The Effect of Age on Color Memory

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Abstract

The purpose of this study is to investigate the effects of age on short-term color memory using the method of successive color matching. A group of 11 college students with an average age of 20 was compared to a group of experienced art dealers and collectors with an average age of 63. Using 24 hues of three cuts in three delay conditions, a total of 72 trials were presented to each group. The results show that a delay condition with verbal interference decreased the accuracy of response for both populations, but proportionately more so for the student group. The seniors performed overall less accurately than did the students across colors and cuts, with the seniors exhibiting a significant decrease in accuracy for the short wavelength colors, blue and purple. This suggests that lenticular senescence is an important factor in indicating which hues are most easily remembered by senior subjects. Another implication of these results is that color memory for the seniors is more contextual, also involving material, surface texture, and patina.

Introduction

Success in the art business, especially in the selling of colorful textiles, paintings and objects, involves the ability to distinguish and remember subtle color variation. This ability, in the case of several of my colleagues, is the result of decades of experience in handling art and conveying to potential buyers the desirability of one color over another. This acquired skill suggested that a testable difference might exist between this particular group of experts and a similar number of students, either trained or untrained in the arts.

Color memory, or successive color matching, seemed an appropriate method to measure possible differences between these two populations. Might the years of experience mitigate the expected age-related losses in color vision? In other words, would expertise trump physiology?

Experiments have shown that the ability to perceive and discriminate colors most accurately is strongest between the ages of 16 and 35 (Lakowski, 1958). There is deterioration in the ability for fine color discrimination after the age of 55, with more losses in the perception of short wavelength blue light (Weale, 1973). With aging, the lens of the eye undergoes crystalline yellowing, which effectively absorbs short wavelength light, allowing fewer of these photons to hit the receptors in the retina. The amount of blue light available to the retina of a 60 year-old is approximately one-third less than that present in the retina of a 20 year-old. This shifts the sensitivity toward the longer wavelengths for seniors (Weale, 1973). Lenticular senescence, another term for this yellowing of the nucleus of the lens, was also shown by Werner and Steele (1988) to significantly reduce perceptual sensitivity to short wavelengths. A reduced amount of light entering the eye by pupil constriction (senile miosis) further compromises color recognition in the older eye (Weale, 1961). With these considerations, we expected to find a difference in the performance of color memory by hue between senior and student subjects.

Color memory is also affected by how visual information is encoded. Two theories (Paivio, 1969) (Baddlely and Hitch, 1974) suggest that separate mechanisms are used in short-term memory: perceptual and verbal. I hypothesized that the seniors might have developed verbal descriptions of colors that enable them to remember color nuance better than the average person. In addition to the basic color terms proposed by Berlin and Kay (1969) - black, white, red, green, blue, yellow, orange, brown, purple, pink, and gray – other descriptors are used to differentiate particular shades, such as navy blue and cherry red. Perhaps after years of describing color, the senior group would more accurately cue their short-term memory with verbal associations, increasing their rate of accuracy.

This experiment investigates the use of verbal cues by varying the delay conditions on each trial, including one delay with verbal interference, which should show an increase in errors of color memory. The effect of age on color memory will be revealed by overall performance as well as by the accuracy of remembering particular hues, especially the short wavelength blues and purples.

Methods

Participants

The participants were eleven UC Berkeley students with a mean age of 20, and eleven seniors with a mean age of 63. In the student group, nine of the participants were female and two were male. In the senior group, five were female and six were male. One of the male seniors reported a perceived color deficiency, but tested as having normal color vision; all other subjects in both groups had normal color vision. The student subjects were enrolled in an extended course on color perception, they participated voluntarily, and they served as subjects in several other color experiments. The senior group was comprised of art dealers, collectors, and artists who participated voluntarily, and had no other recent testing experience.

