successive stimulus presentations. Instructions given the subjects included the following key statements: "I will present you with one color at a time. It is important that you take time to just look at the color and to think of how it makes you feel before you start to rate it. Look at the color as often and as long as you need to get an accurate rating."

Subjects responded to Mehrabian's (1978) three PAD emotion scales while viewing each color sample. When a subject completed rating a color sample, the completed emotional-response forms were removed, and a new set of blank forms was presented along with the next sample to be rated. A 5-min break followed the rating of the fourth color sample and was intended to maximize subject attentiveness in rating the remaining samples.

Results and Discussion

Reliabilities of the Dependent Measures

The 250 subjects in Study 1 each rated a minimum of seven color samples. In this way, pleasure, arousal, and dominance reactions were assessed a total of 1,896 times across color samples and subjects. Alpha internal consistency–reliability coefficients, based on these data, were .97 for the 24-item Pleasure–displeasure Scale, .85 for the 8-item Arousal–nonarousal Scale, and .90 for the 15-item Dominance–submissiveness Scale.

The preceding coefficients were high and provided evidence of satisfactory levels of internal consistency (reliability) for all three dependent measures of emotional state.

Computation of Averaged Emotional Reactions to Each Color Sample

A total of 76 color samples was used in Study 1, and each color sample was rated by approximately 25 subjects. Group reactions, rather than individual reactions, to each color sample were of primary interest from a pragmatic standpoint (i.e., with respect to possible generalizations from the present results to everyday life situations). Therefore, we computed average emotional reactions on pleasure, arousal, and dominance for each color sample across all subjects who rated that sample. These averaged values of pleasure, arousal, and dominance response to each color sample served as the dependent variables in subsequent data analyses reported below. It is important to note that basing statistical analyses of the data on such averaged (instead of individual reaction) scores to the color samples reduced the number of observations and provided more conservative estimates of statistical significance in the following analyses.

Linear Regression Analyses

We used stepwise multiple regression analyses to explore possible contributions of brightness and saturation to each of the three dependent measures of emotional state (pleasure, arousal, and dominance).

In the first of three regression analyses, averaged pleasure–displeasure responses to each of the 76 color samples constituted the dependent variable, and brightness and saturation were independent variables. Two analogous regression analyses were done for arousal–nonarousal and dominance–submissiveness. Significance was assessed at the .05 level and yielded the following three equations, which are written for standardized variables to facilitate comparisons of the magnitudes of various significant effects. The numbers in parentheses to the right of each equation are multiple regression coefficients.

$$\text{Pleasure} = .69\ \text{Brightness} + .22\ \text{Saturation} \quad (.69) \tag{1}$$

$$\text{Arousal} = -.31\ \text{Brightness} + .60\ \text{Saturation} \quad (.73) \tag{2}$$

$$\text{Dominance} = -.76\ \text{Brightness} + .32\ \text{Saturation} \quad (.87) \tag{3}$$

The multiple regression coefficients for Equations 1–3 range from .69 to .87, showing that a substantial portion of variance in emotional response to colors is explained by brightness and saturation levels of colors. This result is of considerable importance in considering possible effects of color hue on emotional response (investigated in Study 2).

The positive relationships of brightness and saturation with pleasure were hypothesized. As expected, brighter and more saturated colors were more pleasant (Equation 1). However, the differential magnitudes of these two effects had not been anticipated. The present results indicate that brightness had a considerably stronger effect than saturation on pleasure–displeasure reactions to color samples. Although this result was not anticipated, it nevertheless represents an important generalization regarding emotional responses to color.

Equation 2, for arousal, indicates that less bright and more saturated colors were more arousing. Here, the hypothesized positive relationship between saturation and arousal was correct; however, results were exactly opposite to that hypothesized for the relationship between brightness and arousal.

One reason for the incorrect hypothesized relationship between brightness and arousal is that the latter hypothesis was inferred from reports that used experimental methods that confounded brightness and saturation levels while testing for the effects of brightness. In retrospect, and given the present findings, it is apparent that previous studies tended to select highly saturated and bright colors when sampling for bright colors. Reexamination of each set of Munsell color chips within each hue shows that it is easy to think of bright colors as those that also are more saturated. Thus, the greater arousal response to such highly saturated color samples (used in previous studies) was incorrectly attributed to brightness rather than to saturation. This error was possible because the contribution of saturation to arousal is almost twice the magnitude (note the coefficient of +.60 in Equation 2) of the effect of brightness on arousal (a coefficient of −.31).

Equation 3 indicates that less bright and more saturated colors induced greater feelings of dominance in viewers. The effect of brightness had been hypothesized, although no hypothesis was offered regarding the relationship between saturation of colors and feelings of dominance they induced.

An alternate description of the results in Equation 3 is that the darker (less bright) colors elicited feelings of strength or boldness. Also, more saturated colors (being more vivid, purer, or stronger) also induced feelings of dominance. The regression results in Equation 3 also indicated that the effect of brightness was considerably stronger than that of saturation in determining dominance responses to color.

Separate Linear Regressions for Men and Women

We replicated the data analyses reported in the previous section separately for male and female subjects in Study 1. The objective of such additional analyses was to ascertain possible differences in emotional responses of men and women to brightness and saturation of colors. Results of these additional regression analyses are given in Table 1. For reference, Table 1 also contains overall results for the combined sample of men and women reported in the previous section.

Examination of Table 1 shows that men and women reacted with highly similar emotional responses to brightness and saturation levels of color samples. Overall, results for women were slightly stronger, as evidenced by a larger number of significant effects (in Table 1, color saturation related significantly to pleasure for women but not for men). Also, the magnitudes of the multiple regression coefficients were greater in the equations obtained for women, compared with men.

The statistical significance of this pattern of differences for men and women was assessed as follows. In six out of six comparisons of regression coefficients, the coefficients for women were larger than those for men, and this result was significant using the cumulative binomial distribution ($p = .0156$). This result suggested that women, compared with men, were slightly more sensitive in terms of their emotional reactions to brightness and saturation levels of colors.

Previous reviews of sex differences in color preferences (Norman & Scott, 1952; Whitfield & Wiltshire, 1990) have suggested general similarities in male and female preferences for (or rankings of) various colors, while noting sex differences in the strengths of those preferences. The present findings help shed additional light on the question of possible sex differences in reactions to colors. Very simply, men and women reacted in highly similar emotional ways to brightness and saturation levels of colors, with women consistently showing a slightly stronger pattern of reactions.

