An Investigation of the Effects of Practice on Color Memory as a Function of Condition, Dimension and Color

By

Britten G. Remus

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Committee Members:

Albert M. Prestrude, Ph.D. (Chair)

Martha A. Bell, Ph.D.

Helen J. Crawford, Ph.D.

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Abstract

Forty-two college aged participants took part in a mixed repeated measures factorial design experiment that assessed color memory as a function of condition (practice with feedback, practice without feedback and no practice), dimension (hue, saturation and lightness) and color (red, yellow, green and blue). Attention was focused on the distinction between memory color and color memory, color experience and preference, mechanisms of color perception and theories of color vision (see below). Only two significant effects were found: a significant main effect for dimension and a significant interaction between dimension and color. Pearson correlations were assessed between color memory and color experience, color preference and observer imagery. None of the correlations were significant. The results of the experiments revealed that practice does not have a significant effect on color memory and the conclusion, therefore, is that the phenomenon of color memory is not improved by practice. A tentative explanation involves the early stages of color processing which are presumed to be computational in nature and to take place independently of cognitive processes such as learning and memory, which do not take place until visual information has reached the extrastriate areas. By that time, color information has been combined with information about context, in area V4 of the human visual cortex (Zeki & Marini, 1998). Although it has been shown through this experiment that practice does not improve memory for color, the possibility remains that practice may improve memory color for specific objects - namely ecologically relevant stimuli - since memory color involves higher order processing, such as learning and memory.

An Investigation of the Effects of Practice on Color Memory as a Function of Condition, Dimension and Color

Investigations into human memory for color unrelated to a specific object have been sparse. Research concerning memory color on the other hand, has been quite extensive. Color memory and memory color are different concepts, yet they are often confused in the literature. Hering (1961) first evoked the concept of memory color to explain color constancy in perception. He pointed out that the most typical color of an object becomes an integral part of the memory representation for that class of objects and significantly influences our perception of that object's color. Memory color has since been defined as the color of an object as it is remembered and as it influences the perception of a present color (Siple & Springer, 1983). Color memory, however, refers to the actual memory for color alone, independent of a specific object.

Memory Color

Investigations into memory color have yielded detailed information about the phenomenon. For instance, Siple and Springer (1983) looked at the effects of dimension (hue, lightness and saturation) on memory colors of objects and preferred colors of objects. They found a significant effect of dimension. Participants' memory color and preferred color were more accurate to the actual color of the objects for hue and lightness but not for saturation. Participants overestimated saturation of objects relative to their actual color.

Siple and Springer (1983) also reported that memory for colors of objects is not dependent upon contextual information (ex. shape, form) and subsequently concluded that our memory for colors of various objects is coded independently of contextual information. This conclusion, however, is unsupported by more recent data from neuroanatomical experiments.

Visual information is conveyed to the cortex via two separate pathways, the Magnocellular (M) and Parvocellular (P) (Kandel, Schwartz & Jessell, 2000). Whereas the M pathway relays information about motion and depth, the P pathway transmits information about color and form. Research suggests that color is processed with information about context, specifically in the V4 region of the visual pathway (Zeki, Watson, Lueck, Friston, Kennard, & Frackowiak, 1991; Zeki & Marini, 1998). Positron Emission Tomography (PET) scans have also compellingly demonstrated that color perception occurs in this area (Zeki et al., 1991).

Clinical observations indicate that color and context are processed together in V4. Individuals with lesions in the inferior temporal cortex, where color is mainly processed, have difficulty in discriminating between different forms (Kandel et al., 2000). Individuals with these lesions have poor visual memory for forms; therefore, this temporal region is thought to be specialized for object recognition (Kandel et al., 2000). Individuals with achromatopsia, in which the ventral occipital lobe is damaged, cannot discriminate between hues. As we will see, these factors have strong implications for the processing of color with context.

Ratner and McCarthy (1990) argued that it was better to use ecologically relevant stimuli rather than the traditionally used Munsell color chips to investigate memory color. They found that appropriateness (ex. a green tree rather than a pink tree) was a more powerful variable than independent color (focality) for memory color. Thus, under conditions of appropriateness (as opposed to non-appropriateness) memory was more accurate. Interestingly, Van Essen and Gallant (1994) discovered that a variety of inferior temporal cells respond differentially to certain specific combinations of shape and color. For example, a stop sign has a color component (red) and a shape component (octagon), but it is more efficient for our brain to recognize this as a single entity (stop sign) rather than as a red object combined with an octagonal object.

Color Memory

Research concerning color memory has focused primarily upon the effects of hue, dimension and delay intervals. For example, Jin and Shevell (1996) reported that long and medium wavelengths were more accurately remembered than shorter wavelengths.

Laws (1999) used test hues of blue, green and orange and found that all test hues differed significantly from one another. He discovered that green had the most errors followed by blue, then orange.

The hue green revealed some interesting results. Individuals seemed to be most sensitive to the hue green (as measured by d’), but at the same time they committed the highest number of errors for it when they had to select the correct green target stimulus from three green distracters that varied by hue, saturation and lightness (Laws, 1999). Although the discrepancy was attributed to procedural rather than perceptual differences, the current author believes that this can be attributed to the location and span of green on the visible spectrum. Green occupies a large range of the visible spectrum (from approximately 480nm to 540nm) and consequently has more variations in hue than blue and orange. Green is also located near the center of the visual spectrum. Every rod and every cone is activated in this region of the spectrum, whereas at the far end of the spectrum (towards 700nm, red) only one cone system is activated (L-cone), as well as the rod system (Hurvich, 1981). At the short end of the spectrum (towards 400 nm, violet) only two cones are activated, namely, the S- and M-cones. Since more cones are activated in the green region of the spectrum, the retina is more sensitive to this color than other colors. It occupies a larger area of the spectrum and has greater variations than other hues. This may be a possible explanation why more errors are committed for green. Sensation and perception of color will be elaborated upon in the discussion.

In another study (Perez-Carpinell, Baldovi, de Fez, & Castro, 1998), participants were presented with simultaneous and memory color matching tests utilizing Munsell color chips. Yellow, light green, blue and pink were remembered less accurately than orange, which was the most accurately remembered color. Memory for green was worse than that for orange, consistent with Laws' (1999) findings.

Nilsson and Nelson (1981) found a significant hue effect while investigating color memory shifts. They used spectral light beams to produce 16 discrete monochromatic stimuli in order to test observers' short-term memory for color via a momentary stimulus-matching technique. They determined that the most accurately remembered colors were violets, green-blues and yellow-oranges.

Color memory and dimension

Studies of color memory have focused on the three perceptual dimensions of color: hue, saturation, and lightness. Research on the effects of dimension on color memory has yielded consistent results. Overall, individuals seem to make more errors for lightness than for hue or saturation (Hamwi & Landis, 1955; Laws, 1999). One study found that the majority of errors committed on a color memory task were made towards more saturated comparisons as well as towards lighter comparisons (Henderson, Morley, & Halstead, 1971). The current experiment assessed the effects of manipulating hue, saturation, and lightness on color memory.

It is crucial to examine how visual information (namely color) is processed. It is equally important to understand theories of color vision. The mechanics of neuroanatomical data, coupled with color vision theories, help to provide an understanding of how the brain perceives color and how color perception interacts with memory processes.

Mechanisms of Color Perception

The visual process is first engaged when light rays from some stimulus source enter the pupil of the eye. Light then travels through the lens, which focuses the light rays on the rear surface of the eye, the retina. The lens, however, is not perfectly transparent to all wavelengths of light; it filters out shorter wavelengths (Hurvich, 1981). As humans age, the lens becomes more yellow in appearance and a decreased amount of short-wavelength light is transmitted to the retina (Hurvich, 1981). The retina contains the photoreceptors (rods and cones) for vision. Before the light reaches the retina, however, it must also pass through an area called the Macula Pigment, which behaves like the lens in that it absorbs more short-wavelength light than mid- or long-wavelength light (Hurvich, 1981). This important step affects color matching because it transmits less short-wavelength light. Interestingly, this pigment varies from one individual to the next and may account for interobserver variability in color matching.

Because short-wavelength light has the potential to be differentially absorbed at two steps early in the color vision process, this may account for decreased accuracy of human memory for shorter wavelengths as evidenced in the research findings concerning color memory.

Evidence from monkey and human eyes provides support for the existence of three cone photopigments (alluded to above) that have absorbance peaks at three different spectral areas: 450 nm, 530 nm, and 560 nm (Goldstein, 1999; Hurvich, 1981; Kandel et al., 2000; Matlin & Foley, 1997; Zeki & Marini, 1998). The S-cones are maximally sensitive to shorter wavelengths of light (ex. blue, 450nm), the M-cones are more sensitive to medium wavelengths of light (ex. green, 530nm) and the L-cones are most sensitive to the longer wavelengths (ex. red, 560nm) (Livingstone & Hubel, 1984). Hurvich (1981) points out, however, that knowledge of different amounts of absorbance by these three pigments does not mean much for color vision because it does not tell us anything about the ultimate appearance of the colors. To obtain a better understanding of how we perceive color, we need to look at processes evoked after the level of the retina.