Stimuli and Design

The design of this experiment consisted of the independent combination of four factors: hue (red, orange, yellow, chartreuse, green, cyan, blue, or purple), cuts (light, muted or dark), memory delay (0 or 6 seconds), and rehearsal condition (counting or no-counting). In the 6-second delay condition with counting, subjects counted backward by fives, starting with a random two-digit number that was presented on the distracter slide. The combination of three cuts and eight hues created 24 unique colors, shown in Figure 1, equidistant from the central axis, which were then used in each delay condition. The experiment, therefore, consisted of 72 trials (24 colors x 3 delay conditions = 72 trials).

Figure 1. The Palmer Lab color spindle. The three cuts used were light, muted, and dark, all equidistant from the central axis. The saturated color cut was not included.

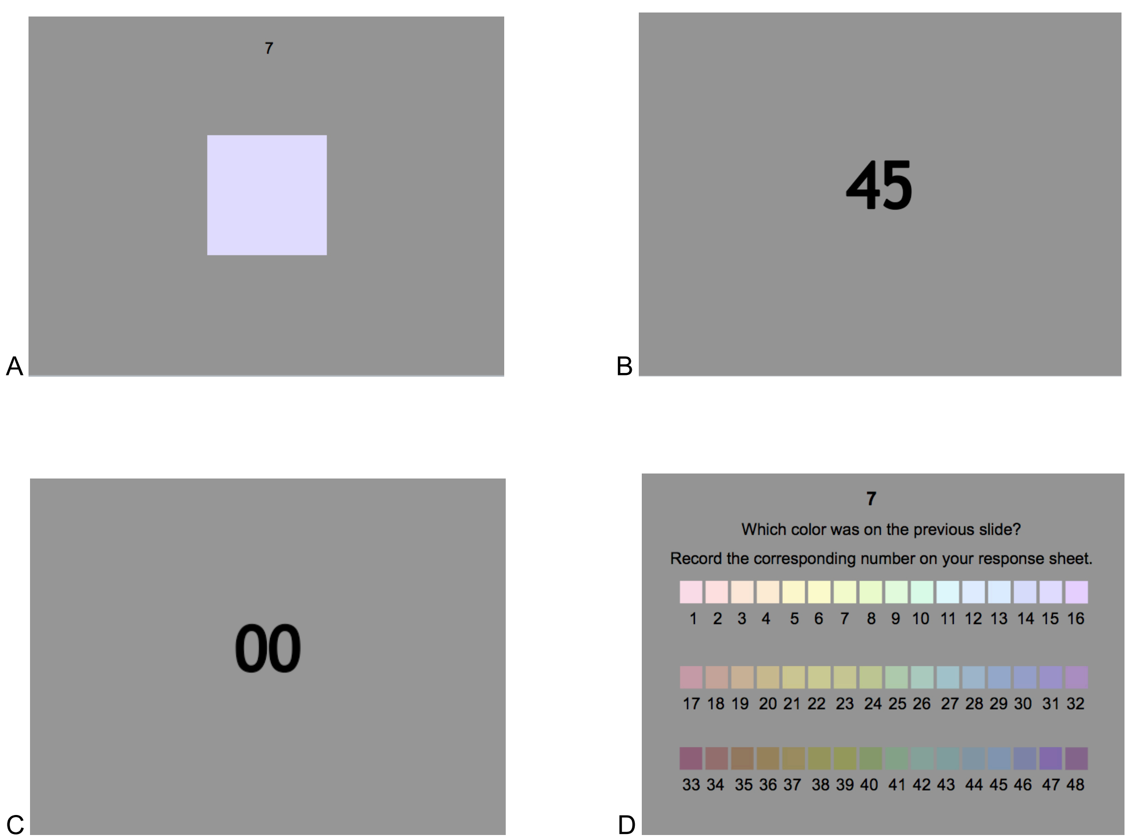

Figure 2: (A) An example of a target stimulus that began each trial. (B) The mask that appeared during the 6-second delay condition with counting. (C) The 6-second delay with no interference mask. (D) The test array from which subjects made their response.

The stimulus was a square patch of color presented in the center of a neutral gray field, with the trial number in the upper center margin of the screen, as shown in Figure 2A. The 24 colors were combinations of the eight different hues of medium saturation and three lightness conditions: light (high lightness), muted (medium lightness), and dark (low lightness).