Table 1
Regression Coefficients for Brightness and Saturation as Determinants of Pleasure, Arousal, and Dominance in Study 1

Dependent variable	Regression coefficients (beta weights): Brightness	Saturation	Multiple regression coefficient
Pleasure			
Men & women	.69***	.22*	.69
Men only	.61***		.61
Women only	.68***	.23*	.68
Arousal			
Men & women	−.31***	.60***	.73
Men only	−.27**	.54***	.65
Women only	−.31***	.60***	.72
Dominance			
Men & women	−.76***	.32***	.87
Men only	−.72***	.21**	.79
Women only	−.73***	.36***	.86

Note. All coefficients are given for standardized variables (as beta weights) to facilitate comparisons of the relative magnitudes of effects.
* $p < .05$; ** $p < .01$; *** $p < .001$.

Nonlinear Regression Analyses

We conducted additional regression analyses to test for possible second-order curvilinear relationships between the dependent and independent variables. First we conducted three separate regression analyses (for the dependent variables pleasure, arousal, and dominance, respectively) to test for possible significance of saturation and (saturation)^2. None of these three regression analyses produced significance for the (saturation)^2. Emotional reactions to different saturation levels of color are thus described best as linear effects, as given in Equations 1–3 and in Table 1.

We conducted a second set of three regression analyses to test for effects of brightness and (brightness)^2 on pleasure, arousal, and dominance, respectively. No significant effect of (brightness)^2 was obtained for pleasure. Thus, the linear effect of brightness on pleasure, as given in Equation 1, and the separate effects of brightness on pleasure for each sex, as given in Table 1, are sufficient.

However, the corresponding analyses for arousal and dominance yielded the .01-level significant effects given in Equations 4 and 5 that follow. These equations are written for raw (nonstandardized) arousal and dominance scores and brightness values (of which six discrete levels had been sampled and ranged from 5 to 60) taken from the Munsell system.

$$\text{Arousal} = 8.724 - 0.62(\text{Brightness}) + .007173(\text{Brightness})^2 \quad (4)$$

$$\text{Dominance} = 28.156 - 1.66(\text{Brightness}) + .016(\text{Brightness})^2 \quad (5)$$

The multiple regression coefficient for Equation 4 is .52. Actual mean values of arousal and those predicted from Equation 4 were plotted against brightness (for each of the six brightness values sampled) and showed extremely close agreement (see Figure 1). Both the actual and predicted plots showed arousal declined steeply and monotonically with increasing brightness up to a brightness value of 43, beyond which arousal reversed and increased slightly for the highest brightness value. Generally, then, arousal decreases as colors range from dark to light, but there is a small reversal and increase in arousal for the lightest colors.

The multiple regression coefficient for Equation 5 is .88. Actual mean values of dominance and those predicted from Equation 5 were plotted against brightness (for each of the six brightness values sampled) and showed extremely close agreement (see Figure 2). Both the actual and predicted plots showed that dominance declined steeply and monotonically with increasing brightness up to a brightness value of 43, beyond which dominance leveled off. Generally, then, dominance decreases as colors range from dark to light but levels off for the lightest colors.

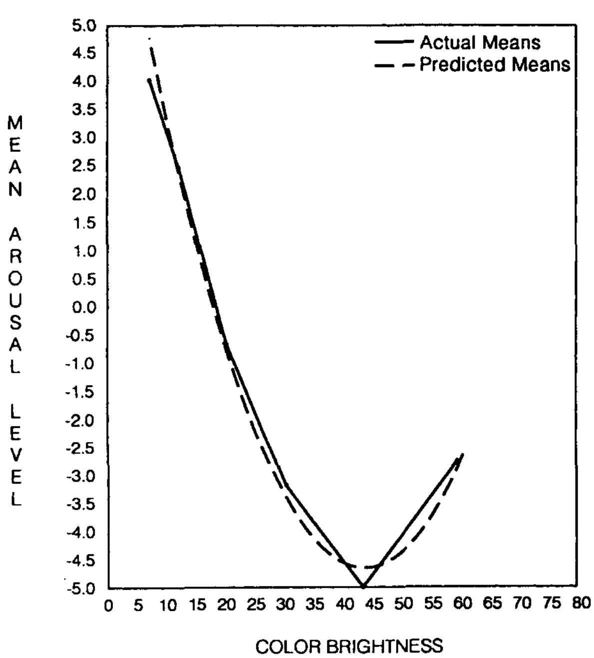

Figure 1. Actual and predicted average arousal levels as functions of color brightness in Study 1.

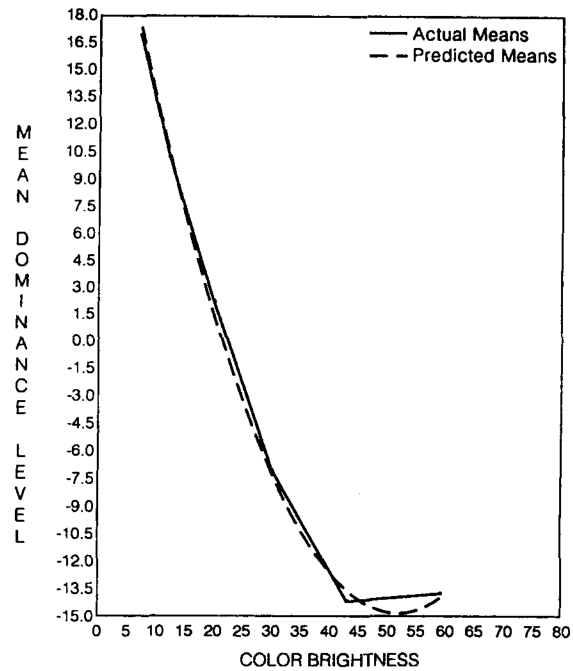

Figure 2. Actual and predicted average dominance levels as functions of color brightness in Study 1.

Study 2

In Study 2 we focused on the effects of color hue on emotions. Each subject rated 10 different hues of approximately the same brightness and saturation levels. Thus, here, hue was a within-subjects factor, and brightness and saturation, along with subjects, provided replications.

