# THE COMPLEX PATH FROM COLOR TO EMOTION

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# SUMMARY

The information that color provides, most notably the ripeness of vegetation, is often credited as the source of evolutionary pressure most responsible for the development of human color vision (Regan, et al., 2000; Osorio & Vorobyev, 1996). Although the purpose of this adaptation remains uncertain, there is little debate over the importance placed on color in various aspects of human culture (Berlin & Kay, 1969; D'Andrade & Egan, 1974). As cultures vary in complexity and geographic placement, they also vary in the number and kinds of associations made with color, but all known cultures use colors extensively in metaphor or ritual (Berlin & Kay, 1969). A cursory internet search produces products and publications that promote the use of color in efforts to maximize productivity, minimize violent behavior, and promote healing although very little reliable and valid research exists to support the efficacy of such practices.

Some well-designed studies which have established that humans show preference for specific hues and link hues with emotion terms also show that these associations differ significantly among genders, age groups, and cultures (Zentner, 2001; Hupka, et al., 1997). Whether preferences and associations are responses to physiological factors or learned through experience is unclear.

Many of the studies examining physiological or emotional responses to color claim to reveal its relationship to emotion, but few have employed methodology capable of leading to valid causal inferences. Some hypotheses are suggested by the findings, but their explanatory power is limited.

Correlational studies suggest that highly-saturated shades of red are more arousing than comparable shades of yellow or blue (Drescher, 2004; Leichenring, 2004). Green appears to differ from other hues in preference and ratings of pleasantness (Drescher, 2004).

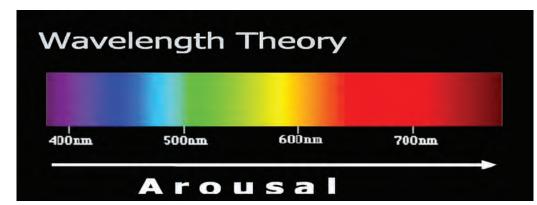
To quantify a causal relationship between color and emotion, the present study employs reliable, reproducible, and valid definitions in a unique experimental procedure. Participants viewed a series of 'inkblot" images and rated each image on the emotion dimensions of arousal and valence (pleasantness). As a between-subjects variable, half of the images were colored inkblots on a light gray background and half were reversed in color placement. Colors varied between-subjects in brightness (light, medium, or dark) and within-subjects in hue (red, yellow, green, or blue).

We hypothesized that red inkblots would elicit higher arousal ratings than yellow and blue regardless of color placement and brightness. We further hypothesized that green would elicit higher valence ratings than red, yellow, or blue when presented as a property of the inkblot. Our findings partially support these hypotheses, but additional findings complicate the relationships. Multivariate effects of hue and brightness clearly show that color affects emotion, however several two-way interactions of color placement, brightness, and hue on arousal and valence suggest that the relationship between color and emotion is more complex than the hue associations found in past research. A growing body of knowledge about the distribution of receptors and their pathways to the brain may provide insight into the nature of this interaction. Findings are discussed in terms of these structures and the role they may play in attention and arousal.

## Introduction

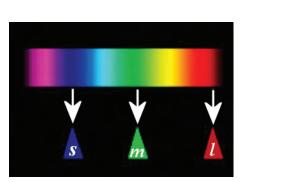
The belief that color affects our emotions has been prevalent throughout human history, yet empirical evidence fails to clearly reveal if we are affected by color and, if so, how and why. Some studies have explored the ways in which we associate feelings with colors (D'Andrade, & Egan, 1974). The basis for these associations has not been fully investigated. We would like to assume that they stem from actual emotional responses; however, it is uncertain whether these associations are gained through experience, or they are actual physiological responses.

Most previous work tested the hypothesis that the wavelength of a color (Wilson, 1966; Ward, 1995; Valdez & Merhabian, 1998), which corresponds to its hue, is correlated negatively (a linear relationship) with the arousal that viewing that color produces. This "wavelength theory", however, cannot be easily reconciled with the mechanisms of a complex human visual system.



The linear relationship between wavelength and arousal portrayed here (left) is a simplistic view of a more complex processes.

Receptors in the retina receive information in a trichromatic fashion (right).



Research to date has been inconsistent, most likely due to poor methods. Research in this area generally fails to address one or all of three important issues. The first involves how color is defined, the second is to define or manipulate emotion. Finally, since a direct measure of emotion is not possible, the true distal cause of any emotion responses to color will be unknown. Alternative hypotheses must be eliminated.