In the delay condition, a neutral gray slide appeared with either a random number from which to count backward by fives (Figure 2B), or two zeros, which indicated a delay with no counting (Figure 2C). When there was no delay, the test array appeared (Figure 2D). The test array was composed of three rows of hues corresponding to the three cuts, with an intermediate hue between each possible target hue. A number was placed beneath each color square, from 1 to 48. The array was displayed for 15 seconds during which time subjects were able to record their chosen response.

Apparatus

The visual displays were presented using PowerPoint Mac 2008 on a Macintosh Air computer that was connected to a Dell 4210X color projector. The students recorded their responses on an Excel document on their personal laptop computers, while the experts wrote their responses on printed Excel documents.

Procedure

The participants were seated in a darkened room with enough light to record their responses. Subjects were instructed to look at the color patch on the screen with the intent to remember it. After one second, the target screen was replaced by a test array (in the no delay condition) or a screen that presented one of two 6-second delay conditions: a pair of numbers from which to count backward, out loud, by fives, or the numbers 00 on a gray screen, which indicated a delay with no counting. A screen with a response array was then shown, from which subjects were asked to choose the color patch that best fit the target color, and record the associated number. Subjects were provided with four practice trials before beginning the experiment to familiarize them with the different delay conditions.

The students did the experiment as a group during class time. The seniors met in the same classroom on two different evenings, with one group of seven and another of four. The total experiment took approximately 40 minutes per group.

Results

There was an overall main effect in the delay type for both groups combined [$F(2, 40) = 15.16$, $p < .001$], as seen in Figure 3. The no delay and the delay with no interference showed no significant difference in performance, with both conditions

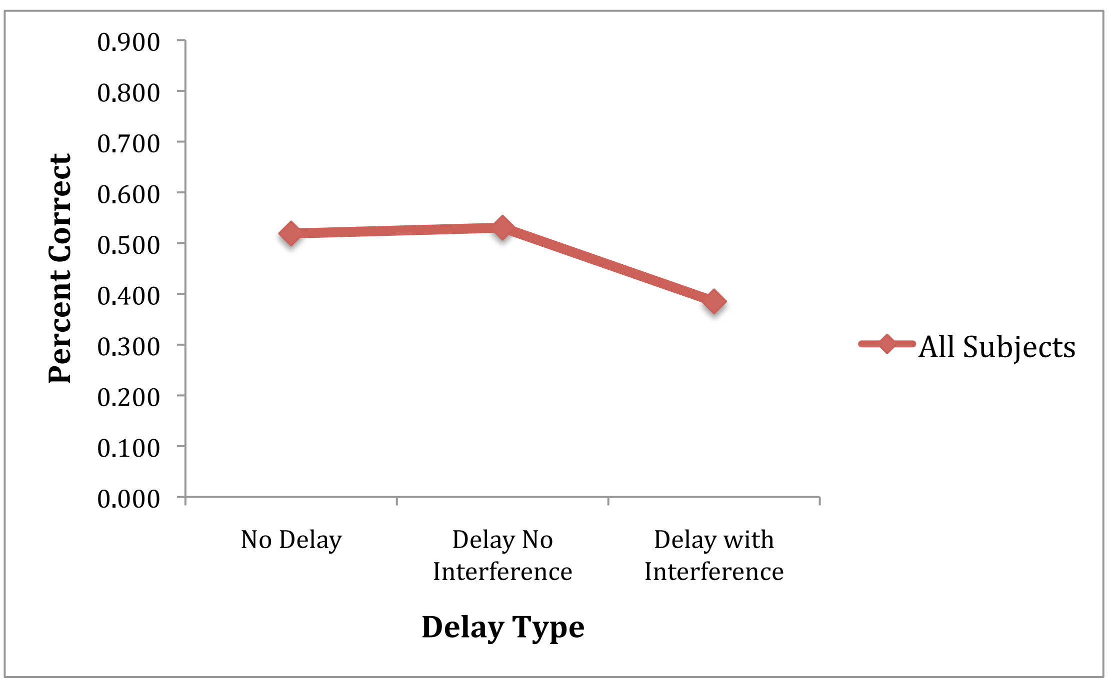

Figure 3. The average performance of all subjects in each delay condition shows the decrease in performance with verbal interference.