Rods and cones generate electrical signals in response to the light, and these signals leave the retina via the optic nerve. Signals travel to the lateral geniculate nucleus (LGN) of the thalamus where the color opponent cells reside (Livingstone & Hubel, 1984). From the LGN, information goes through the optic radiations to the occipital lobe where further color processing takes place (Livingstone & Hubel, 1984). Signals then leave the visual cortex, continuing to the extrastriate cortex (Goldstein, 1999). The hippocampus and area V4 are also activated during normal viewing conditions (Livingstone & Hubel, 1984; Kandel et al., 2000; Zeki & Marini, 1998).

More specifically, when light reaches the retina, the wavelength information is passed on to one of two visual pathways: the Magnocellular (M) or Parvocellular (P) (Zeki et al., 1991). The M pathway extends dorsally to the posterior parietal cortex, whereas the P pathway extends ventrally to the inferior temporal cortex. The Magnocellular pathway is specialized for processing information about motion, depth and spatial orientation; the Parvocellular pathway processes information about form and color. Thus, in investigating memory for color, we are concerned with the P pathway. Furthermore, PET scans have demonstrated that color processing takes place in area V4, which is located in the inferior temporal cortex (Zeki et al., 1991).

Theories of Color Memory

We may be able to attribute much of the interest and research produced in the area of color vision to the debate between supporters of three color vision theories. The trichromatic theory and the opponent-processes theory of color vision are cognitive in nature (Hering, 1961), while Retinex theory (Land, 1977) is computational (Livingstone & Hubel, 1984) .

The Young-Helmholtz trichromatic theory states that the retina has three types of color receptors, each differentially sensitive to red, green and blue. Each receptor may be stimulated at any wavelength but maximally responds to the wavelength to which it is most sensitive (Goldstein, 1999).

Psychophysical evidence exists for three cones that each have absorbance peaks at different areas of the visible spectrum corresponding to red, green and blue. The trichromatic theory assumes that the differential input received from the three cone systems serves as the basis for the colors we perceive (Matlin & Foley, 1997). Trichromatic theory may be accurate in describing the beginning stages of the visual transduction process, but it is not sufficient by itself to account for color perception. At this point then, the opponent-processes theory of color vision takes us to the next level.

The opponent-processes theory of color vision postulates the existence of three pairs of spectrally opponent, broadband cells: one which is stimulated by green and inhibited by red, a second which is stimulated by yellow and inhibited by blue, and a third which is activated by achromatic (black and white) stimuli (Hering, 1961). Hering proposed that each of these pairs responds in opposite ways to different wavelengths of light. The red (+) green (-) cells respond positively to red and negatively to green. The blue (-) yellow (+) cells respond negatively to blue and positively to yellow. Finally, the black (-) white (+) cells respond negatively to black and positively to white. Thus, the neurons in each of these cells respond in opposite ways (excitation and inhibition) to different wavelengths (Hurvich, 1981).

Hering also discovered that different areas of the retina were sensitive to different wavelengths. The fovea is the small area of the retina where color discrimination is most highly developed (largest aggregation of cones) and where rods are essentially absent (Stiles, 1978). It is the most sensitive to reds and greens, whereas the peripheral area is most sensitive to blues and yellows and the extreme periphery has the greatest sensitivity to blacks and whites (Hering, 1961). Whereas the trichromatic theory explains color perception at the level of the retina, opponent-processing theory begins in the retinal ganglion cells through the lateral geniculate nucleus of the thalamus. This processing occurs before information travels to the primary visual cortex, and thus it can be inferred that these processes occur before the actual act of perception.

Retinex theory (Land, 1986) proposes that the composition of light radiated from an object does not determine the color of an object. Instead, Land proposes that the cone systems (S, M and L cones) each separately detect the ratio of lightness that an object has in proportion to other objects in the visual field. Each cone system calculates the ratio of lightness that the object has when compared to surrounding objects in the visual field and the ratio of lightness that the object has when compared to the average lightness of the entire visual field. Land calculated a formula, known as the Retinex algorithm, which contains all of the necessary procedures to generate a value. The three cone systems compare their independent results and combine them into a trio of values, which the higher cortical areas perceive as a color. Land coined the term Retinex to describe the location where lightness is processed. Since it could occur in the retina or the cortex, or partially in both, he joined the two words retina and cortex into Retinex (Land, 1986).

Livingstone and Hubel's (1983) research directly supports the Retinex theory. The results of their experiments, in which they stained areas of the primate primary visual cortex to determine the anatomy and physiology of its color system, suggest that the major blob cell types process color. These blobs are located in the V1 and V2 areas of the visual cortex. The color processing which occurs in V1/V2 is transduced to V4 (Livingstone & Hubel, 1983). This system of color sensation runs parallel and separate from contextual processing and is in three coordinate values. These can be transformed into the trio of values in Land's Retinex algorithm.

Color sensation versus color perception

Zeki et al. (1991) demonstrated through PET scan research that perception or cognition does not occur until information reaches area V4. This area is where color information combines with contextual information. Color sensation occurs prior to the V4 region and is separate from contextual information. Cognitive processes such as memory are not invoked until this stage. Since perception does not occur until visual information reaches V4, we can conclude that memory for color does not exist independent of context.

Color memory and length of delay

A possible factor affecting memory for color is the length of delay between presentation of a target stimulus and comparison stimuli. Research concerning this factor has been consistent as well, regardless of whether short-term or long-term memory was gauged. Nilsson and Nelson (1981) investigated color memory by manipulating length of delay between 0.1 and 24.3 seconds. They found no significant effect for delay and concluded that memory for color is stable up to 24.3 seconds. Hamwi and Landis (1955) investigated long-term color memory manipulating delays of 15 minutes, 24 hours or 65 hours. They too found no effect of delay on color memory. Length of delay did not affect the total number of errors committed. Laws (1999) also manipulated delay intervals and found no significant effect. One study, however, did find an effect of delay on color memory. Perez-Carpinell et al. (1998) manipulated delay intervals (0 seconds, 15 seconds, 15 minutes and 24 hours) and observed that errors increased with longer delay intervals. The current experiment used delay intervals of 3 seconds between the target stimulus presentation and the comparison presentation.

Memory vs. Learning

Memory

Memory commonly refers to the ability to reproduce or recount information that was experienced at an earlier time (Domjan & Burkhard, 1982). Memory results from a process of continual recategorization, which, by its nature, must be procedural and involve continual motor activity and repeated rehearsal (Edelman, 1989; Gegenfurtner & Hawken, 1996).

Humans possess three different kinds of memory: sensory, short-term and long-term memory. Sensory memory retains information for a duration of less than a few seconds with a high capacity, while short-term (working memory) has a more limited capacity but longer duration (less than twenty seconds). Long-term memory has a potentially unlimited capacity and long, or permanent, duration (Baron, 1998). The current experiment will focus on short-term or working memory.

Learning

Learning is an enduring change in the mechanisms of behavior that results from prior exposure to environmental events (Domjan & Burkhard, 1982). Although learning and memory are similar in definition, the major difference between the two is that learning refers to enduring effects of prior experience (Domjan & Burkhard, 1982). Memory, on the other hand, can encompass short-term effects as well as long-term effects. This study examined short-term, or working, memory for color since the delay intervals between the target stimulus and the comparisons was three seconds.

Delayed-Matching-to-Sample

One technique used to study short-term memory is the delayed-matching-to sample technique utilized in the current experiment. The procedure is as follows: the participant is exposed to the target stimulus for a brief interval of time. The stimulus is removed. A delay period occurs between exposure to the target stimulus and the presentation of the comparison screen in which the observer must choose the correct stimulus from a number of stimuli that are similar in appearance. If the match is chosen the response is reinforced (Grant, 1976).

Reinforcement and Feedback

Given that memory for color is a phenomenon that exists (Jin & Shevell, 1994; Laws, 1999; Nilsson & Nelson, 1981), the purpose of the current study was to determine what effects, if any, practice had on color memory. Color memory, like any other type of memory should lend itself to the principle of reinforcement. Reinforcement increases the probability of a response. In the case of the current experiment, selecting the correct target stimulus is the desired response. Participants were exposed to one of three conditions: no practice, practice without feedback and practice with feedback. Differences between the conditions were then assessed. In the practice with feedback condition, participants received feedback after each response that would show which answer was correct and whether the observer chose correctly. If the feedback showed a correct answer, this reinforced the participant by confirming that the strategy being used was the correct one. If the feedback showed that the individual was incorrect in their response, they could attempt to employ a different strategy in subsequent trials. In theory, practice should improve memory for color. Given enough practice, participants' performance on the color memory task should improve.

Laws (1999) suggested further research on color memory focus on variables such as participants' experience with color and color preference. The current experiment, therefore, investigated any correlations between color preference, color experience and color memory utilizing a color experience questionnaire (Appendix A). Participants completed the questionnaire to determine whether they had relevant experience working with or employing color (i.e. photography, computer graphics, commercial or artistic painting). The questionnaire also assessed the participant's preferential color(s). Participants were asked to report their preferred color(s) to wear and which color(s) they preferred to see in their environment. This information helped determine whether a participant would have a greater memory for their preferential color. In addition, as the current study is concerned with practice and color memory, color experience (which can be thought of as practice with color) was assessed for each individual to help determine whether a positive correlation exists between color experience and a greater memory for colors.