## Pilot Studies

A series of pilot studies in the form of classroom exercises has yielded consistent patterns of arousal among hues. In these studies, red (and sometimes green) produced greater arousal ratings than yellow and blue. This suggests the involvement of opponent cells in the retina, the layer of cells that leaves the eye to deliver information to the brain. The studies consistently fail to demonstrate effects of brightness, however, green is often rated higher than other hues in pleasantness.

We address the methodological issues and hypothesize that the hue of red will result in higher ratings of arousal than other hues.

- O IAPS color images that are neutral in normed arousal ratings were bordered by each hue. These images produce large variances, however, effect sizes tend to be large and a large sample usually provides enough precision to "see" effects.
- Inkblots altered to appear in solid colors produce strong effects with less variability.
- O Both IAPS and Inkblot presentations were consistent with the findings of past research, however, neither arousal nor pleasantness is related to hue in a linear fashion.

# Methodological Considerations

#### **Defining Color**

All colors can be created using v (Red, Green, & Blue).

Computers use RGB to display colors. Hues used in this study are the four unique hues perceived by humans: Red, Yellow, Green, and Blue.

iminating Cognitive Appraisa

Asking "How does this color make you

participant has chosen rather than a true

Participants must believe that what they

are evaluating is something other than

The IAPS provides images that have been

ated on emotional content. These images

serve as both a "baseline" for comparison

and stimuli to direct emotional responses

Another method of eliminating cognitive

Participants believe ratings based on the

researchers with insights, however, no

shape of an inkblot will provide

shape comparisons are made.

appraisal of color is the rating of inkblots.

feel?" results in a response that the

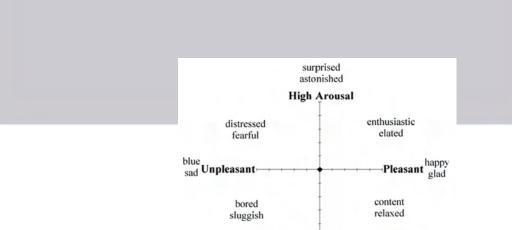
emotional response that is free from

# Which one is "blue"?

PRIMARY HUES OF LIGHT

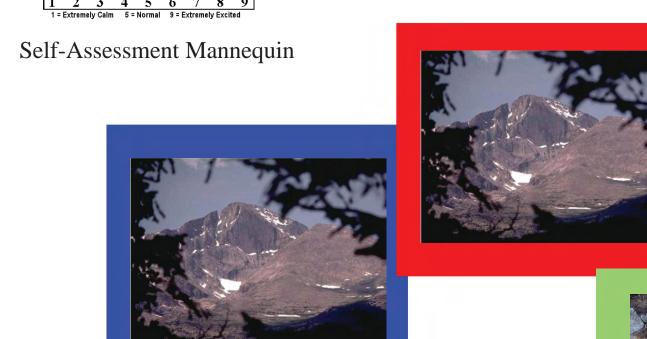
# Defining & Measuring Emotion

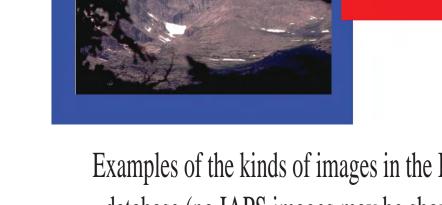
investigate by collecting measurements from multiple domains simultaneously. O All emotions can be described fully using

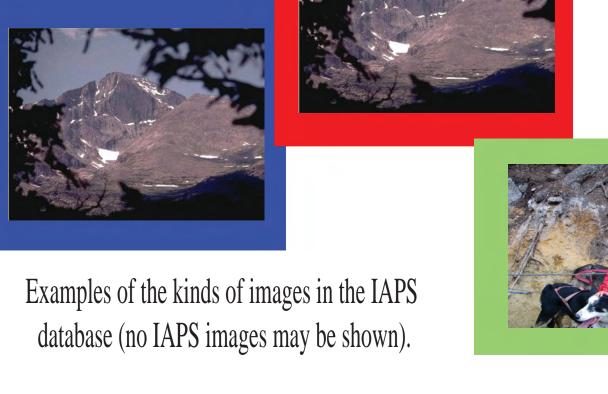


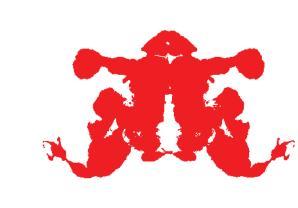
coordinates in two dimensions.