resulting in slightly over 50% correct. The average performance in the delay with no interference trials, however, was significantly higher than in the delay with interference trials [t (21) = 3.261, p < .005]. This suggests that by confounding the internal verbal encoding of color names with a verbal distracter activity, color memory can be disrupted.

When we look at the delay conditions by group (Figure 4) we see that the students performed better than the seniors in all three delay conditions [F (2, 40) = 5.61, p < .01]. The difference in performance between groups was similar in the two 6-second delay conditions, but diverged significantly in the no delay trials, perhaps due to the rapidity with which the response array appeared, resulting in confusion for the seniors.

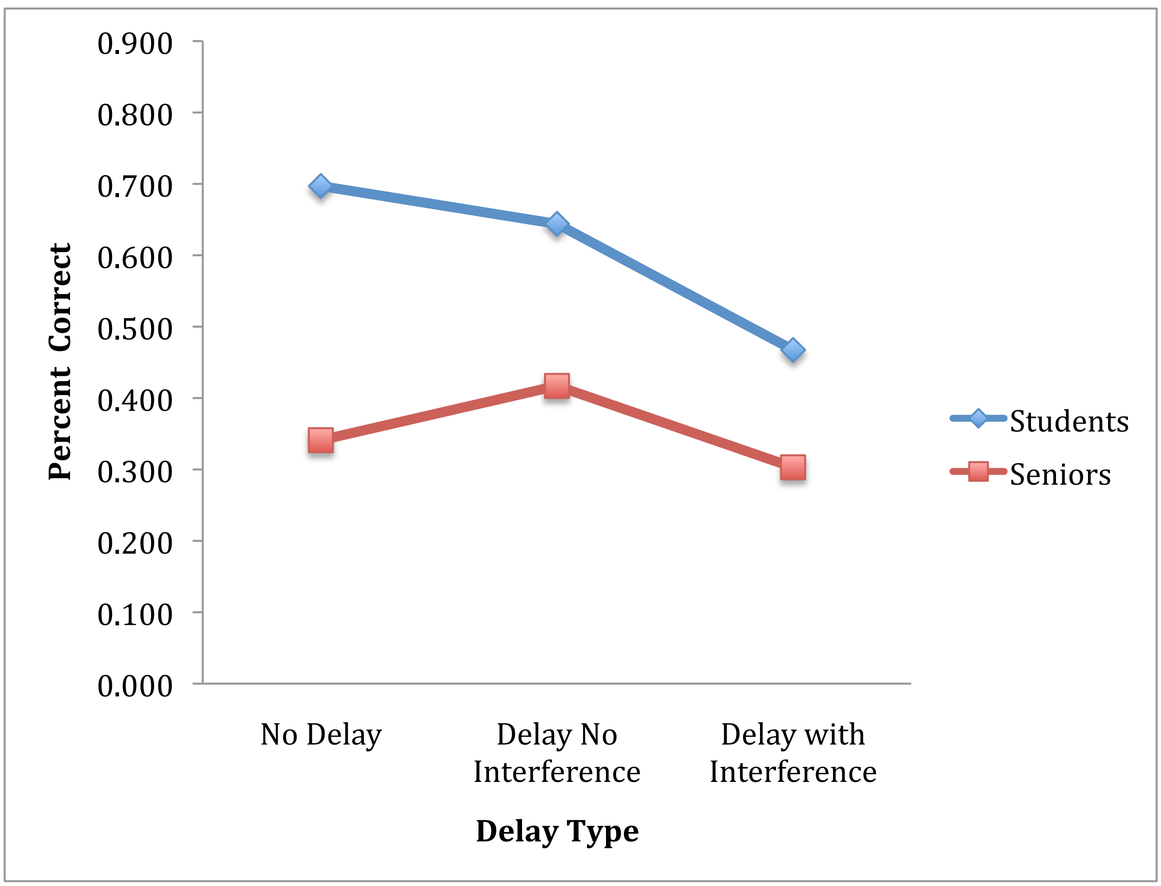

Figure 4. The average performance in each delay condition for students and seniors shows better accuracy for the student group overall.