Method

Subjects

Subjects were 121 University of California undergraduates (47 men, 74 women) who served in partial fulfillment of a course requirement.

Materials and Setting

Five replication sets of 10 different hues were used. The 10 different hues in each replication were of equal brightness and saturation values. Furthermore, each of the five replications represented different levels of brightness and saturation.

The testing room, lighting, presentation of each color sample framed in the window of a middle-grey background, and the emotional-state measures were identical to those used in Study 1.

Procedure

Subjects were run 2 at a time. Each subject rated his or her emotional reactions to a succession of 10 color samples, all of which were of equal brightness and saturation and varied only in hue. Subjects received instructions analogous to those in Study 1.

Each subject rated his or her reactions to the first color sample, was given a fresh set of rating sheets while he or she viewed the second color sample to rate, and so forth. To minimize subject fatigue, we gave subjects a 10-min break after they rated the fifth sample. Five more color samples were rated after the break. Order of presentation of the 10 hues varied between subjects and was designed to avoid ratings of adjacent wavelengths in succession.

Results and Discussion

Reliabilities of the Dependent Measures

The 121 subjects in Study 2 each rated 10 color samples. In this way, pleasure, arousal, and dominance reactions were assessed a total of 1,210 times across color samples and subjects. Alpha reliability coefficients obtained from these data were .97 for the Pleasure–displeasure Scale, .76 for the Arousal–nonarousal Scale, and .90 for the Dominance–submissiveness Scale. All three reliability coefficients were deemed satisfactory.

Computation of Averaged Emotional Reactions to Each Color Sample

Fifty color samples were used in Study 2, and each color sample was rated by nearly 25 subjects. As in Study 1, average pleasure, arousal, and dominance reactions to each color sample were computed across all subjects who had rated that sample. These averaged values of pleasure, arousal, and dominance response to each color sample served as the dependent variables in the data analyses reported below.

Multivariate Analysis of Variance (MANOVA)

We used MANOVA to explore possible effects of hue (10 levels), subject sex, and Hue × Sex on pleasure, arousal, and dominance reactions to colors. Significance of MANOVA effects was assessed at the .001 level. When significant multivariate effects were obtained, the corresponding significant univariate effects were interpreted.

The Hue × Sex interaction failed to achieve significance, $F(27, 240) = 0.66$, $p > .50$, thus indicating that men and women did not differ significantly in their emotional reactions to the sample of 10 hues.

The MANOVA yielded significance only for hue, $F(27, 240) = 5.85$, $p < .001$. Significant .01-level main effects were obtained in the univariate analyses of all three dependent measures: pleasure, $F(9, 80) = 21.21$; arousal, $F(9, 80) = 3.80$; dominance, $F(9, 80) = 3.06$.

Tukey's Multiple Comparison Procedure was used to test for simple effects of hue on each of the three dependent variables.

Effects of Color Wavelength on Pleasure

A difference exceeding 22.50 in mean pleasure ratings for any two hues (Tukey's $W = 22.50$) was significant at the .05 level. Figure 3 depicts a plot of mean pleasure responses to each of the 10 hues and is helpful in describing the significant findings. In Figure 3, the 2 complementary hues, purple and red–purple, are listed separately in the right-hand section of the graph.

Pleasure levels for blue, blue–green, green, red–purple, and purple were significantly greater than those for green–yellow, yellow, and yellow–red. Furthermore, pleasure levels for purple–blue and red were significantly greater than those for green–yellow and yellow. Finally, the pleasure level for yellow–red was significantly greater than that for yellow.

We analyzed data for the eight noncomplementary colors in a regression analysis in which wavelength was the independent variable and pleasure was the dependent variable. (The two complementary colors could not be included in the regression analysis, because these are not scaled alongside noncomplementary colors with respect to wavelength.)

Forty pleasure means (corresponding to five different colors in each of eight wavelength values) were available for analysis. Because the plot of actual means in Figure 3 suggests a curvilinear relationship, the regression analysis tested for effects of wavelength and (wavelength)^2 on pleasure ratings. The results of this regression analysis are summarized in Equation 6, which is written for raw pleasure scores and wavelength values of the color samples in the Munsell system. Significance of effects was assessed at the .05 level. The multiple regression coefficient for Equation 6 is .68.

$$\text{Pleasure} = 1561 - 5.48(\text{Wavelength}) + .0048(\text{Wavelength})^2 \quad (6)$$

Figure 3 also shows predicted pleasure scores, computed from Equation 6, for the eight noncomplementary wavelengths. The plot of predicted pleasure values in Figure 3 shows that Equation 6 provides only a rough approximation of the obtained means: Pleasure–displeasure reactions to noncomplementary colors were approximately a U-shaped function of wavelength, with yellows (green–yellow, yellow, and red–yellow) at the bottom portion of the U.

The latter findings were generally consistent with hypotheses derived from review of the literature. Nevertheless, the present findings provided a more concise way of describing relations of hue to pleasure: Short-wavelength hues were rated as being the most pleasant, with intermediate-wavelength hues being assigned low levels of pleasantness. Furthermore, yellow–red and red (the long-wavelength hues) reversed this trend and showed an increase in pleasure ratings. Finally, complementary colors (red–purple and purple) elicited high pleasure ratings comparable to ratings for the short-wavelength noncomplementary colors.

Effects of Color Wavelength on Arousal

As noted, the univariate effect of wavelength was significant for the dependent measure arousal. Using the Tukey test, a difference exceeding 4.55 in mean arousal ratings for