The current experiment also assessed observer imagery vividness to determine if there was a relationship between visual imagery and color memory. The Vividness of Visual Imagery Questionnaire (VVIQ) determined whether participants were high or low imagers (range: 16 – 80, see Appendix B) (Marks, 1973). Research concerning the relationship between visual imagery and color memory has yielded conflicting results.

For example, Walczyk and Hall (1988) found a positive correlation between scores on the VVIQ and image recall. Individuals who scored high on the VVIQ (high imagers) performed better on an imagery accuracy test. Cohen and Saslona (1990), however, found that high imagers performed worse on a color recall task. Laws (1999) did not find a relationship between high imagers and performance on a color memory test; however, the majority of participants in Law's study were high imagers. The current study attempted to get a larger range of imagers in order to determine more accurately whether a positive correlation exists between high imagers and color memory recall.

Hypotheses

The current experiment employs both between and within subjects variables. The between subjects variable is condition, which has three levels: practice with feedback, practice without feedback and no practice. The within subjects variables are dimension and color.

Hypothesis 1: Number of correct responses on the color memory task will be highest in the practice with feedback condition followed by the practice without feedback condition and the no practice condition will yield the least number of correct responses.

Hypothesis 2: Numbers of correct responses will be greatest for the hue dimension followed by saturation and the lightness dimension will display the least number of correct responses.

Hypothesis 3: Number of correct responses on the color memory task will be highest for red followed by yellow, green and blue, respectively.

Hypothesis 4: Color preference will be associated with greater memory for the participant's preferred color.

Hypothesis 5: Color experience will be associated with greater memory for color.

Hypothesis 6: Participants who are high imagers on the VVIQ will have greater memory for color.

Method

Participants

Sixty undergraduate students enrolled in psychology courses participated in the experiment for extra credit. They received a maximum of two extra credit points, one point for each phase of the experiment. Of the original 60 participants, 9 did not pass the screening phase (5 did not have normal color vision, 4 were excluded for having learning disorders), and 9 others failed to appear during the experimental phase. This left forty-two college aged participants (14 men, 28 women).

Screening Phase

The experiment consisted of two phases: a screening and an experimental phase. The principle investigator conducted both phases of the experiment. Participants were informed that there were two phases to the study and that their participation in both phases was vital to the investigation.

The screening session was conducted individually and lasted approximately 20 – 25 minutes. The investigator explained the purpose of the study, to investigate the effects of practice on memory for color. Following the explanation of the experiment, each participant was given an informed consent form to be signed (Appendix C). They were also assigned a subject number, which was recorded along with their last name on a separate sheet of paper. This paper was used in the second phase of the experiment to inform participants of their subject number which they needed to type into the computer at the beginning of the experimental phase. After participants were given their respective subject numbers in the experimental phase, the lists were destroyed.

Visual acuity and color vision were assessed with a Stereo Optical Optec 2000 Vision Tester (industrial model, serial number: 120-2093). Participants wearing colored contacts or tinted eyeglasses were excluded from the study along with those participants found to have color vision or learning deficits. As stated above, five individuals (all male) were excluded for color blindness and four individuals were excluded on the basis of learning disorders.

Three questionnaires were administered (see appendices). First, participants were given a medical screening questionnaire that assessed any medical problems that may have interacted with the study (Appendix D). For example, those who self-reported learning disorders, epilepsy or who had experienced head trauma were excluded from the experimental phase. The second questionnaire concerned experience with and preference for color. The color experience questionnaire (Appendix A) assessed color experience and color preference for each individual. The third questionnaire administered was the VVIQ (Appendix B), which gives a measure of imagery vividness and was used to distinguish between high and low imagers (Marks, 1973).

Finally, participants were asked to sign up for one of two three-hour experimental sessions that will be elaborated upon below. The investigator obtained a phone number, e-mail address, and provided the participants with an index card reminding them of the exact time and place of the second phase of the experiment. The investigator accordingly thanked the participants for their involvement in the experiment.

Experimental Phase

Participants arrived at the specified lab during their scheduled time. Forty-two participants returned for the experimental phase. The lab was completely dark except for the computer screens. The experimenter greeted the participants and gave them another informed consent sheet. The purpose of the experiment was reiterated. The computer procedure was designed to be self-explanatory. The participants were reminded of their subject number and then instructed to enter it at one of thirty computer stations to begin the procedure. Each of the three conditions lasted no longer than fifteen minutes.

The current experiment made use of three trial conditions: no practice, practice without feedback, and practice with feedback. In the no practice condition, participants viewed one example for clarification purposes and began the test trial immediately following the example. They did not have a chance to become familiar with the task as did the participants in the practice without feedback condition nor did they receive any feedback concerning their response selections as did the participants in the practice with feedback condition.

The practice without feedback condition was essentially practice with the task. Participants received practice material consisting of 16 trials in which they were to become used to the nature of the task. Becoming familiar with the task before they knew they were actually being tested was hypothesized to enhance performance.

As discussed above participants in the practice with feedback condition had the best chance of improving their color memory because they received feedback. They were essentially getting a chance to determine if their strategy for remembering the colors was working. If they determined their strategy was working they would be more likely to do better on the test trials. Conversely, if they believed their strategy to remember the target colors was not working they had an opportunity to change strategies, an advantage the participants in the other two conditions did not have.

The no practice condition had forty-eight trials, which lasted approximately ten minutes. The practice without feedback condition had sixteen practice trials, followed by forty-eight test trials for a total of sixty-four trials lasting approximately thirteen minutes. The practice with feedback condition also had sixteen practice trials and forty-eight test trials, for a total of sixty-four trials lasting about thirteen and one-half minutes (due to the sixteen feedback slides that were displayed for one second each).

The experiment was run on two separate occasions. Each lab was reserved for three hours. The first hour was dedicated to calibrating and degaussing the computer monitors, with the help of a computer systems engineer. Participants were scheduled to arrive at one of four timeslots of thirty minutes each. They were allowed to leave when they reached the last screen of the experiment.

Materials and Design

A Graseby Optronics SLS 9400 Colorimeter (Serial Number: 8U007) measured hue, saturation and lightness to ensure that the target stimuli did not vary from monitor to monitor or from one time to the next. Stability of each computer monitor for displaying test hues was assessed, following the suggestions made by Laws (1999) that each monitor should be allowed to warm up for one hour before testing.

Delay times up to 30 seconds had no effect on color memory (Laws, 1999). Nilsson and Nelson (1981) concluded that memory for color remained stable for 24.3 seconds, and The Armed Forces Color Vision Test specified that vision tests should be administered at a distance of roughly thirty inches from the participant’s eyes and stated that two seconds was adequate response time to each plate (slide in the case of the current experiment) (Paulson, 1973).

Based upon the above information, the current experiment required the participants to be within thirty inches from the computer monitor. This distance is a normal ergonomic range for individuals to work at a computer station. Participants were instructed not to lean back in their chair or to move the chair further away from the computer than was originally marked. A piece of tape was placed as a guide behind each chair in order for the participant to maintain a maximum distance of thirty inches from the monitor.

The color memory test consisted of a computer program written in Hypertext Markup Language (HTML). The program was created using Microsoft FrontPage 2000 and hosted on a server running Microsoft Internet Information Server 5.0. The program recorded the test data to a Microsoft Access 2000 database. The software presented a target stimulus against a plain gray background for three seconds followed by an empty gray screen for three seconds. A pseudo-random assignment method was employed to ensure that no consecutive trials were of the same color.

The comparison grid was composed of four choices, one of which was the target stimulus. The other three distracters varied by hue, saturation or lightness. The participants viewed the comparison screen for four seconds and then clicked on the perceived appropriate match.

The design was a 4 (colors: red, yellow, green, blue) X 3 (dimensions: hue, saturation, lightness) X 3 (conditions: no practice, practice without feedback, practice with feedback) with total number correct on the color memory task as the dependent variable. Since this was a mixed design, with both between (conditions) and within (hue and dimensions) subjects factors, a repeated measures factorial ANOVA was used to analyze the results.

Results

Before any hypothesis testing was performed, a preliminary ANOVA assessed for gender differences between men (n=14, $\bar{x}$ = 19.93, std= 3.91) and women (n=28, $\bar{x}$ = 21.18, std= 5.24). No differences in total score on the color memory test were observed. Therefore, gender was not a factor in any other analyses (see Table 1, Figure 1).

Hypotheses 1, 2, and 3 were tested with a Mixed Model repeated measures ANOVA (see Table 2). Hypothesis 1 proposed that the number of correct responses would be highest in the practice with feedback condition (n= 14, $\bar{x}$ = 20.64, sd= 1.33) followed by the practice without feedback condition (n= 15, $\bar{x}$ = 20.20, sd = 1.13) and the no practice condition (n= 13, $\bar{x}$ = 21.54, sd= 1.45) would yield the least number of correct responses. This assertion was not supported (see Figure 2). Performance in the three conditions did not differ significantly from one another.