The three-way ANOVA analysis of all subjects (Figure 5) shows a main effect of hue [$F (7, 140) = 11.02$, $p < .001$]. These results show that all subjects were most accurate in their response to the orange target colors, verifying findings in a study done by Perez-Carpinell et al (1998), which found that among ten colors studied, orange was the easiest to remember. Both groups performed significantly less accurately for the blue stimuli, an intriguing result, especially given that blue was demonstrated to be the preferred color in a recent study by Palmer and Schloss (2010). One possible explanation is that blue has only one basic color term, as opposed to red, which enjoys two: red and pink. This could affect the internal verbal coding, producing less accuracy for the blue trials (personal communication, Schloss 2011).

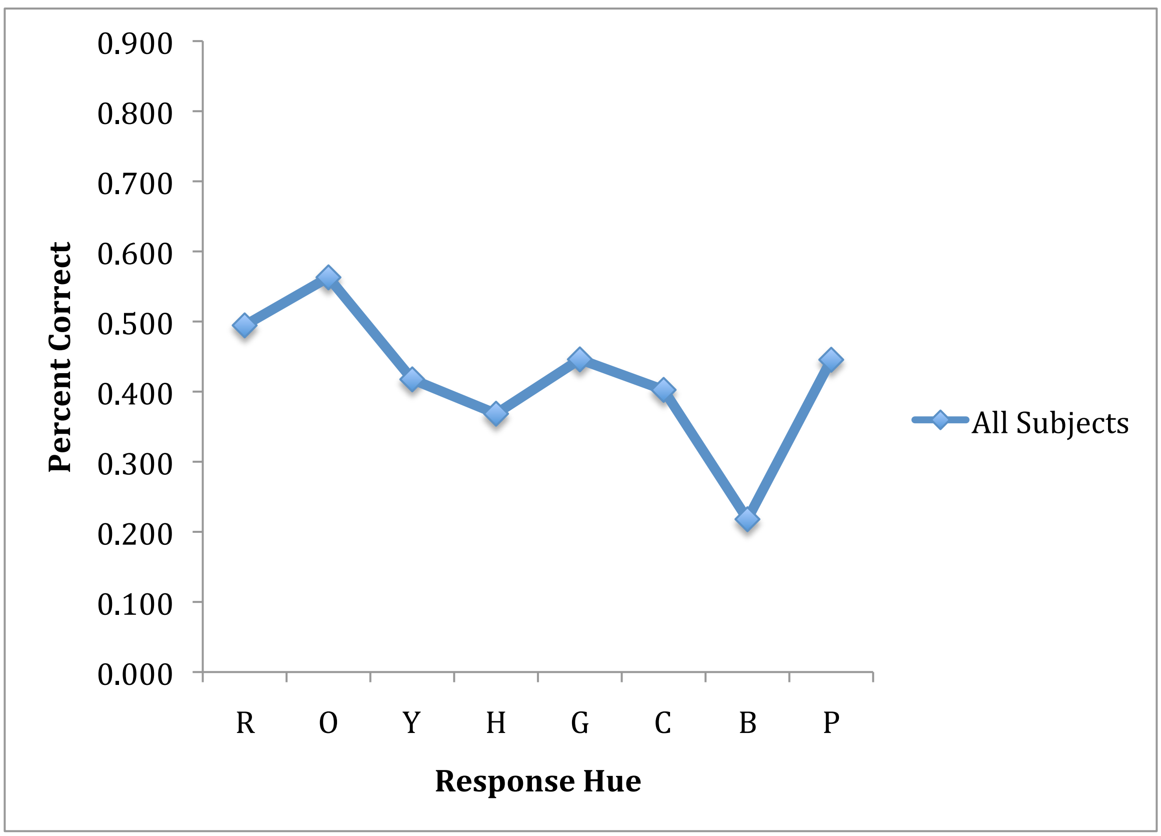

Figure 5. The average correct responses for each hue by group shows the difference in accuracy for the students and the seniors.