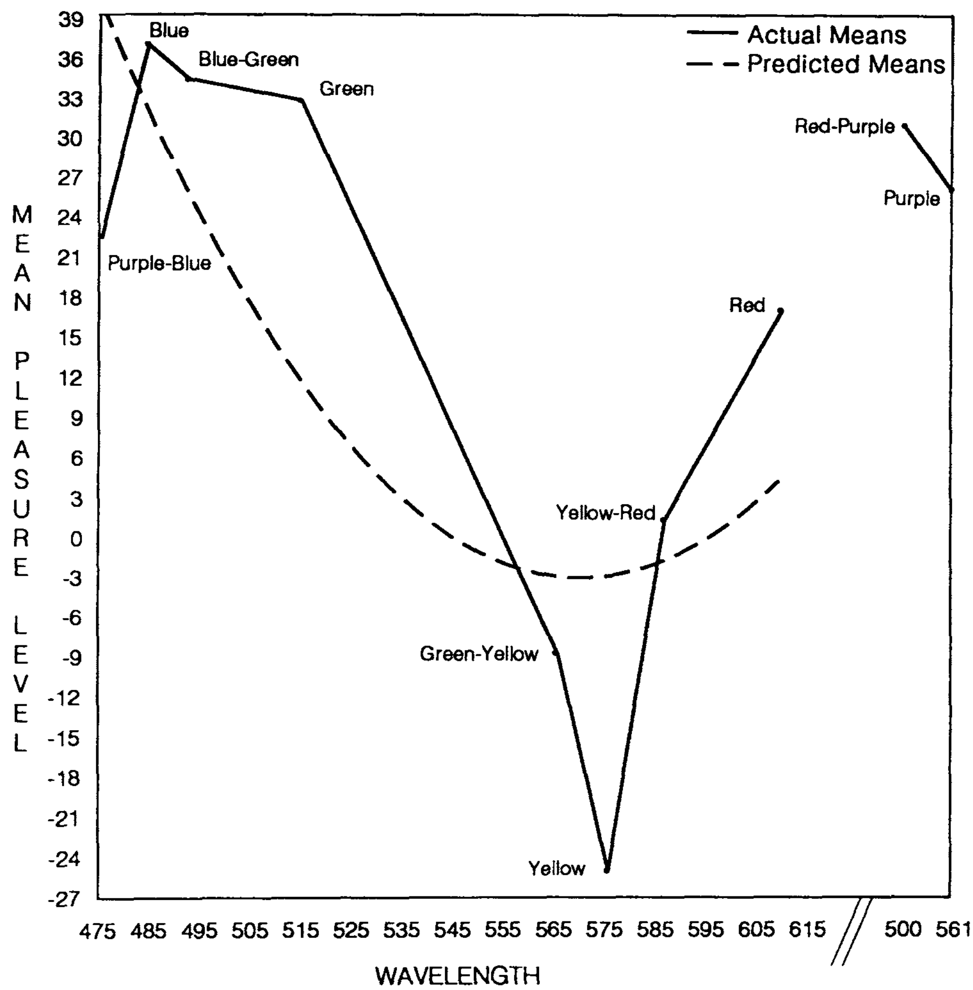

Figure 3. Actual and predicted average pleasure levels as functions of color wavelength in Study 2.

any 2 hues (Tukey's $W = 4.55$) was significant at the .05 level. Figure 4 provides a plot of mean arousal responses to each of the 10 hues. In Figure 4, the 2 complementary hues, purple and red–purple, are listed separately in the right-hand section of the graph.

The results given in Figure 4 did not support any of the hypothesized relationships between hue and arousal. Instead, the findings in Figure 4 showed that mean arousal level for green–yellow was significantly greater than the mean arousal levels for purple–blue, yellow–red, and red–purple. Also, the mean arousal level for blue–green was significantly greater than the mean arousal level for purple–blue.

We used a regression analysis to test for possible significance of a parabolic relationship of arousal (the dependent variable) to wavelength (the independent variable). Significance was not obtained for either the linear component of wavelength or for $(\text{wavelength})^2$.

The obtained results relating hue and arousal were generally weak and nonsignificant. The only noteworthy generalization is that the green hues (green–yellow, blue–green, and green) elicited the highest arousal reactions from subjects. In this context, it is interesting to note that some fire departments are replacing their traditional highly saturated red trucks with trucks that have been painted green–yellow. The changeover to green–yellow as a choice for an attention-getting (or highly arousing) color is most appropriate in terms of the present findings.

Effects of Color Wavelength on Dominance

The univariate effect of wavelength was significant for the dependent measure of dominance. Using the Tukey test, a difference exceeding 12.48 in mean dominance ratings for any 2 hues (Tukey's $W = 12.48$) was significant at the .05 level. Figure 5 depicts a plot of mean dominance responses to each of the 10 hues.

No hypotheses had been offered regarding relationships of hue to dominance. The obtained results, shown in Figure 5, were generally weak and nonsignificant. The only pattern of significant differences was as follows: Green–yellow and

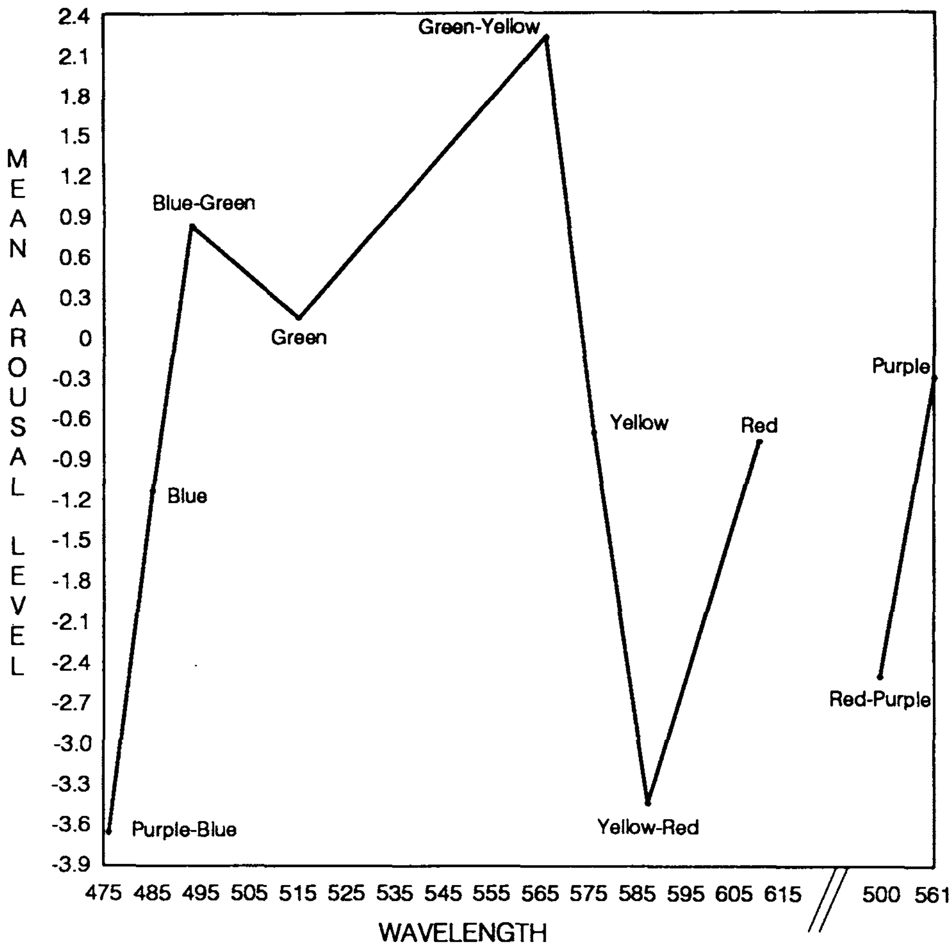

Figure 4. Mean arousal level as a function of color wavelength in Study 2.