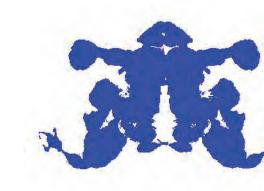
# 1 2 3 4 5 6 7 8 9 1 = Extremely Unhappy 5 = Normal 9 = Extremely Happ 1 2 3 4 5 6 7 8 9 1 = Extremely Calm 5 = Normal 9 = Extremely Excited













### Experiment 1

#### Method

62 participants rated 52 images from IAPS Images were converted to greyscale before

- Images were less than 1 SD from 0 in
- Original design: Between-subjects factor of rightness; hue was within-subjects. Mixed multivariate design – 3 (brightness) x 4
- (hue) with 2 dependent variables. Technical difficulties forced the removal of the "medium" brightness condition.

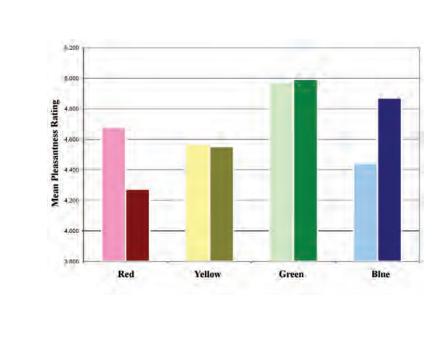


# Results • There was a main effect of hue on arousal,

 $F_{(3,144)} = 3.328, p < .05.$ Green elicited higher arousal ratings than

 No effects of brightness Interesting pattern suggesting a possible interaction of hue and brightness when

medium brightness is added. MAIN EFFECT OF HUE ON **AROUSAI GREEN SIGNIFICANTL** 



**HIGHER THAN RED** 

POSSIBLE INTERACTION WITH FULL DESIGN AND **MORE POWER?** 

#### Discussion

- O Results support the hypothesis that hue affects arousal, however, our specific predictions were contradicted.
- While green is often significantly higher on arousal than yellow and sometimes blue in our pilot studies, red is always clearly the
- To reconcile this, we should consider differences in methodology:
- Image in the pilot study were in color to retain their emotional context.
- The variable of color (hue), which is the variable of interest, is not controlled with the images averaging across images within a condition maintaining validity, but possibly at the cost of creativity.
- IAPS tends to provide strong effects, but Variability is high.
- Inkblots are a solid color and the entire subject of participant ratings. They tend to produce strong effects

## Experiment 2

**Discussion** 

While the results the two studies seem to contradict one another, and Experiment 1 contradicts consistent pilot study results, there

is a parsimonious explanation for opposite effects. The morphology of the eye is complex, with 4 major types of receptors and layers

of both excitatory and inhibitory cells with convergent circuitry that culminates in center-surround opponencies. The three color

receptors differ in sensitivities, abilities, pathways and distribution, which may be the key to understanding variation in non-perceptual

documented, others remain somewhat controversial. Still others have yet to be conceived. Whatever environmental pressures are

responsible, the pattern of results we have seen suggests that the resulting visual system does more than just "see".

To understand how the behavior we have documented reflects physical structures, a bas

The average human eye contains three color receptors: one that is maximally sensitive to

This trichromatic system follows a pathway through layers of cells until the information it

The red/green system is upstream from the yellow/blue; it becomes the yellow component of

Red and green receptors are similar in abilities, sensitivities, and distribution, but they differ a

great deal from blue receptors. At one point in our evolution, red and green cones were one and this

long-wavelength light (perceived as red), one to medium wavelength light (perceived as green)

communicates is transformed into opponencies of red/green and yellow/blue.

This morphology, like other organic phenomena, arises from evolutionary pressures. While some of these pressures are well

The retinal mosaic, or "map" of the retina (left) illustrates the large

In Experiment 1, the center of the object participants are to

ratio of red and green cones to blue. In addition, notice the absence of blue

cones at the very center, the fovea, where the highest resolution of receptors

rate is greyscale while the periphery is colored. In Experiment

2, the object itself is colored, leaving grey in the periphery. If

placement of specific cones in the eye is responsible for these

findings, then inkblots that are grey on a colored background

should elicit different emotional reactions than those that differ

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- 42 participants rated 16 inkblots on Images were colored on a gray
- · Between-subjects factor of brightness hue was within-subjects. Mixed

### Results

- There was a main effect of hue on arousal,  $F_{(3, 120)} = 4.797, p < .01.$
- Red elicited higher arousal than blue
- No effects of brightness.
- Marginal findings are consistent with previous research that suggests green produces more pleasant emotional states than other hues.
- brightness resulted in higher ratings than the dark inkblots. O Hue on valence,  $F_{(3,492)} = 3.398$ , p < .05. Green elicited higher valence ratings than red.