The performance of each group (Figure 6) in a three-way ANOVA analysis shows significant results [F (7, 140) = 2.99, p < .01]. Both groups were similarly accurate for the orange and cyan targets, with the seniors performing less accurately for each of the other six hues.

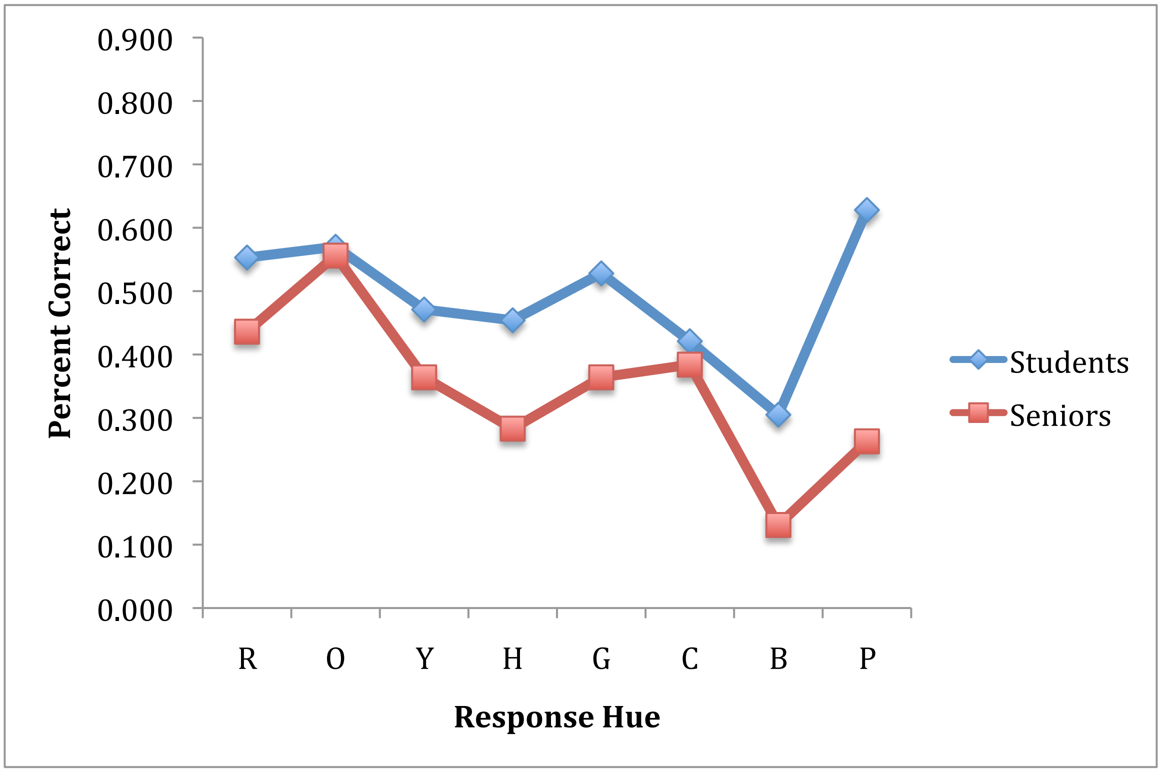

Figure 6. The average correct responses for each hue by group shows the difference in accuracy for the students and the seniors.

A three-way ANOVA analysis of cut shows a main effect (Figure 6) for the average performance of all subjects [F (2, 40) = 5.39, p < .01]. Subjects were nearly equally accurate for the light and muted cuts, but declined in accuracy for the dark cut [t (21) = 2.695, p < .05].

