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Effects of Color on Memory Encoding and Retrieval in the Classroom

Jennifer V. Martinez, Crystal D. Oberle, and Jon G. Thompson Jr.

Texas State University

oberle@txstate.edu

ABSTRACT

We investigated whether retrieval would be best when study materials and tests are printed on the same colored paper, consistent with the encoding specificity principle. Undergraduates read a passage printed on red or green paper (Experiment 1) or white paper (Experiment 2), and took a test printed on red or green paper (Experiment 1) or white, blue, green, yellow, or pink paper (Experiment 2). ANOVAs revealed no significant interaction and no significant effect of the test's paper color ($p > .05$), but a small effect of the passage's paper color did very closely approach statistical significance ($p = .052$). Participants who studied material on green paper outperformed those who studied material on red paper. These findings suggest that educators using different colors to distinguish test versions will not negatively impact students' performance, but that the color of study materials will affect the amount retained.

INTRODUCTION

Professors in large-sized classes often employ different colored sheets of paper to denote different versions of an exam. Although the exam information presented to groups receiving different forms is identical, many students and professors may claim that there is a bias in the scores based on the color of the exam material. In the present experiment, these claims were tested in regards to the situational based learning theories.

With situational based learning effects, reinstating the original learning environment at the time of memory retrieval will aid in the retrieval of that information. Research on situational based learning reveals effects of environmental contexts (Godden & Baddeley, 1975; Smith, Genberg, & Bjork, 1978), mood states (Bower, Monteriro, & Gilligan, 1978; Eich, 1985; Weingarter, Miller, & Murphy, 1977), differences in the script of stimuli (Reder, Donavos, & Erickson, 2002), and semantic messages (Light & Carter-Sobell, 1970; Mckenzie & Tiberghien, 2004; Tulving & Thompson, 1973). Generally, such findings have been attributed to Tulving and Thompson's (1973) encoding specificity principle. According to this principle, encoding operations govern the storage of information by directing the location of this information, and the ease and effectiveness of recalling this information is dependent on the initial encoding. Research manipulating study-versus-test contexts with different rooms (Dalton, 1993; Fernandez & Glenberg, 1985; Smith et al., 1978; Smith & Vela, 1992, 2001) and underwater compared to land settings (Emmerson, 1986) supports the encoding specificity principle and demonstrates the importance of encoding operations in the facilitation of memory reinstatement.

Of particular interest with the present study is the use of color as an environmental cue in the recognition of studied material, as often done in classroom settings. Researchers, who have used laboratory experimental settings with simple stimuli, have found that color affects memory in the direction predicted by the encoding specificity principle. For example, in studies with nonsense syllables or word pairs, several researchers found that memory performance on recognition tasks was greater when the background colors were the same at the time of recognition as they were at the time of initial presentation (Dulsky, 1935; Murnane & Phelps, 1993, 1994, 1999; Weiss & Margolius, 1954). Similarly, in studies with pictures of natural scenes, several researchers found that memory performance on recognition tasks was greater when the pictures were the same in color (either color or monochrome) at the time of recognition as they were at the time of initial presentation (Spence, Wong, Rusan, & Rastergar, 2006; Suzuki & Takahaski, 1997; Wichmann, Sharpe, & Gegenfurter, 2002). These findings suggest that color does play a critical role in the encoding and retrieval phases of information processing.

Further studies, however, indicate a need for active processing of both color and explicit information in order for the encoding specificity effect to occur. In one such study, participants completed computerized instructional lessons that were followed by either multiple-choice or fill-in-the-blank tests (Prestera, Clariana, & Peck, 2005). Color coded borders were displayed during each lesson, and during the tests, the border were either the same or a different color than they were during the lesson. The results suggested that the integration of color with information can only help retrieval if the color was actively processed. In a similar experiment, Hanna and Remington (1996) found that color is a part of memory representation, that color and form can be represented separately and retrieved independently, and that the binding of color and form requires attention. In other words, the color and the information are not automatically bound together in memory; rather, attention and active processing are prerequisites for the encoding specificity effect. Yet, it is possible that in these studies, the color was too far removed from the information, resulting in a weak bond between the two. For instance, in Presta et al.'s research, the participants' attention was likely focused centrally on the information, which was removed from the colored borders in the periphery. Perhaps the encoding specificity effect may have occurred if the entire background, as opposed to page border, was colored.

In summary, the situational based learning theories, such as the encoding specificity principle, have received support from numerous empirical studies, some of which used color as the contextual cue (Dulsky, 1935; Murnane & Phelps, 1993, 1994, 1999; Spence et al., 2006; Suzuki & Takahaski, 1997; Weiss & Margolius, 1954; Wichmann et al., 2002). Although other researchers have found that the binding between the contextual color and the target information requires attention and active processing, the color in their studies was not a central cue (Hanna & Remington, 1996; Prestera et al., 2005). Furthermore, these past research studies employed computerized experimental settings, often with such simplistic stimuli as word pairs and pictures. The present experiment further explores the role of color context with respect to the encoding specificity principle, using more meaningful stimuli (i.e., a reading passage from a textbook) and a more naturalistic environment in which learning routinely occurs (i.e., a university classroom). This research will help determine whether using different colored versions of an exam may negatively impact students who study the information on another colored paper.