• A MANOVA revealed a number of effects.

Brightness:  $F_{(2, 164)} = 3.339, p < .05.$ Hue by Brightness:  $F_{(6, 160)} = 2.488, p < .05.$ 

Hue:  $F_{(6, 159)} = 4.069, p < .01.$ 

 $F_{(2, 164)} = 2.826, p = .062.$ 

ratings than yellow or blue.

O Multivariate Effects of Hue and Brightness as well as an interaction.

O Multivariate interaction of color placement and brightness is marginal,

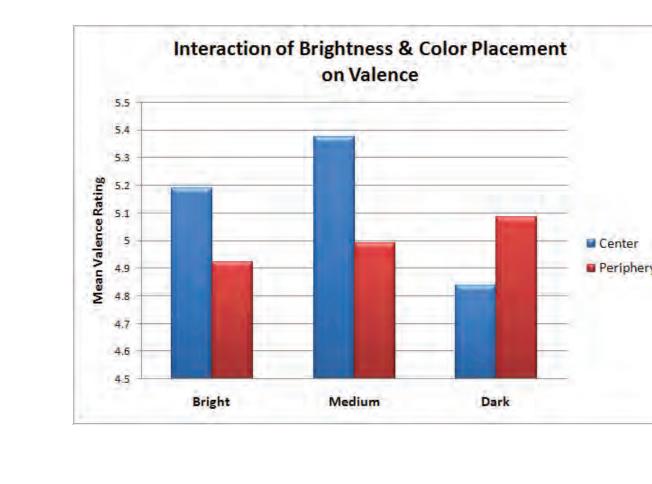
O Hue on arousal,  $F_{(3,492)} = 3.398$ , p < .01. Red elicited higher arousal

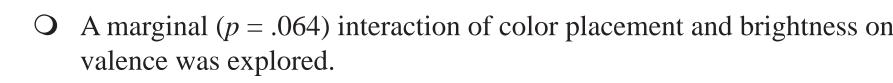
O Brightness on arousal,  $F_{(2, 164)} = 3.075$ , p < .05. The medium

#### **INTERACTIONS**

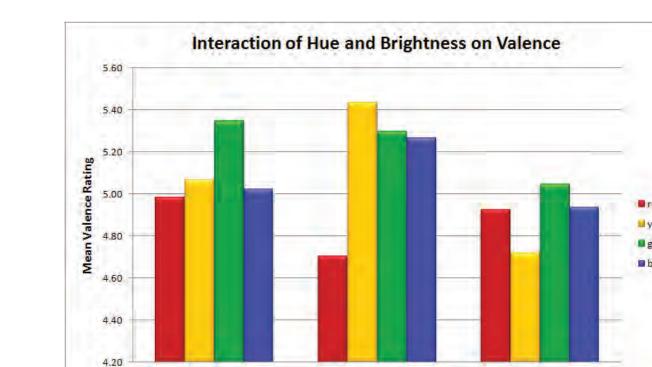
MAIN EFFECTS

- O Hue and brightness on valence,  $F_{(6,492)} = 2.753$ , p < .05.
- O No effect of hue on valence occurred in the dark condition. • A simple effect of hue on valence was found in the bright condition:
- Green was rated higher in pleasantness than red and blue.
- A simple effect of hue on valence was also found in the medium condition: Red inkblots were rated lower than green and yellow.





- A simple effect of brightness on valence occurred when the inkblots were colored. Dark inkblots were rated significantly lower in pleasantness than bright inkblots, mean difference = .350, p < .05 and medium inkblots, mean difference = .534, p < .05.
- O There was no effect of brightness when inkblots were grey on a colored



The findings support our hypothesis that red elicits higher arousal than other hues and that, overall, green produces more pleasantness than other hues. There is also reason to further investigate the placement of color as a factor or mediator in emotional responses. Emotional responses to color appear to depend on the nature of its presence in the environment - direct and central or extraneous and peripheral. However, the present methodology does not allow us to determine if this factor is one of exposure or appraisal.