Hypothesis 2 purported the number of correct responses would be greatest for the hue dimension (n= 16, $\bar{x}$ = 8.50, sd= 2.58) followed by saturation (n= 16, $\bar{x}$ = 5.60, sd= 1.85) and then lightness (n= 16, $\bar{x}$ = 6.67, sd= 2.07). The 3 dimensions were significantly different from one another (see Table 2, Figure 3). Total number of correct responses was greatest for hue as predicted, however, participants performed better on the lightness dimension than they did on saturation dimension.

Hypothesis 3 stated that the number of correct responses on the color memory task would be highest for red (n= 12, $\bar{x}$ = 4.62, sd= 2.04) followed by yellow (n=12, $\bar{x}$ = 5.72, sd= (1.56) green (n= 12, $\bar{x}$ = 5.21, sd= 1.68) and blue (n=12, $\bar{x}$ = 5.21, sd= 2.07) respectively. This hypothesis was not supported (see Table 2, Figure 4). Participants performed best on yellow, followed by green, blue and then red.

An unexpected interaction between dimension and color occurred (see Table 2, Figure 5). Paired sample t-tests (with Bonferroni corrections) analyzed the dimension by color interaction. The color yellow was significantly different from all the other colors (see Table 3, Figure 5). In addition, the dimensional qualities of yellow (hue, saturation and lightness) were all significantly different from each other (see Table 3, Figure 5). Green hue was also significantly different from green saturation (see Table 3, Figure 5).

Hypothesis 4 proposed that color preference would be associated with greater memory for the participants' preferred color. Color preference was obtained for each participant based upon questions 6 through 8 on the color experience questionnaire (see Appendix A). Participants were asked to check which statement or statements best described them in question 6. Each statement was associated with a particular color used in the experiment (red, yellow, blue and green) and derived from research conducted by

Jaensch (1930) and Luscher (1969). In question 7, participants were asked what colors they preferred to wear and question 8 referred to which colors they preferred to see in their environment. Color preference was obtained by calculating the number of times a participant chose red, green, yellow, or blue. A maximum of 3 times per color was possible because there were only 3 questions pertaining to color preference. Participants were categorized as having no preference if, for example, they indicated a preference for red on question 6, green on question 7, and blue on question 8. Two participants preferred yellow, 9 preferred green, 12 preferred blue and 19 had no preference. Paired sample t-tests showed that color preference was not correlated with high performance for that specific color on the color memory task (see Table 4, Figure 6). Therefore, hypothesis 4 was not supported.

Color experience was assessed by obtaining a score for questions 1 through 5 (representative of color experience) on the color experience questionnaire (see Appendix A). The rationale for each question is described below. On question 1, participants rated their overall artistic ability from 1 (poor) to 6 (excellent). Since the color memory test was computer-based, question 2 measured the frequency in which the participant used a computer, with frequencies ranging from 1 (seldom) to 6 (repeatedly). Question 3 required participants to name as many colors as possible (not exceeding 20). One point was given for each response. Question 4 required participants to list any relevant experience they had with color (ex. house painter, art classes). One point for each response was added to the score. Finally, participants rated their ability to discriminate colors from one another on a scale of 1 (poor) to 6 (excellent). The point value for each question was totaled. This value was used to determine the participants' color experience. Hypothesis 5 was not supported. No correlation was found between color experience and greater memory for color (see Figure 7).

To assess the reliability of the color experience questionnaire, a Cronbach's alpha showed a moderate reliability coefficient (.50) for questions 1 through 5 (indicative of color experience). Therefore, the 5 items related to color experience in the color experience questionnaire are reasonably reliable. Questions 6 through 8 were designed to assess color preference (see Appendix A). Question 6 required the participant to choose a statement that directly corresponded to one of the 4 test colors, ensuring that each individual chose at least one of the colors used in the color memory test. Questions 7 and 8, on the other hand, were open-ended questions. Since they directly asked participants for their preferred color(s), they possess sound face validity. Future studies assessing color preference, however, should include more than 3 questions on a questionnaire to enhance the reliability of the measure and accuracy of results.

Participants who are high imagers on the VVIQ were hypothesized to have greater memory for color (Hypothesis 6). This hypothesis was not supported. No correlation existed between imagery and recall. Unfortunately, much like Laws (1999), this sample contained no low imagers (see Figure 8). Because of this restricted range, the current author suggests the VVIQ be used in future color memory experiments in an attempt to gain information on both high and low imagers and their relationship to color memory.

Discussion and Implications

Practice had no significant impact on color memory performance. This finding suggests that color memory does not lend itself to practice and supports Land's (1986) computational Retinex theory. Crucial color comparisons implemented in early visual processing regions take place without regard to cognitive factors such as memory and learning. As Zeki and Marini (1998) point out, these early processes in the visual pathway are concerned with registering the intensity of various wavelengths (carried out automatically) without regard to learning, memory or judgment. Land's (1986) findings along with Zeki and Marini's (1998) and Livingstone and Hubel's (1984) findings support the premise that color computations take place without respect to cognitive factors such as learning and memory.

A main effect of dimension was found, but not in the order hypothesized. All dimensions differed significantly from one another, with the greatest number of correct responses for hue, followed by lightness and then saturation. It was proposed that the greatest number of correct responses would be for hue, then saturation followed by lightness. As discussed above, the finding for hue is consistent with other studies that have demonstrated that people usually perform best on hue manipulations (Laws, 1999, Nilsson and Nelson, 1981). The finding in the current experiment, that individuals performed better on lightness then saturation, is puzzling since the majority of evidence points to the dimension of lightness as being the most difficult to discern differences between. For example, Matlin and Foley (1997) point out that individuals are not very precise in judging the amount of light a stimulus reflects onto their retinas.

Although it was hypothesized that a color effect would be found with total number of correct responses being greatest for red, then yellow, then green and finally blue, no overall significant effect was found. This order was different from hypothesized, however, with number of correct responses being greatest for yellow, then green and blue (which had the same mean 5.214), then red (see Figure 3). Yellow and red were, however, significantly different from one another.

The color, yellow, occupies a very limited portion of the visible spectrum. As such, variations in yellow hue are perceived more distinctly than those of other colors, which occupy more of the spectrum. The number of correct responses was greatest for yellow, corresponding to Birren's (1969) study that the eye has maximum sensitivity to yellow and yellow-green and that yellow occupies a very limited portion of the spectrum.

Total number of correct responses was less for the green than yellow. The color green occupies a large range of the visible spectrum (from approximately 480nm to 540nm) and consequently has more variations in than the other colors. As it occupies a larger area of the spectrum and has greater variations than other hues, this may be a possible explanation why more errors are committed for the hue green.

Light passes through the lens and macular pigment before reaching the photoreceptors, which reduces the amount of short wavelength light reaching the receptors (Hurvich, 1981). Short wavelength light corresponds to the color blue test. The current study shows that total correct responses were equivalent for blue and green but were less than yellow. This may correspond to the reduced amount of short wavelength light reaching the retina.

In addition, only one cone system (L-cones) is activated by wavelengths at the red end of the spectrum (Hurvich, 1981). Since only one cone system can detect light at the red end of the spectrum, it can be inferred that red had the least amount correct in the current study because red has the least amount of photoreceptors sensitive to its wavelengths.

A significant interaction was found between dimension and color. Laws (1999) also found a significant interaction between dimension and test hue, which lends support to this finding. A trend is noticeable in which individuals performed better for hue, then lightness, then saturation for the yellow, green and blue test hues. Hamwi and Landis (1955) pointed out that color memory for an object tends to be overly saturated. The red test hues resulted as hypothesized for dimension: individuals performed better for hue then saturation, then lightness. Hurvich (1981) pointed out that under lightness conditions, red was worse than all other colors because the absorption rate for red is lower than for that of other hues. Performance for the hue condition for the colors blue, green, and yellow can be contributed to the fact that these colors correspond to wavelengths which activate all 3 cone systems and the rods. Performance for red , conversely, is lower because only the L cones are activated by this wavelength. The interaction across dimensions for yellow, green, and blue may be attributed to the spectral sensitivity of rhodopsin and the relative sensitivities of the cone systems. Observers perform better for lightness than saturation in this portion of the spectrum (yellow, green, blue) – this is the portion where the rod system (which detects overall luminance) is maximally sensitive. Since the L cone is the most sensitive of the cone systems to overall luminance, and is more readily bleached at low levels of light it can be inferred that changes in lightness at normal levels would be more difficult to perceive.

Finally, it was hypothesized that color experience and color preference would significantly correlate with performance on the color memory test and the participants' preferred color(s), respectively, but this was not found. These findings suggest then, that experience with color and/or preference for color does not relate to how well an individual performs on a color memory test.

A correlation was also run between participants' score on the VVIQ and total number correct on the color memory test to determine whether observer imagery had any relationship to how well individuals performed on the test. High imagers were hypothesized to do better on the color memory task than low imagers. The correlation was non-significant. As discussed above there were no low imagers either in the current or in Laws (1999) experiment. Therefore, further studies concerning color memory should include the VVIQ in an attempt to gather data from low as well as high imagers so a more accurate relationship between visual imagery and color memory can be investigated.