EXPERIMENT 1

Method

Participants. Two hundred and four students (80 men, 124 women), who were enrolled in an undergraduate psychology course at Texas State University, participated in exchange for extra credit in the course. Participants ranged in age from 19 to 30 years (M = 21.41, SD = 5.16), and the majority were White (63%), Hispanic (22%), or Black (5%). None were informed of the hypotheses until after all data were collected.

Materials. The materials included a reading passage and corresponding test that were printed on either red or green paper. The reading passage was an excerpt from *The Holistic Guide to Canine Health* (Volhard & Brown, 2000), which included a 570-word explanation and one-page table covering the five-element theory applied to canine health, a topic that is likely unknown by most of the students. The corresponding test included 25 multiple-choice questions that assessed the participants' retention of the material in the reading passage. The passage and test were printed on 24-lb stock paper that was either red or green. To avoid brightness and readability from being potential confounds, care was taken to select colors with equal luminance (see Table 1). This concern was one of the main reasons that we opted to only include two colors (one warm color and one cool color) and to not include white, which possesses the greatest luminance. Regarding the other reason for the inclusion of only two colors, we opted for a between-subjects design in order to eliminate negative practice and carryover effects, and we wanted to ensure an adequate number of participants in each condition for sufficient statistical power.

Procedure. In a completely between-subjects design, participants were randomly assigned to one of four conditions that represented each possible combination of colors for the reading passage and corresponding test: (a) passage on red paper and test on red paper, (b) passage on red paper and test on green paper, (c) passage on green paper and test on green paper, and (d) passage on green paper and test on red paper. Upon receiving the reading passage, participants were instructed to read and study the passage for 10 minutes. After the 10-minute study period, the passages were collected and the tests were distributed. Participants were given 5 minutes to complete the test. After the 5-minute test period, the tests were collected and the experiment was concluded.

Table 1

Color Properties for the Paper

Paper color	Hue	Saturation	Luminance
Red	1	255	175
Green	68	226	175

Note. The paper was scanned into an electronic Microsoft document to determine these values.

Table 2

Results of the Independent-Measures Analyses of Variance

Source	*df*	*F*	*p*	η^2
	Instructor evaluation rating			
Participant sex (PS)	1	1.44	.23	.007
Color of reading (CR)	1	3.83	.05*	.019
Color of test (CT)	1	0.06	.80	.000
PS × CR	1	0.16	.69	.001
PS × CT	1	1.73	.19	.009
CR × CT	1	0.30	.59	.002
PS × CR × CT	1	0.41	.53	.002
Within-group error	196	(23.88)		

Note. Value in parentheses is mean square error.
*p = .052.

Results

A 2 x 2 x 2 independent-measures analysis of variance (ANOVA) was used to analyze the data. For this analysis, the dependent variable was the test score, and the three grouping variables were participant sex (men vs. women), color of paper on which the reading material was printed (red vs. green), and color of paper on which the test was printed (red vs. green). With a standard alpha level of .05, this ANOVA revealed no statistically significant interactions between any of the variables and no statistically significant main effects of either participant sex or paper color for the test (see Table 2). Yet, the main effect of the paper color for the reading passage very closely approached statistical significance, $F(1, 196) = 3.83$, $p = .052$, $\eta^2 = .02$. The test scores were higher for the participants who read the passage on green paper ($M = 20.13$, $SD = 4.62$) than for the participants who read the passage on red paper ($M = 18.88$, $SD = 5.10$). Although this difference failed to meet the exact alpha level criterion, the combination of the low probability value and corresponding effect size measure does suggest that a small effect exists.

EXPERIMENT 2

The results from Experiment 1 revealed no evidence of the encoding-specificity principle, as well as no effect of the color of paper on which the test was printed. However, only two colors of paper were used in an attempt to ensure a large number of participants per condition and to minimize potential confounding variables. Experiment 2 will serve as a replication, but with a greater number of colors and a design that more closely approximates students' experiences. In particular, most students study material that is printed or written on white paper, and they then take a test that is printed either on white paper or on a pastel-colored paper.

Method

Participants. Seventy-four students (14 men, 60 women), who were enrolled in an undergraduate psychology course at Texas State University, participated in exchange for extra credit in the course. Participants ranged in age from 19 to 49 years (M = 21.46, SD = 4.13), and the majority were White (46%), Hispanic (42%), or Black (4%). None were informed of the hypotheses until after all data were collected.