yellow were rated as significantly more dominant than red–purple.

General Evaluation of Effects of Hue on Emotions

Findings in the present study that bear on relationships of hue to emotions were much weaker than anticipated. Although effects of hue on emotions were expected to be weaker than the effects of brightness and saturation, results were nevertheless disappointing. In particular, results relating hue to arousal and dominance were weak. In comparison, results bearing on relationships of hue to pleasure were far more detailed and provided substantial support for the corresponding hypotheses.

Study 3

In Study 3 we focused on the emotional impact of achromatic colors (i.e., white, three greys, black). Each subject judged all five samples.

Method

Subjects

Subjects were 25 University of California undergraduates (7 men, 18 women) who served in partial fulfillment of a course requirement.

Materials and Setting

Five achromatic color samples (corresponding to Munsell brightness values of 3, 12, 30, 43, and 79) were selected to represent the entire brightness dimension. The testing room, lighting, presentation of each color sample framed in the window of a middle-grey background, and emotional-state measures were identical to those used in Study 1.

Procedure

Subjects were run 2 at a time. Each subject rated his or her emotional reactions to all five achromatic color samples, one at a time. Subjects received instructions analogous to those in Study 1. Order of presentation of the five color samples was randomized across subjects.

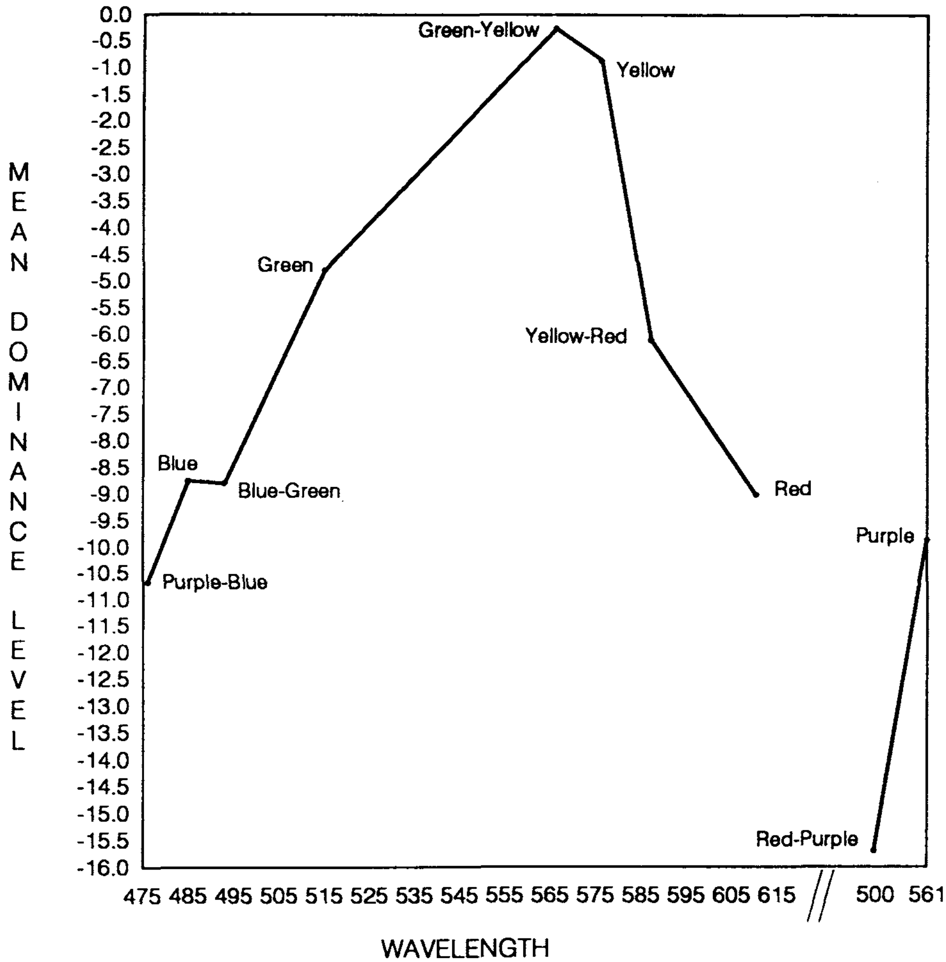

Figure 5. Mean dominance level as a function of color wavelength in Study 2.

Results and Discussion

Reliabilities of the Dependent Measures

The 25 subjects in Study 3 each rated five achromatic color samples, thus providing 125 pleasure, arousal, and dominance ratings. Alpha reliability coefficients were .98 for the pleasure scale, .80 for the arousal scale, and .93 for the dominance scale.

Computation of Averaged Emotional Reactions to Each Achromatic Color Sample

Five achromatic color samples (ranging from white to black) represented brightness variations only. Each color sample was rated by 25 subjects. As in Studies 1 and 2, we computed average pleasure, arousal, and dominance for each color sample across all subjects who rated that sample. These averaged emotional-response scores were used in subsequent data analyses.