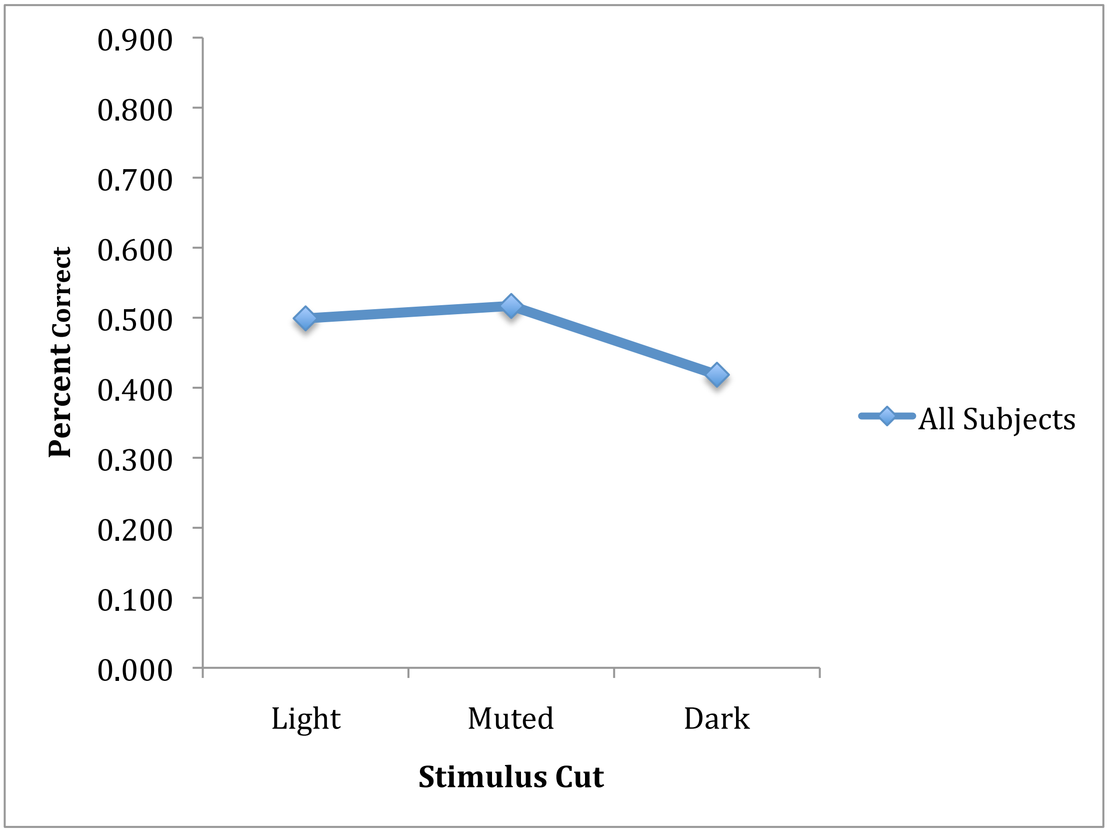

Figure 6. Average percent correct of all subjects over the three different stimulus cuts shows a decline in accuracy for the darker target colors.

In a three-way ANOVA analysis of cut by group, as displayed in Figure 7, there are significant differences [F 92, 40) = 27.78, p < .001]. Both seniors and students were equally accurate during light cut trials, at about 50% correct. The performance of the seniors deteriorated as the cut went from light to muted [t (10) = 2.653, p < .05] and further from muted to dark [t (10) = 2.568, p < .05]. The students, however, increased in accuracy from the light to medium cut, decreasing only slightly from the muted to dark cut.