Materials. The materials included the same reading passage and corresponding test that were used in Experiment 1. The reading passage was printed on white paper, and the test was printed on white, blue, green, yellow, or pink paper. The latter four pastel colors were chosen because they are the colors of paper that instructors typically use to distinguish different forms of an exam in their courses.

Procedure. In a completely between-subjects design, participants were randomly assigned to one of five conditions that represented each color of paper on which the test was printed: white, blue, green, yellow, and pink. As in Experiment 1, upon receiving the reading passage, participants were instructed to read and study the passage for 10 minutes. After the 10-minute study period, the passages were collected and the tests were distributed. Participants were then given 5 minutes to complete the test. After the 5-minute test period, the tests were collected and the experiment was concluded.

Results

A one-way independent-measures ANOVA was used to analyze the data. For this analysis, the dependent variable was the test score, and the grouping variable was the color of paper on which the test was printed (white, blue, green, yellow, or pink). With a standard alpha level of .05, this ANOVA revealed no statistically significant effect of paper color for the test, $F(4, 69) = 0.28$, $p = .89$, $\eta^2 = .01$.

DISCUSSION

This research assessed whether color would be a contextual cue that either aids or hurts memory retrieval, consistent with the encoding specificity principle. Some past research, which utilized less meaningful stimuli and computerized experimental tasks, suggests that identical background or foreground colors at presentation and test times will lead to enhanced recognition (Dulsky, 1935; Murnane & Phelps, 1993, 1994, 1999; Spence et al., 2006; Suzuki & Takahaski, 1997; Weiss & Margolius, 1954; Wichmann et al., 2002). However, we failed to find the encoding specificity effect in the present study, which utilized more meaningful stimuli and a more naturalistic or applied environmental setting.

Whereas the encoding specificity principle states that the cues present at encoding will enhance memory and serve to aid retrieval, the effectiveness is determined by the system of encoding operations. It is presumed that the neural areas that are activated during encoding are activated during retrieval and in turn, will aid ease of access of information stored in memory. However, in this particular situation, the color of the paper does not serve as a sufficiently strong retrieval cue. Color still remains an integral part of memory representation, but because color and words are processed in different areas of the cortex, the use of color as a retrieval cue likely requires focal attention (Allington, 1974; Hanna & Remington, 1996; Prestera et al., 2005). Along with this attention component, perhaps the likelihood of color serving as a contextual cue is influenced by students' cognitive style, whereby color is generally a contextual cue for only field dependent learners (Dwyer & Moore, 1991, 2002; Moore & Dwyer, 1991, 1994, 2001). Future research is needed to assess the joint influence of attention and cognitive style during encoding and retrieval of information in the presence and absence of contextual color cues.

Interestingly, in Experiment 1, we did find that participants who studied the material on green paper outperformed those participants who studied the material on red paper of equal luminance. There is related evidence that color plays a role in psychological functioning. For example, Elliot and Maier (2007) explored the role of the use of red on intellectual performance and found that the color red negatively impacts performance in achievement contexts, perhaps because colors have specific meanings that have learned associations. In particular, the color red in a given context will invoke avoidance behavior and aggression. In virtual online games and sports, these same effects have been demonstrated with the use of the color red (Hagemann, Strauss, & Leibing, 2008; Ilie, Ioan, Zagrean, & Moldovan, 2008). Additional research on this phenomenon may help determine the behavioral and physiological changes that color mediates, especially with respect to situational based learning theories.

Finally, the results of both experiments revealed no effect of the color of paper on which the exam was printed. Although these findings are consistent with research showing no general effect of colored paper on exam performance (Michael & Jones, 1955), they conflict with the findings from three other studies. First, Jacobs and Blandino (1992) found that students taking an exam on red or yellow paper outperformed students taking the exam on white, blue, or green paper. These researchers concluded that the superior performance was due to the decreased test anxiety experienced with the red and yellow paper, as determined with the *Profile of Mood States* (McNair, Lor, & Droppleman, 1971), in spite of other research revealing that red may actually increase anxiety and negatively impact achievement (Elliot & Maier, 2007; Hagemann et al., 2008; Ilie et al., 2008). Second, Sinclair, Soldat, and Mark (1998) found that students taking an exam on blue paper outperformed students taking the exam on red paper. These researchers believed that blue paper influences affect and is implicitly perceived as being more serious and requiring a systematic processing protocol, compared to red. Finally, consistent with the findings from the preceding study, Skinner (2006) found that students taking an exam on white, blue, or green paper outperformed students taking the exam on red or yellow paper. All of these varied results still leave the question of how color influences performance on examinations. In addition to contrast or novelty effects, the combined influence of the Yerkes-Dodson law (Yerkes & Dodson, 1908) and the affective responses to certain colors is an area for future investigation, so that we may learn the true overall effects of color on exam performance.

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Author Note

Address correspondence to Crystal Oberle, Department of Psychology, Texas State University, 601 University Drive, San Marcos, TX, 78666, or e-mail (oberle@txstate.edu).