Implications

The results of this study, coupled with the evidence discussed above, suggests that memory for color is dependent of context. Although support has been given to the notion that color memory exists independent of context (Jin and Shevell, 1996; Laws, 1999; Nilsson and Nelson), more recent evidence utilizing advanced technology lends support to computational color processing early in the visual pathways in which cognitive factors do not come into play. It is not until visual information reaches higher cortical levels that cognitive factors impact visual perception. Subscribing to Land's computational theory, it does not seem possible for color memory to exist if no cognitive factors are involved. By the time visual information reaches higher cortical areas, the visual information has already passed through area V4, which combines color information with contextual information (Zeki & Marini, 1998). This then feeds to higher-level cortical areas capable of cognitive processes (Kandel et al., 2000; Zeki & Marini, 1998).

This leads to an interesting question. Can practice improve memory for colors associated with objects? In other words, the current study found that practice does not improve memory for color independent of context, but this result does not preclude the possibility that practice may very well improve memory color. The rationale for carrying out an experiment to test this research question is that memory color, or memory for color associated with an object, brings cognitive factors into play. Zeki and Marini (1998) studied color vision processing using Mondrians and naturally and unnaturally colored common objects and found that memory for color only exists when it is associated with an object. They demonstrated that environmental scenes are far easier to remember than independent colors.

Ratner and McCartney (1990) also found that memory was better for ecologically relevant stimuli. It is the opinion of the author that practice may very well improve memory color, especially with ecologically relevant stimuli, and that whenever an association of any type is made between color and context, the stronger the association, the more likely that memory for color will improve. Further studies should have participants report strategies for remembering colors, and compare the participants that employ such strategies as opposed to those who did not. The use of strategies would require the use of cognitive abilities and thereby reinforce memory for color.

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Table 1

Gender ANOVA

	df	SS	MS	F	Sig
Between groups	1	14.583	14.583	.620	.436
Within groups	40	941.036	23.526		
Total	41	955.619			

Table 2

Mixed Model repeated measures ANOVA

Source	df	SS	MS	F	Sig
Dimension	2	45.145	22.573	25.344	.000
D x Cd	4	1.882	.470	.528	.715
Error (dim)	78	69.471	.891		
Color	3	6.752	2.251	2.457	.066
C x Cd	6	5.001	.834	.910	.490
Error (Color)	117	107.157	.916		
Dim x Color	6	31.857	5.310	7.444	.000
D x C x Cd	12	7.958	.663	.930	.518
Error (D x Cd)	234	166.895	.713		
Condition	2	1.064	.532	.264	.769
Error (cond)	39	78.570	2.015		

Table 3

t-tests for Dimension X Hue Interaction

Pair no.	Paired samples		mean		Std deviation		t	df	Sig. (p ≤ .005)
	Sample 1	Sample 2	1	2	1	2			
1	Red Hue	Red Light	1.71	1.33	.17	.14	2.153	41	.037
2	Red Hue	Red Sat	1.71	1.69	.17	.15	.113	41	.911
3	Red Light	Red Sat	1.33	1.69	.14	.15	-1.858	41	.070
4	Yellow Hue	Yellow Light	2.74	1.81	.12	.10	6.730	41	.000
5	Yellow Hue	Yellow Sat	2.74	1.17	.12	.13	9.799	41	.000
6	Yellow Light	Yellow Sat	1.81	1.17	.10	.13	4.348	41	.000
7	Green Hue	Green Light	2.14	1.67	.12	.16	2.424	41	.020
8	Green Hue	Green Sat	2.14	1.40	.12	.14	4.611	41	.000
9	Green Light	Green Sat	1.67	1.40	.16	.14	1.230	41	.226
10	Blue Hue	Blue Light	1.90	1.86	.19	.16	.224	41	.824
11	Blue Hue	Blue Sat	1.90	1.33	.19	.13	2.322	41	.025
12	Blue Light	Blue Sat	1.86	1.33	.16	.13	2.842	41	.007
									Bonferroni Corr sig. (p ≤ .0028)
1	Red Hue	Yellow Hue	1.71	2.74	1.11	.77	-5.354	41	.000
2	Red Hue	Green Hue	1.71	2.14	1.11	.78	-2.371	41	.023
3	Red Hue	Blue Hue	1.71	1.90	1.11	1.25	-1.091	41	.282
4	Yellow Hue	Green Hue	2.74	2.14	.77	.78	3.719	41	.001
5	Yellow Hue	Blue Hue	2.74	1.90	.77	1.25	3.609	41	.001
6	Green Hue	Blue Hue	2.14	1.90	.78	1.25	1.220	41	.230
7	Red Light	Yellow Light	1.33	1.81	.90	.67	-2.963	41	.005
8	Red Light	Green Light	1.33	1.67	.90	1.05	-1.711	41	.095
9	Red Light	Blue Light	1.33	1.86	.90	1.25	-2.454	41	.018
10	Yellow Light	Green Light	1.81	1.67	.67	1.05	.758	41	.453
11	Yellow Light	Blue Light	1.81	1.86	.67	1.05	-.274	41	.785
12	Green Light	Blue Light	1.67	1.86	1.05	1.05	-.840	41	.406
13	Red Sat	Yellow Sat	1.69	1.17	.98	.85	2.945	41	.005
14	Red Sat	Green Sat	1.69	1.40	.98	.89	1.355	41	.183
15	Red Sat	Blue Sat	1.69	1.33	.98	.87	1.727	41	.092
16	Yellow Sat	Green Sat	1.17	1.40	.85	.89	-1.302	41	.200
17	Yellow Sat	Blue Sat	1.17	1.33	.85	.87	-.805	41	.426
18	Green Sat	Blue Sat	1.40	1.33	.89	.87	.424	41	.674

Table 4

t tests for Color Preference

Pair No	Paired Samples		mean		Std deviation		t	df	Sig
	Sample 1	Sample 2	1	2	1	2			
1	Blues	Greens	5.33	5.67	2.31	2.15	-.443	11	.666
2	Blues	Reds	5.33	5.17	2.31	2.04	.233	11	.820
3	Blues	Yellows	5.33	6.00	2.31	1.76	-.853	11	.412
4	Greens	Reds	5.67	5.17	2.15	2.04	.761	11	.463
5	Greens	Yellows	5.67	6.00	2.15	1.76	-.421	11	.682
6	Reds	Yellows	5.17	6.00	2.04	1.76	-.923	11	.376