Nonlinear Regression Analyses

We conducted three regression analyses to test for possible second-order curvilinear relationships between brightness (the independent variable) and pleasure, arousal, and dominance (the three dependent variables). Each regression analysis tested for possible significant effects of brightness and (brightness)^2 on each dependent measure. Significance was assessed at the .01 level, and the results are summarized in Equations 7, 8, and 9.

$$\text{Pleasure} = .71(\text{Brightness}) \tag{7}$$

$$\text{Arousal} = 8 - 0.6915(\text{Brightness}) + .0073(\text{Brightness})^2 \tag{8}$$

$$\text{Dominance} = 25 - 1.2675(\text{Brightness}) + .0088(\text{Brightness})^2 \tag{9}$$

Equation 7 is written for standardized variables and shows a multiple regression coefficient of .71. Equations 8 and 9 are written for raw values of arousal and dominance and for brightness values given in the Munsell system. Multiple regression coefficients are .47 and .65 for Equations 8 and 9, respectively. Plots of the actual and predicted mean values of arousal and dominance as functions of brightness are given in Figures 6 and 7, respectively.

The positive relationship between brightness of achromatic colors and pleasure, given in Equation 7, had been hypothesized. As expected, pleasure reactions increased as color samples ranged from black, through greys of increasing brightness, on to white. Stated otherwise, black was rated as least pleasant, greys were assigned intermediate values in pleasantness, and white was the most pleasant. The relationship between brightness and pleasure was very strong (note the beta weight of .71 in Equation 7) and highly significant.

The relationship of arousal to brightness of achromatic colors is given in Equation 8. No corresponding hypothesis had been offered. The results, plotted in Figure 6, show that arousal reactions to achromatic colors were a U-shaped function of brightness: Arousal response was greatest to black, diminished steadily for the three successive greys of increasing brightness, but increased to an intermediate value for white. Figure 6 also shows that the obtained arousal means for all five levels of brightness were predicted extremely well by Equation 8.

The relationship of dominance to brightness of achromatic colors is given in Equation 9. A negative relationship

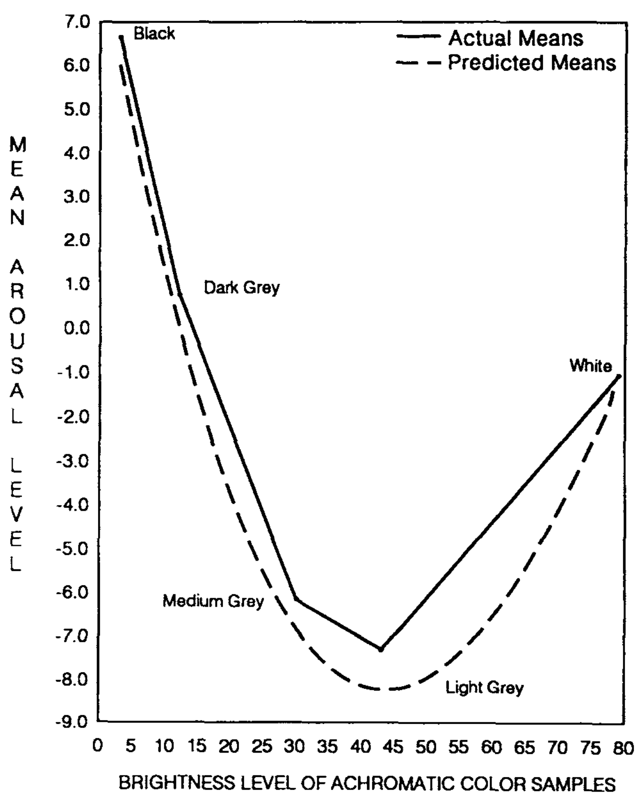

Figure 6. Actual and predicted average arousal levels as functions of brightness of achromatic colors in Study 3.

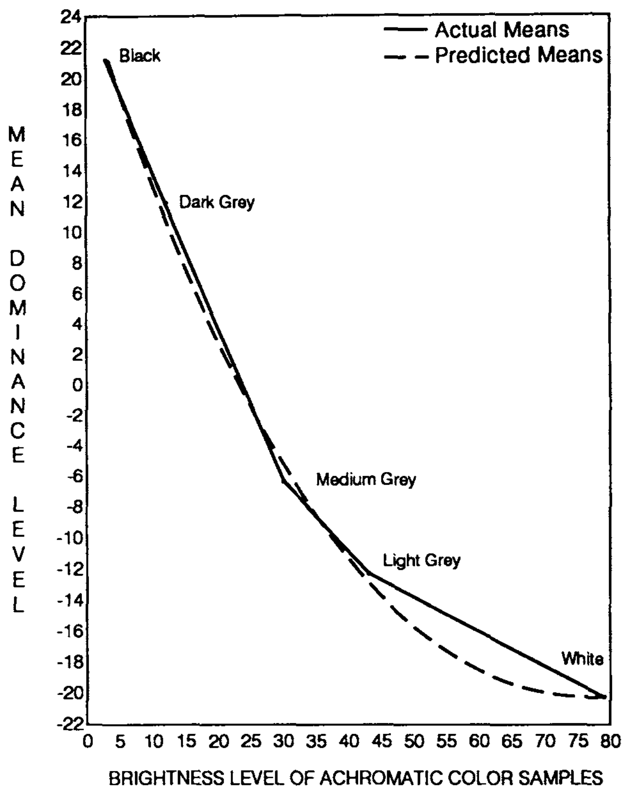

Figure 7. Actual and predicted average dominance levels as functions of brightness of achromatic colors in Study 3.

between dominance and brightness had been hypothesized. Results plotted in Figure 7 support this hypothesis but show the relationship to be parabolic: Although dominance decreased monotonically with increasing brightness, the slope became less steep for brighter colors. Thus, the color black elicited the highest level of dominance, greys elicited intermediate levels of dominance, and white elicited the lowest level of dominance. Figure 7 also shows that the obtained dominance means for all five levels of brightness were predicted extremely well by Equation 9.

General Discussion

Summary of Major Findings

The present studies provided highly consistent evidence regarding strong and highly predictable relationships of color brightness and saturation to emotional reactions. In comparison, relationships of hue to emotions were surprisingly weak, particularly for arousal and dominance reactions.

Effects of Brightness and Saturation

Results given in linear Equations 1–3 (or in Table 1) provided a surprisingly accurate description of the effects of color brightness and saturation on emotions. In addition, Figures 1 and 2 provide further refinements regarding effects of very high brightness (i.e., the lightest colors).