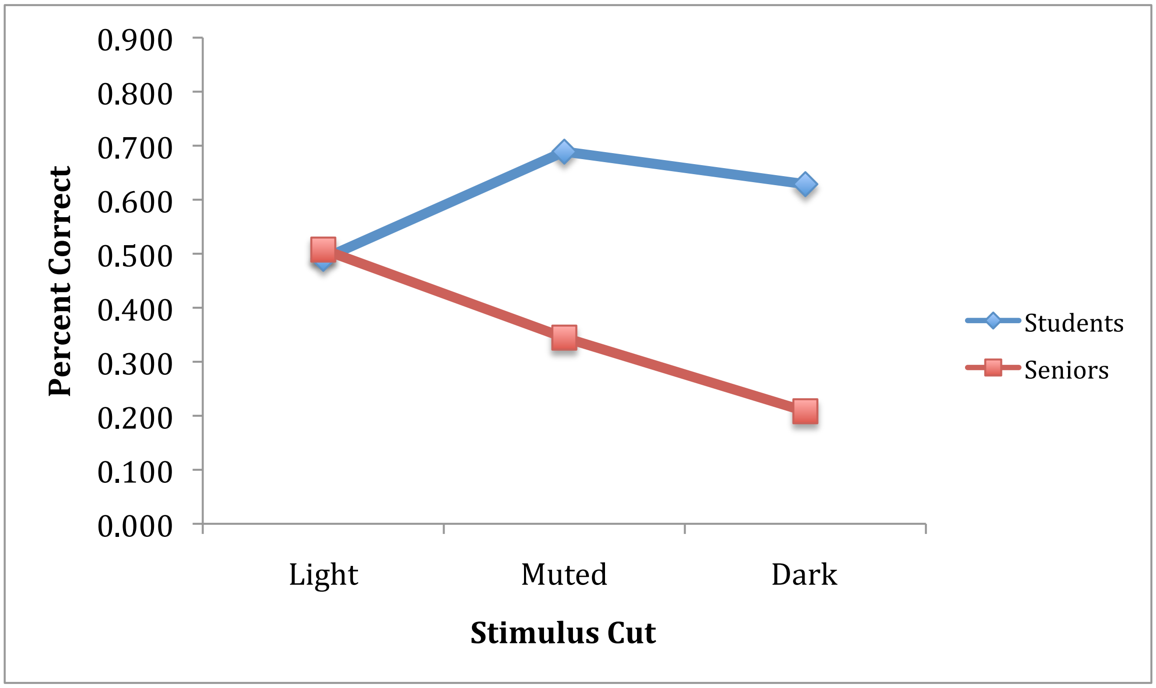

Figure 7. The average correct responses over delay conditions by group show parity in the light cut with gradual divergence in the two groups toward the dark cut.

Discussion

The results of this experiment illustrate several important aspects of color memory, the first of which is the critical role of verbal encoding. When a verbal distracter was introduced into the delay condition, performance decreased in both young and older subjects. It was hypothesized that perhaps with expertise (even though the visual system is compromised by age), the seniors would compensate by having a greater command over associated verbal cues. The response accuracy of all participants was affected by a confounding of the verbal coding of color names, supporting the dual coding hypothesis.

Another aspect addressed by this experiment concerned the effects of age on color memory. With senile miosis lessening the amount of light that enters the older eye, the luminance of the target colors is diminished, making the darker cuts harder to distinguish. The fact that there was decreased accuracy for the seniors in both the muted and dark cuts supports this effect. The lenticular senescence that causes absorption of some of the short wavelength light hitting the retina of an older eye is also illustrated by the decreased accuracy for the seniors in both the blue and purple hues.

A shortcoming of this experiment that may have affected the seniors more than the students was the absence of a laser sound cue that is often programmed to signal the beginning of each trial. The seniors more often missed the appearance of the target color because they were looking down at their response sheets. Another problem voiced by the seniors that may have affected their performance was the relative size of the target patch to response patch, indicating that a better test for seniors might be simultaneous color matching, where both stimuli are the same size. An analysis of the different types of errors – vertically by cut or horizontally by hue – would be illuminating, but was beyond the scope of this experiment.

In summary, it appears that when color is reduced to a patch of light with no contextual information, the effect of age on color memory is significant. The physiology of the visual system deteriorates with age, and no amount of expertise can compensate in this experimental paradigm.

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