Figure 1

Gender Performance on Color Memory Test

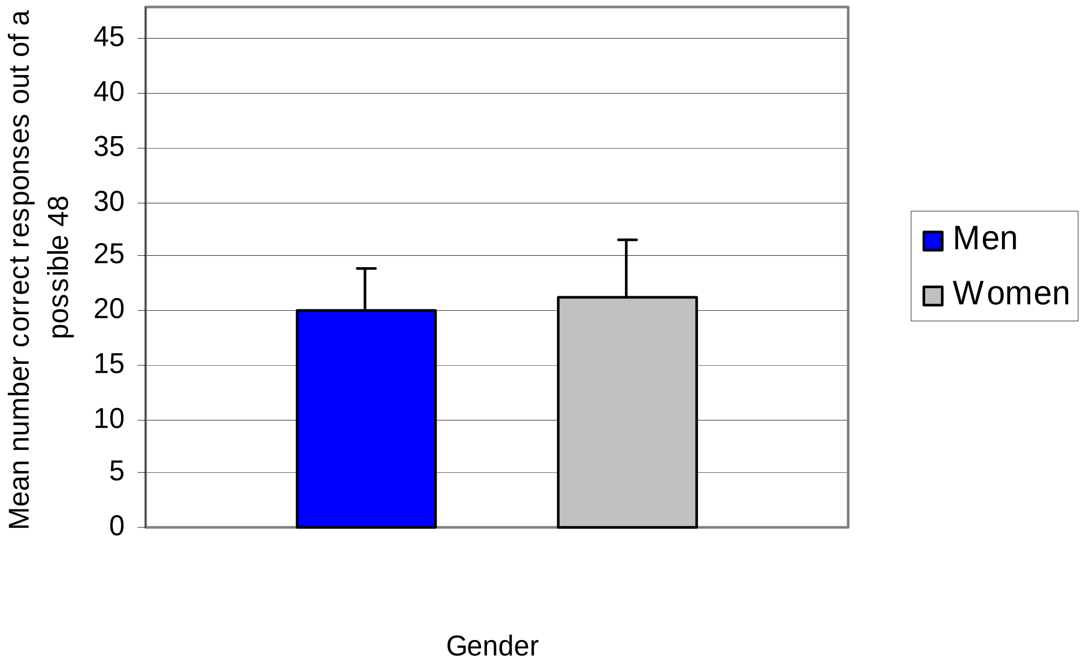


Figure 2

Condition Performance on the Color Memory Test

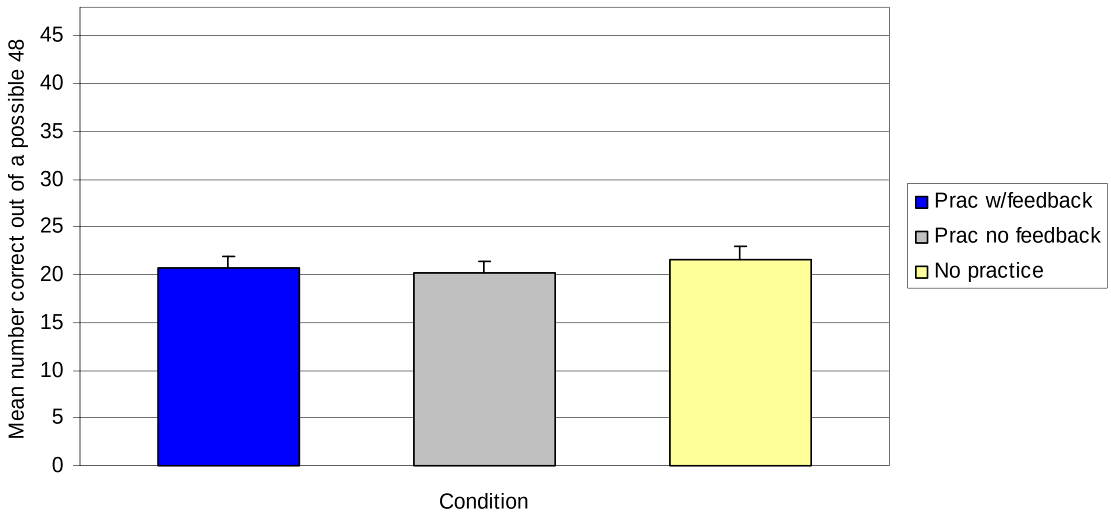


Figure 3

Performance on Color Memory Test for Dimension Factor

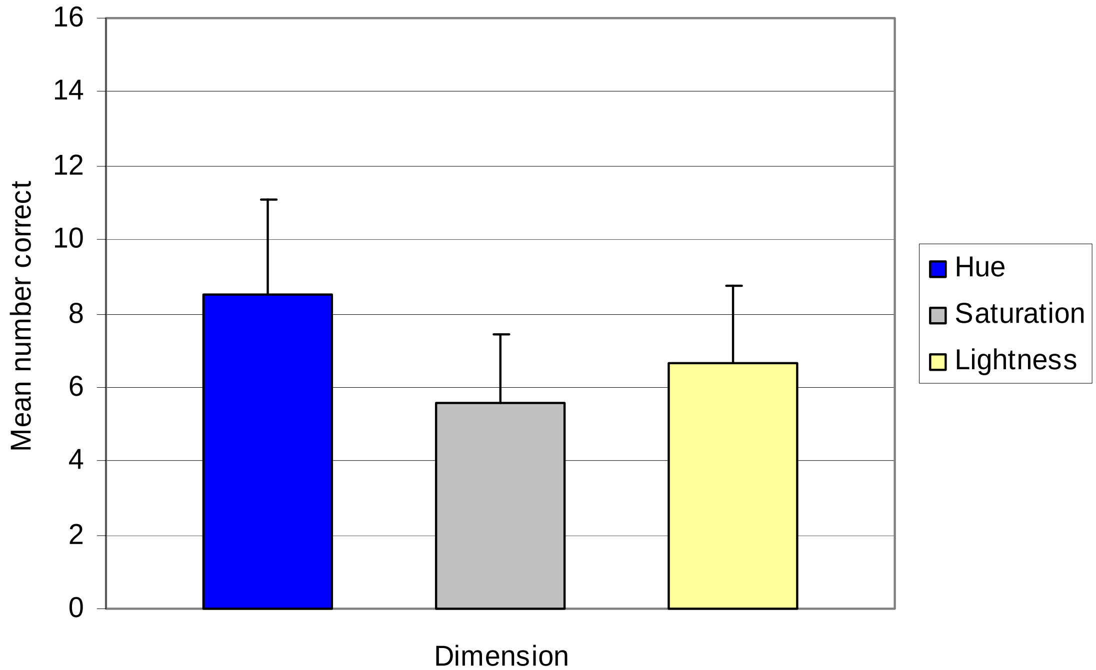


Figure 4

Performance on Color Memory Test for Color Factor

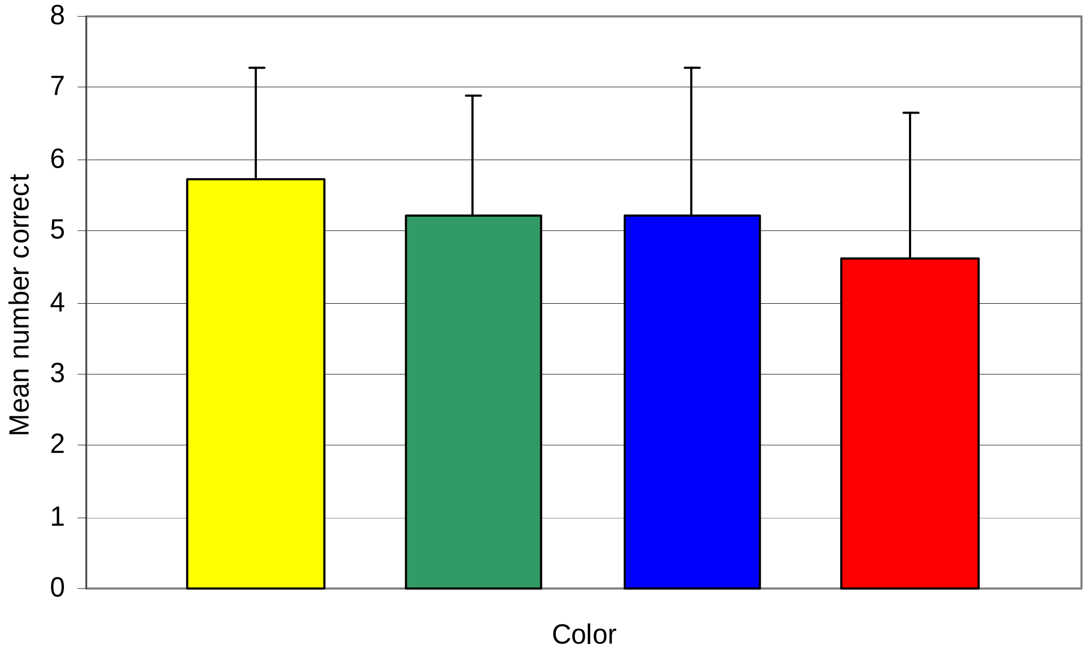


Figure 5

<u>Interaction of Dimension and Color</u>

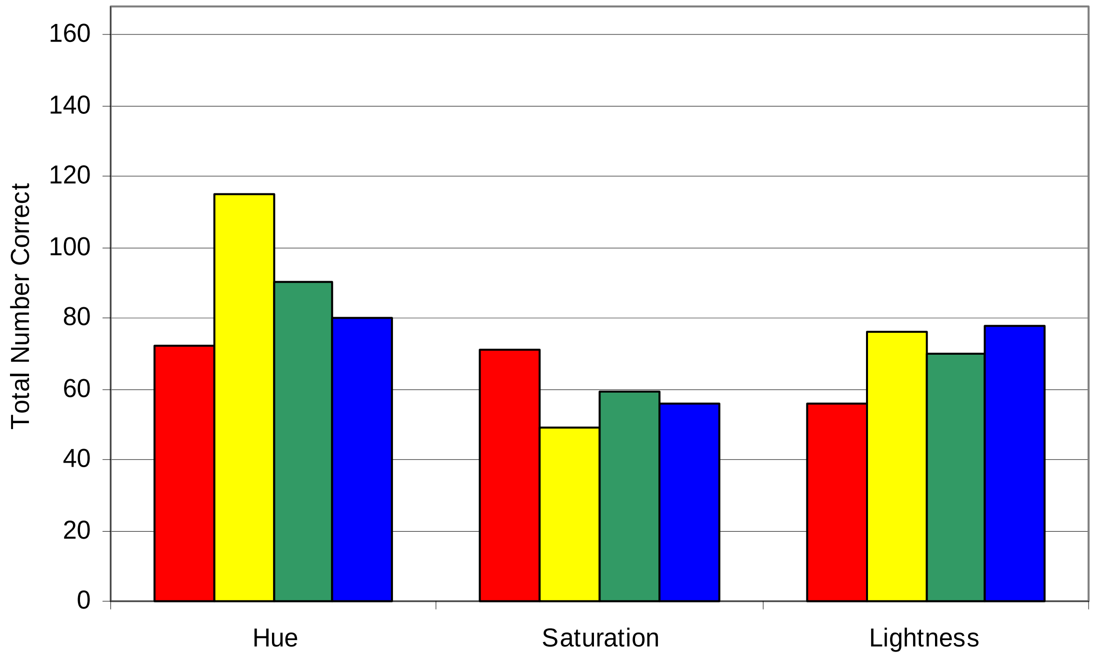
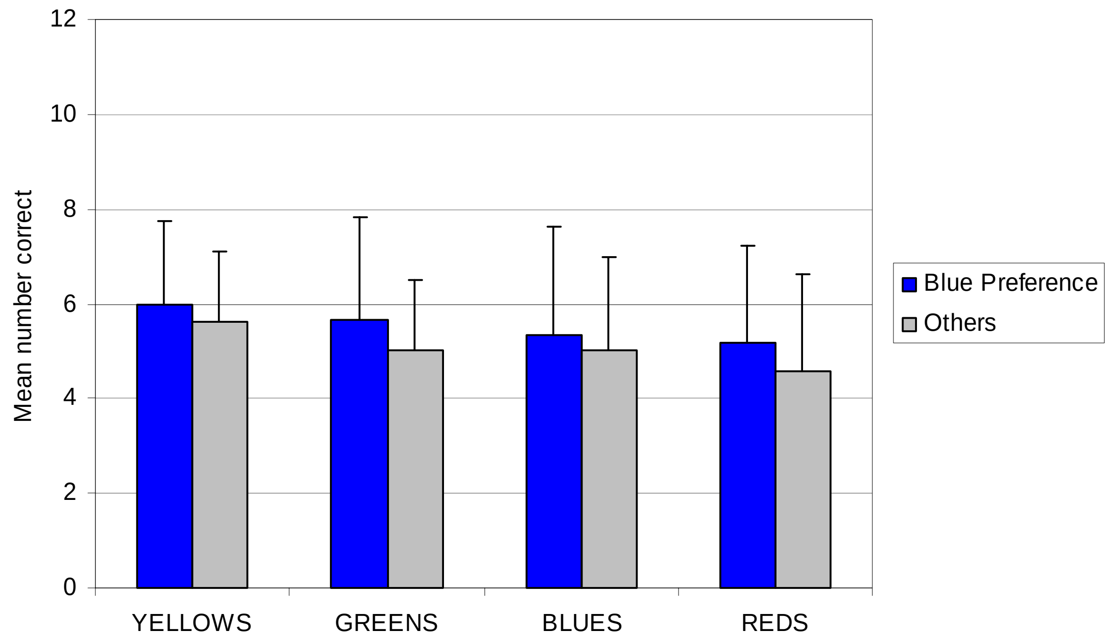