Pleasure was simply a joint positive function of color brightness and saturation, being influenced more by brightness than by saturation. Arousal increased linearly and strongly with color saturation. Also, arousal was a ladle-shaped function of color brightness: It decreased with increases in color brightness up to a Munsell brightness value of 43. Beyond that brightness level, arousal reversed and increased slightly for the highest level of brightness tested (Figure 1).

Dominance increased linearly and moderately with color saturation and decreased sharply with increases in color brightness up to a Munsell brightness value of 43. Dominance leveled off beyond that brightness level (Figure 2).

Findings for the effects of brightness of achromatic colors in Study 3 were very similar to those obtained for chromatic colors in Study 1, which are summarized above. Pleasantness of achromatic colors correlated .71 with brightness (as compared with a corresponding beta weight of .69 in Equation 1 for chromatic colors). As shown in Figure 6, arousal reactions to achromatic colors were a ladle-shaped function of brightness, paralleling the corresponding relationship shown in Figure 1 for chromatic colors. Dominance reactions to achromatic colors, shown in Figure 7, were a monotonically decreasing function of brightness and paralleled the corresponding relationship for chromatic colors shown in Figure 2.

Artists and designers have often distinguished "warm" versus "cool" colors and have assumed that warmer colors induce greater activity (e.g., Hogg, 1969). Mehrabian and Russell (1974, Ch. 4) reviewed findings showing that judgments of color warmth were highly reliable and that color warmth–coolness was a positive correlate of color saturation and a negative correlate of color brightness. The present findings did indeed show consistent patterns of response to cool colors (low saturation, high brightness) versus warm colors (high saturation, low brightness), supporting the more intuitive groupings and interpretations of colors offered by practitioners of the arts.

Effects of Hue

Findings in Study 2 regarding emotional reactions to color hue tended to be weak. Nevertheless, as shown in Figure 3, consistent support was obtained for proposed hypotheses relating pleasure to hue (or wavelength). Blue, blue–green, green, purple–blue, red–purple, and purple were the most pleasant; whereas yellow, green–yellow, and red–yellow were the least pleasant; with red being rated at an intermediate value of pleasantness.

In comparison, far weaker results were obtained relating hue to arousal or to dominance. The most arousing hue was green–yellow, followed by blue–green and green, whereas the least arousing hues were purple–blue, yellow–red, and red–purple (Figure 4). Finally, dominance reactions were greatest to green–yellow and yellow and differed from reactions to red–purple, which elicited submissive feelings.

The latter weak findings failed to support hypotheses bearing on the relationships of hue to arousal (no hypotheses had been offered for hue in relation to dominance). Findings bearing on color saturation and brightness in relation to arousal (Study 1) helped explain some of the common errors in assessing effects of hue on arousal. Examination of the Munsell color chips for each hue shows that there are systematic differences in saturation and brightness of colors considered typical or representative of each hue. For example, the samples of red that are commonly used in experiments are typically of very high saturation. This accounts for the common error in inferring that red is arousing. In fact, it is the high saturation of the red color samples used, rather than its hue, that accounts for the high levels of arousal observed.

Thus, many commonly held assumptions regarding the effects of color hue on arousal can be seen as being due to systematic confounding, in previous studies, of hue with brightness, saturation, or both, in assessing the arousing effects of hue. The hue–arousal hypotheses offered here were based primarily on physiological studies that assessed GSR reactions of subjects to rooms (or to slide projections) described as "green" or "red." All experiments that served as the basis for the proposed hypotheses failed to control for brightness and saturation effects in investigating effects of hue on arousal.

Theoretical Rationale for the Present Findings

A systematic theoretical explanation of the patterns of consensus reactions to color obtained here is beyond the scope of this paper. Nevertheless, it is useful to note Adams and Osgood's (1973) discussion of mechanisms that could explain consensus reactions to color—physiology of vision and commonly shared experiences with the environment. Their comments can be restated as follows in reference to the present findings. Physiological explanations are exemplified by the idea that photoreceptors may be stimulated more strongly by more saturated and darker colors, thus accounting for the association of such colors with high-arousal and high-dominance emotions. Common environmental experiences are illustrated by the association of clean and light-colored objects and their contrast with dirty and dark-colored ones. Although the latter are mere speculations, they may help identify fruitful avenues in the pursuit of a theoretical rationale to explain shared emotional reactions to color.

Implications Regarding the Emotion–State Measures

Assessments of emotional responses to color were reasonably comprehensive. We used the PAD emotion model and associated measures (Mehrabian, 1978, 1980); the PAD model was helpful in formulating general conclusions from previous experimental work that had used a large variety of apparently unrelated measures of emotional reactions to color.

Reliabilities of the PAD emotion scales were consistently high and satisfactory. Across all three studies, alpha reliability coefficients averaged .97 for the pleasure–displeasure scale, .80 for the arousal–nonarousal scale, and .91 for the dominance–submissiveness scale.

Validity of the PAD scales has been established in a large number of studies (e.g., Mehrabian, 1980, 1987). Indirect and tangential assessments of validity were provided here by the extent to which hypotheses derived from the literature were supported. With one exception, all hypotheses relating saturation and brightness to emotional reactions were supported. Failure to support the brightness–arousal hypothesis was explained readily by noting a systematic bias in the selection of highly arousing colors in previous experiments: Typically, experimenters have confounded high saturation with high brightness in investigating effects of brightness on arousal, thereby leading to the present incorrect hypothesis regarding that relationship.

A striking pattern of findings from the present studies also provided construct validity for the PAD scales. Study 1 yielded relationships of color brightness to pleasure, arousal, and dominance for a large sample of chromatic colors. In comparison, Study 3 provided the same relationships for a sample of achromatic colors. As noted in the summary of findings above, these findings for chromatic and achromatic colors were analogous. The similarity of color brightness–emotional reaction relationships in Studies 1 and 3, despite nonoverlapping samples of subjects and stimuli, provided strong evidence not only of replicability of the present findings but also of construct validity of the measurement instruments.

A final issue bearing on the PAD measures pertains to affect–cognition relationships. The adequacy and relevance of verbal-report measures for assessing emotional reactions to color may be questioned. In particular, one may argue that such reports can be attributed to cognitive reactions (e.g., learned conceptual associations to color names) rather than to physiological or visceral responses. A narrow answer to this argument is that the experimental procedure was designed deliberately to elicit emotional, rather than cognitive, reactions to the colors. Thus, no references to color names were made, and subjects were presented simply with various color samples and asked, specifically, to indicate how each sample made them *feel*.