Discussion

We also must determine if unconscious comparisons are made among hues or brightnesses. The early pilot studies blocked stimuli on brightness and controlled hue as a between-subjects factor. When the factors were reversed (brightness became a between-subjects factor and hue a within-subjects factor) effect sizes increased and brightness now appears to be involved. If participants are not unconsciously comparing, the difference may be one of adaptation, which occurs rapidly.

Emotions are thought to have evolved as tools for social interactions. That color may affect them is puzzling from an evolutionary perspective. It may be that emotional responses to color are a by-product of other adaptive systems, or it may be that our emotional responses themselves are adaptive. If red increases arousal, are we more likely to respond to injury quickly? Or, could our cultural associations with color be the result of biological responses, bonding us through shared experiences?

The findings of the present study provide more questions than answers, however, one important question can now be answered with confidence: Does color in the environment affect emotion? Although it is still unclear how, why, to what degree, or even in what way, we may conclude that it does.

# Experiment 3

## Method

O 170 participants rated 20 inkblots each - 5 in each hue.

response patterns when exposed to variations in hue.

understanding of the neural circuitry of the eye is needed.

and one to short-wavelength light (perceived as blue).

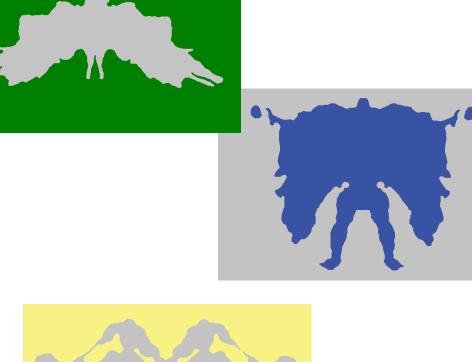
one receptor opposed only blue cones.

its sister-system.

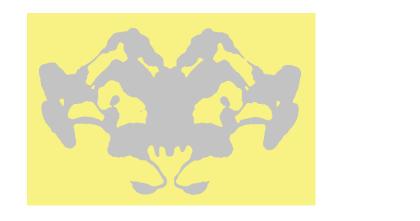
- O Variable added: Color placement. Half viewed grey inkblots on colored backgrounds.
- O Multivariate Mixed Factorial:

2 (color placement) x 3 (brightness) x 4 (hue)

O Hue is a within-subjects variable; color placement and brightness are between-subjects.



Receptor Pathway



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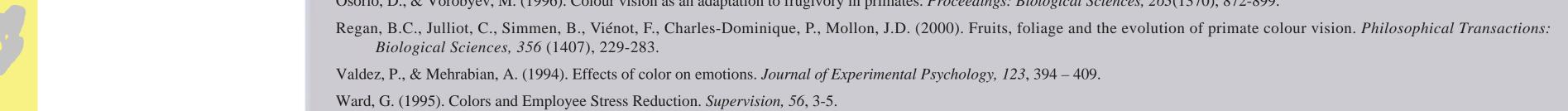
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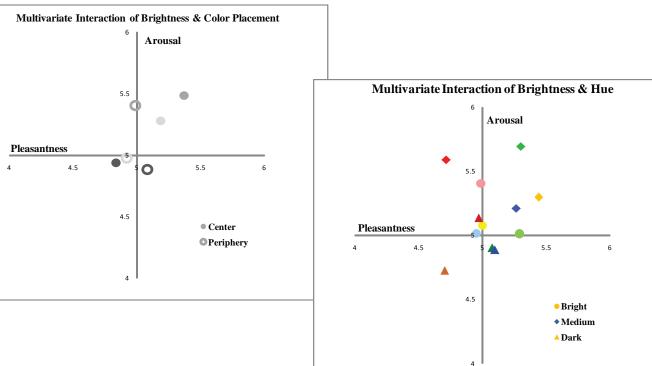
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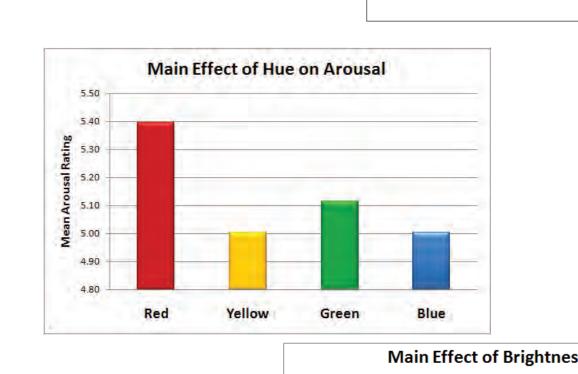
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Results