Figure 6

<u>Color Preference</u>



<u>Figure 6,</u> Relationship between color preference and mean score (by color) on the color memory test. Since the majority of participants preferred the color blue (N=12), the figure demonstrates the performance of individuals who preferred blue as compared to all other participants.

Figure 7

Color Experience

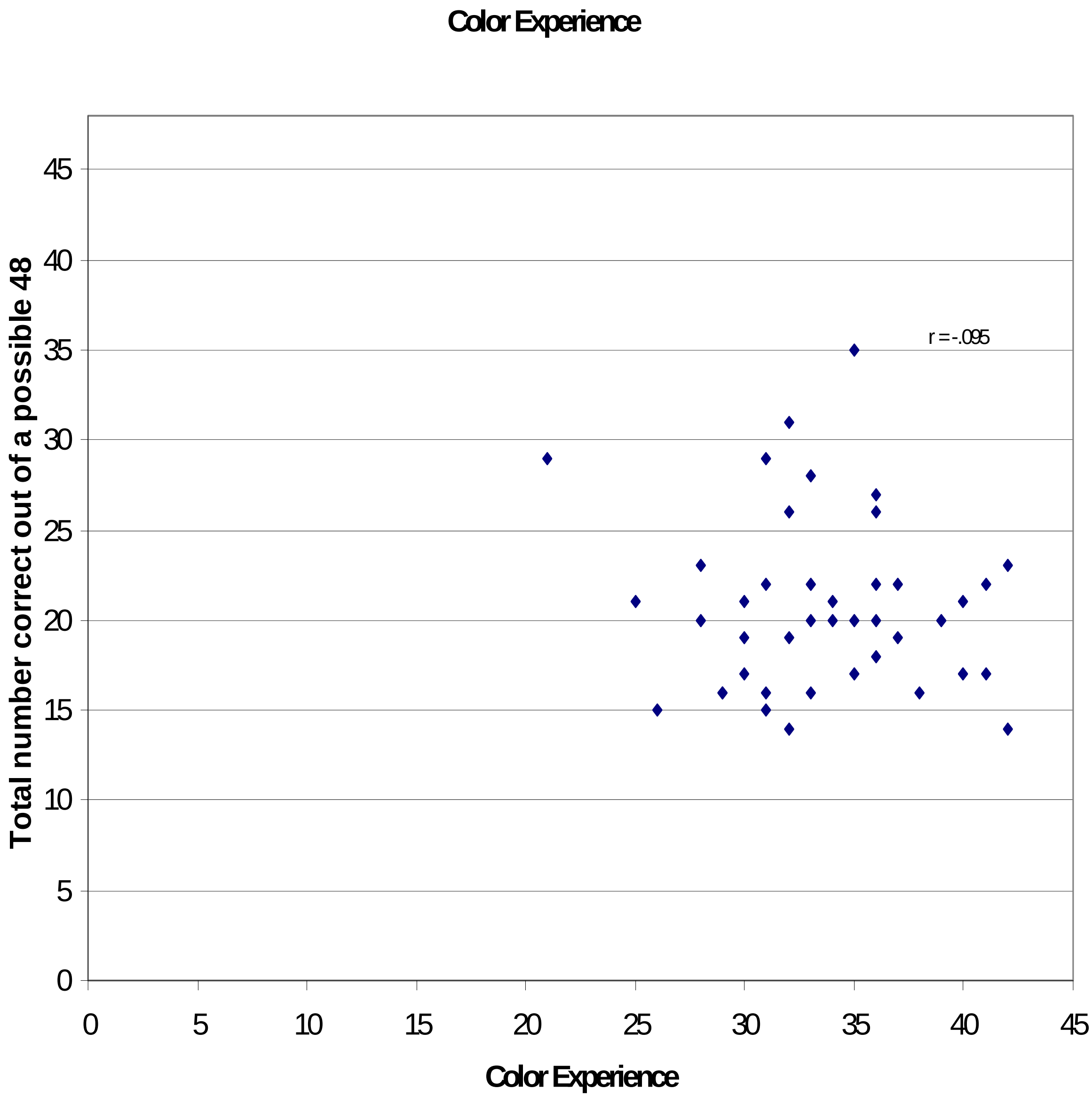
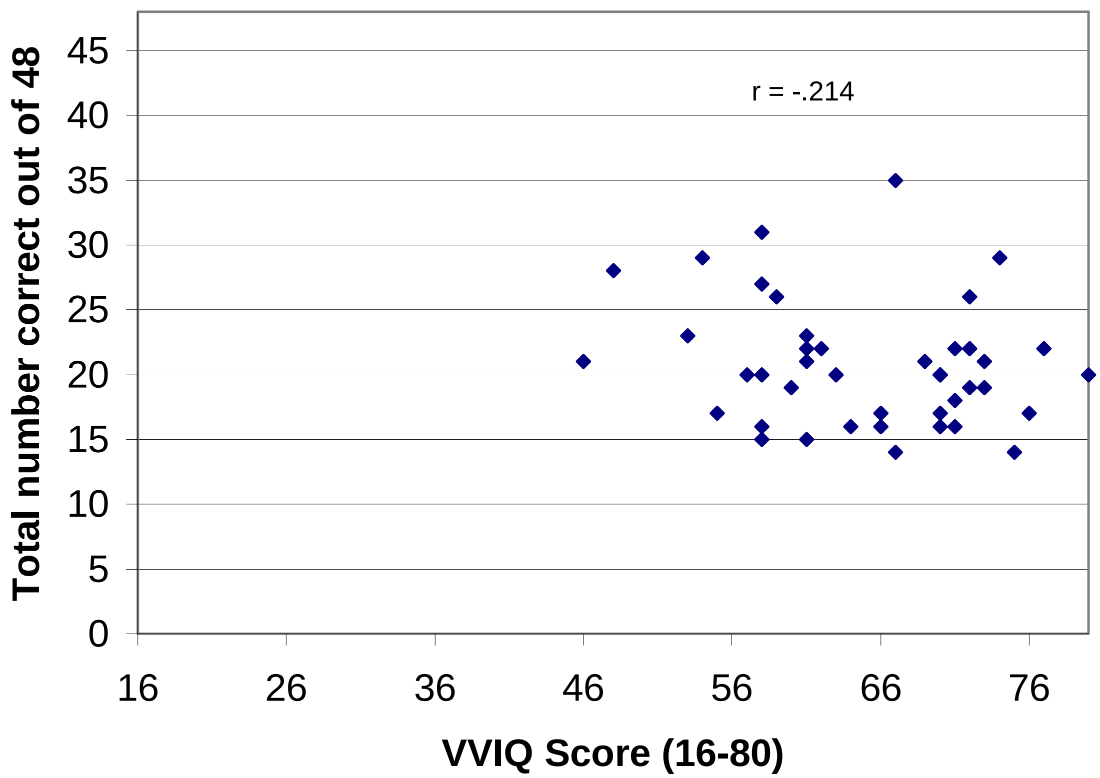


Figure 8

VVIQ X Total Number Correct



Appendix A

Color Experience Questionnaire

1. How would you rate your overall visual artistic ability?

1	2	3	4	5	6
Poor	**Fair**	**Average**	**Above Average**	**Very Good**	**Excellent**

2. How often do you use a computer?

1	2	3	4	5	6
Seldom	**Rarely**	**Occasionally**	**Daily**	**Frequently**	**Repeatedly**
Once every Few weeks	Once a week	2 - 3 times Per week	At least once a day	2 -3 times a day	> 3 Times A day

3. On the lines below please name as many colors as possible (not exceeding 20). Please avoid using qualifiers such as “light” blue or “dark” green.