On a more general level, although our procedures focused on emotions, the theoretical basis of the PAD emotion model suggests strong associations between cognition and affect. Indeed, the PAD scales are analogues of the Evaluation, Activity, and Potency factors which, in turn, may be characterized as the lowest common denominators of cognitive response. Thus, within the PAD model, the most rudimentary cognitive judgments (such as those that adult humans share with infants or animals) cannot be distinguished easily from emotional reactions. Instead, emotional responses are viewed as providing the essential foundation to cognitive judgments (i.e., attitudes, judgments, or preference are not considered possible in an emotional vacuum).

The association between affect and cognition is likely to be strongest in psychological functions that develop without the benefit of instruction or formal education (i.e., where cognition is unsophisticated and rudimentary). Because reactions to colors or odors exemplify such functioning, using the PAD scales to measure reactions to color is likely to produce emotion-based assessments.

Sex Differences

Results in Study 1 (Table 1) showed that men and women responded with highly similar emotional reactions to variations in color saturation and brightness. However, a small, though consistent and statistically significant, difference showed that women were more sensitive to brightness and saturation than men; that is, they exhibited more extreme emotional reactions to varying levels of color brightness and saturation.

Results in Study 2 showed that the multivariate Hue × Sex interaction on pleasure, arousal, and dominance was not significant. Thus, we inferred that men and women responded with similar emotional reactions to various hues (or wavelengths).

Together, findings from Studies 1 and 2 showed that emotional reactions to colors tended to be surprisingly similar for men and women. Large differences in magnitudes of effects or dramatic reversals of effects were totally lacking when comparing men's and women's reactions to colors.

Generalizability of Findings

A weak case for generalizability of findings can be made from findings in Study 1 that showed more saturated colors elicited greater feelings of arousal. Certain colors have been shown to elicit higher levels of GSR, pulse rate, or blood pressure in laboratory situations. Our preceding discussion suggested that the color samples that have been used (typically, red vs. green) also have exhibited differences in saturation values. Thus, more saturated colors (e.g., highly saturated red rooms or 3-ft × 5-ft [0.9-m × 1.5-m] projections of red) have elicited greater levels of arousal than have the less saturated greens used in the studies.

Findings relating brightness to emotions in Studies 1 and 3 provided a much stronger case regarding generalizability of the present findings to situations outside the laboratory. Findings in both studies showed that brighter colors (e.g., whites, light greys, or lighter colors) are more pleasant, less arousing, and less dominance-inducing than are the less bright colors (e.g., dark greys, blacks, and darker colors).

Using the abbreviations P for pleasure, A for arousal, and D for dominance, the effect of brightness is thus summarized as follows:

$$\text{Brightness} = +\text{P} - \text{A} - \text{D} \tag{10}$$

or

$$\text{Darkness} = -\text{P} + \text{A} + \text{D}. \tag{11}$$

The constellation $-$P $+$A $+$D, elicited by dark colors, represents emotions such as anger, hostility, or aggression.

For instance, Mehrabian and O'Reilly (1980) obtained Equation 12 for Jackson's (1967) measure of aggression, and Russell and Mehrabian (1974) obtained Equation 13 for anger.

$$\text{Aggression} = -.36\,\text{P} + .20\,\text{A} + .28\,\text{D} \quad (12)$$

$$\text{Anger} = -.74\,\text{P} + .36\,\text{A} + .09\,\text{D} \quad (13)$$

Thus, one generalization from the present findings is that darker colors are likely to elicit feelings that are similar to (or weaker variants of) anger, hostility, or aggression. Darker colors are also expected to elicit feelings that constitute components of aggression, anger, or hostility (e.g., displeasure, high arousal, or dominance).

Results obtained by Frank and Gilovich (1988) were consistent with the preceding formulations. Black uniforms, compared with nonblack uniforms, not only were associated with greater degrees of perceived aggression but also led to higher levels of aggressive behavior. Also, Damhorst and Reed (1986) showed that models wearing dark jackets were rated as more powerful and more competent than models wearing light jackets. Indeed, brightness of clothing had a stronger effect than facial expressions on viewer perceptions of potency. Thus, Damhorst and Reed's findings were also consistent with the present results in that they both show that darker colors are associated with greater dominance.

A third example of generalization from the present findings bears on reports from correctional facilities regarding the calming and aggression-reducing effects of Baker–Miller pink (Schauss, 1981). The color sample we used in the present studies that is closest to Baker–Miller pink is a bright, low-saturation, red–purple. Red–purple was shown to elicit low arousal levels (Figure 4), brighter colors were less arousing (Table 1), and less saturated colors were less arousing (Table 1). Thus, by virtue of its high brightness, low saturation, and red–purple hue, Baker–Miller pink was shown in the present studies to elicit low levels of arousal.

In addition, bright and low-saturation colors were shown here to elicit low levels of dominance (Table 1). Furthermore, the hue red–purple received the lowest score on dominance (Figure 5). Thus, Baker–Miller pink was shown here to also elicit low levels of dominance. Insofar as reductions of arousal and of dominance tend to reduce aggression or anger (note Equations 12 and 13), the preceding observations of inmates in correctional facilities, then, provide an interesting case for generalization of the present findings to real-life situations.

In a similar vein, Weller and Livingston (1988) found that subjects were less upset when they read about murder or rape printed on pink paper rather than on blue or white paper. Thus, pink elicited less anxiety or anger than blue or white; this is again consistent with the present findings.

Overall, then, evidence available from studies that have used a variety of color stimuli (including colored objects, rooms, or clothing), when interpreted within the PAD Emotion Model, tends to be consistent with results obtained in the present studies. Thus, we conclude tentatively that our results can be generalized to color stimuli encountered in everyday situations.

However, it is noteworthy that the context in which color is used can have a substantial bearing on generalizability of the present findings. Although the present data indicated blue to be a pleasant color, blue hair or blue food, for instance, are not expected to elicit pleasant reactions. On the contrary, such stimuli may elicit unpleasant reactions because of the inappropriateness of the color on the particular stimulus (hair or food). Thus, findings given here are expected to have relevance only in situations in which colors are reasonable and probable elements of those situations.

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