______________________________ ______________________________
______________________________ ______________________________
______________________________ ______________________________
______________________________ ______________________________
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______________________________ ______________________________
______________________________ ______________________________
______________________________ ______________________________
______________________________ ______________________________
______________________________ ______________________________

4. If you rated your visual artistic ability as a 4 or above, please indicate in the space below any relevant experience you have had with color. (Ex. Coursework; I have been a painter for X years; I am a photographer; I work in computer graphics, etc…).

____
____
____
____
____
____
____
____

5. I consider my ability to discriminate colors from one another to be

1	2	3	4	5	6
Poor	**Fair**	**Average**	**Above Average**	**Very Good**	**Excellent**

6. Please put a check mark by the phrase or phrases that you believe best describe(s) you.

____ I am impulsive, quick to speak my mind, prone to emotional ups and downs, athletic, sexy, believe that others beside myself are to blame for any problems I may encounter. I believe that life is always meant to be exciting and happy. I desire all those things in life, which offer intensity of living and fullness of experience.

____ I believe myself to be of above-average intelligence. I am partial to the mental and spiritual aspects of life. I favor originality, innovation and wisdom. I tend to be introspective, discriminating and serious-minded about the world and the talented people in it. I tend to be focused on the future, towards the new, or the modern.

____ I am constantly on the go and enjoy the good things of life. I believe myself to be socially well adjusted, civilized and conventional. I enjoy belonging to clubs and taking part in social activities. I am rather easy-going and not impulsive. I tend to be somewhat of a reformer. I want to be recognized and have my way against opposition and resistance.

____ I consider myself to be rational, cautious, steady and often admirable. I value conservatism, accomplishment, devotion, deliberation and introspection. I consider myself to be successful. I know how to make the right connections in life and seldom do anything impulsive. I feel I am in control of my emotions. I desire a calm and orderly environment free from upsets and disturbances.

7. What color(s) do you prefer to wear?____________________________________

____
____

8. What color(s) do you prefer to see in your environment? ___________________

____
____

Appendix B

VVIQ

Subject #

For each of the following suggested images, please rate its vividness in your mind's eye

as follows:

1. No image at all, you only "know" that you are thinking of the object

2. Vague and dim

3. Moderately clear and vivid

4. Clear and reasonably vivid

5. Perfectly clear and as vivid as normal vision

For the following four items, think of someone whom you frequently see but is not present with you at the moment. Consider carefully the picture that comes before your mind's eye. Rate the vividness of imagery using the above scale. Put your response on the answer sheet.

1 . The exact contour of face, head, shoulders, and body
2. Characteristic poses of head, attitudes of body, etc.
3. The precise carriage, length of step, etc., in walking.
4. The different colors worn in some familiar clothes.

For the next four times, visualize a rising sun. Consider carefully the picture that comes before your mind's eye. take as much time as is necessary to conjure up each image.

5. The sun is rising above the horizon into a hazy sky.
6. The sky clears and surrounds the sun with blueness.
7. Clouds.
8. A storm blows up, with flashes of lightning.

For the next four items, think of the front of a shop to which you often go. Consider the picture that comes before your mind's eye.

9. The overall appearance of the shop from the other side of the road.
10. A window display, including colors, shapes and details of individual items for sale.
11. You are near the entrance. The color, shape, and details of the door.
12. You enter the shop and go to the counter. The counter assistant serves you. Money changes hands

Finally, for the next four times, think of a country scene which involves trees, mountains and a lake. Consider the picture that comes before your mind's eye.

13. The contours of the landscape.
14. The color and shape of the trees.
15. The color and shape of the lake.
16. A strong wind blows on the trees and on the lake, causing waves.

Appendix C

Informed Consent for Participants of Investigative Projects

Title of Project: The Effects of Practice on Color Memory
Primary Investigator: Britten Remus, Derring 5103; e-mail: bremus@vt.edu
Faculty Advisor: Dr. A.M. Prestrude, Derring 5107

Purpose: You are invited to participate in a study that examines the effects of practice on color memory. Your participation will help us to better understand the effects practice has on color memory performance.

Procedures: You will be asked to participate in 2 non-consecutive phases of this experiment each lasting approximately 20-25 minutes. You will receive 1 extra credit point for each phase. In the first phase of the experiment you will receive a vision screening test and complete 2 questionnaires. Upon completion of phase 1 you will choose a time slot for the second phase of the experiment. In the second phase of the experiment you will be presented with various colors and then given a chance to identify those colors out of many possible choices.

Risks and Benefits: There are no apparent risks to participants in this experiment. You will receive a free vision-screening test assessing acuity and color vision.

Confidentiality: The responses that you provide will be completely confidential. A "subject number" which will only be accessed by the primary investigator will identify participants. That is, your responses will not be released to anyone other than the primary investigator without your consent.

Compensation: Since each phase of the experiment is worth 1 extra credit point, you will receive a total of 2 extra credit points towards your class for participating in both phases of the experiment.

Freedom to Withdraw: You are free to withdraw your participation in this study at any time during the course of your participation without penalty.

Approval of Research: This research project has been approved by the Institutional Review Board at Virginia Tech and the Human Subjects Committee of the department of psychology.

Participant's Responsibilities: I voluntarily agree to participate in this study.

Participant's Permission: I have read and understood the Informed Consent and conditions of this project. I have had all my questions answered. I hereby acknowledge the above and give my voluntary consent for participation in this project. I will abide by the rules of this project and understand that I may withdraw at any time without penalty.

___________________________ ___________________________

Signature Date

Should I have any questions about this research or its conduct, I may contact:

Primary Investigator:	Britten G. Remus 961-5927
Faculty Advisor:	Dr. A. M. Prestrude 231-5673
Chair, Institutional Review Board:	Thomas Hurd 231-5281
Chair, Human Subjects Committee:	Dr. David Harrison 231-4422

Appendix D

Medical Screening Questionnaire

Subject # ______

Answers to the following questions are needed to screen for participation in the color memory study. We must know if you have had any medical problems, which might interact with the study. It is important that you be as honest as you can.

1. Since birth have you ever had any serious medical problems requiring hospitalization?

Circle one: yes no (if yes, please explain)

2. Have you ever hit your head and experienced a concussion?

Circle one: yes no (if yes, please explain)

3. Have you ever had any visual problems?

Circle one: yes no (if yes, please explain)

4. Do you currently have or have you ever had any of the following? Circle yes or no.

yes	no	diabetes
yes	no	neurological problems
yes	no	epilepsy or seizures
yes	no	brain disorder
yes	no	stroke

If you circled yes to any of the above conditions, please explain.

5. Have you ever been diagnosed formally to have had…

yes	no	learning deficiency or disorder
yes	no	reading deficiency or disorder
yes	no	attention deficit disorder
yes	no	hyperactivity

6. List any of the over-the-counter or prescription medications you are presently taking.

Curriculum Vitae

Britten Remus
301 Loudon Rd #622
Blacksburg, VA 24060
(540) 961-5927 bremus@vt.edu

Educational Background	Degree:	Masters of Science, expected spring 2002
	Institution:	Virginia Polytechnic Institute and State University
	Major:	Experimental Psychology
	Degree:	Bachelor of Arts, August 1997
	Institution:	Florida International University
	Major:	Psychology

Honors and Awards

Academic Scholarship to Tulane University
Elected Secretary of Psi Chi at Tulane University
Deans List, Tulane University, Spring 1995
Deans List, Florida International University, Summer 1997
Graduated *cum laude,* Florida International University, 1997

Memberships in Scholarly Organizations

Officer in Chi Omega sorority.
Psi Chi (National Honor Society of Psychology)

Professional Experience

Graduate Teaching Assistant (August 1999 – June 2001)
- Virginia Polytechnic Institute and State University:
  Courses Taught:
  - Introductory Psychology Lab (4 sections)

Graduate Research Assistant (January 2000 – May 2000)
- Virginia Polytechnic Institute and State University:
  Responsibilities:
  - I assisted Dr. Martha Ann Bell with her research in an infant developmental lab. My duties included infant EEG data and infant heart rate analysis.

Undergraduate Research Assistant (June 1995 – August 1995)
- University of Miami

Responsibilities:

- I served as a research assistant to a doctoral student on his dissertation investigating the role cognitive reserve played in relation to Parkinson's disease symptoms. My responsibilities included interviewing patients to acquire background knowledge, analyzing and coding the information, and maintaining the appropriate databases. This assistantship also required extensive use of the medical library and computer labs. Investigator: Dr. James Cordle.

Undergraduate Research Assistant (January 1995 – May 1995)

- Tulane University

Responsibilities:

- I served as a research assistant on a study involving impression formation. The purpose of this study was to examine how controversial personal information given by a confederate influenced the participant's overall impression of the confederate. My responsibilities included assuming the role of confederate and encoding data. Investigator: Dr. Lawrence W. Dachowski.

Advanced Graduate Coursework

Statistics for Social Science Research (I & II)
Proseminar in Learning
Research Methods
Developmental Psychobiology
GTA Training Workshop
Developmental Psychology
Biological Bases of Behavior
Cognitive Psychology
Psychophysiology
Neuropsychology
Neurocognition and EEG
Neurochemical regulation
Research & Thesis