Effect of Color on Learning and Memory

Original research report: Lamberski, R. J., and Dwyer, F. M. (1983). The instructional effect of coding (color and black and white) on information acquisition and retrieval. ECTJ. 31 (1): 9-21.

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Abstract

None available, apparently because of journal format.

Introduction

The authors begin by commenting that teachers use visual aids increasingly to improve the quality of instruction. Then, they remind us that we live in a visual environment that is colorful. For that reason they assume that is the reason for using color in educational visual aids. They say it is important to determine how color affects learning, because humans have a limited capacity for registering and processing information and must select and reject non-essential features of complex stimuli.

The authors cite other investigators who showed that the retina and cortex classify visual stimuli by color coding. Many variables affect the coding, such as physical form of detected visual objects, processing time, light intensity, and brain properties.

They cite also a number of studies where color did not contribute to message content, but served only as cueing. These reports suggest that color improved learning of item pairs (called paired associates) and of concepts. However, the value of color as a cue for selecting important information decreases as the number of color-coded items increases. The suggestion is that color can promote learning if use of color is not excessive. Thus, color is an important variable in the effectiveness of instruction.

The purpose of this present study was to measure how color affected learning and ability to remember. Four hypotheses were proposed:

1. Students will have a higher mean test score if their instruction booklets are presented in color than in black and white.
2. Students will have a higher mean test score, both on immediate and delayed recall tests, if their learning materials are in color and their tests are identically color coded, compared to students who have the same color-coded instruction but are tested in black and white. Also, students who received instruction and testing in the same color-coded format should have higher

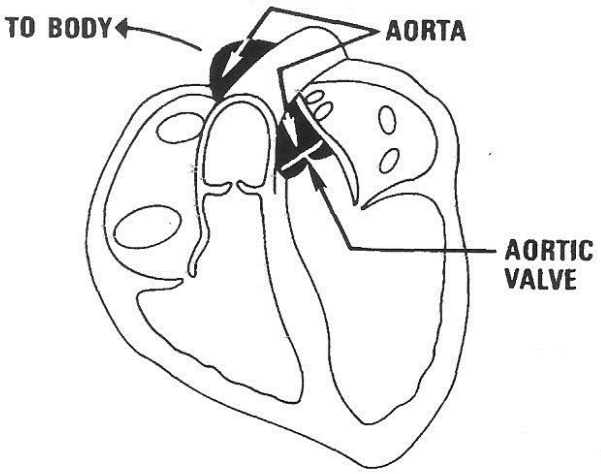
mean test scores than will students who receive black-and-white instruction but are color-coded tested.

3. Students who received color-coded instruction will retain more memory between immediate testing and testing delayed six weeks than will students who learn from black and white booklets.
4. Students who receive color-coded instruction will have greater mean test score differences on tests that depend more on visual recall than on verbal recall than will students who learn from identical black and white booklets.

Methods

Subjects. 176 university students in an instructional media course volunteered, for extra credit.

Materials. The authors modified an existing 7″ x 8.5″ spiral-bound booklet of instruction on the heart. Each booklet contained about 2,000 words in linear logic order on 21 pages. Each page included a 2.75″ x 3.1″ drawing with printed labels to illustrate what was described in the text on that page. Arrows, lines, and shaded areas indicated what students needed to focus on.



THE CONTRACTION OF THE LEFT VENTRICLE PUMPS THE BLOOD THROUGH THE ENTIRE BODY. FOR THIS REASON IT IS THE LARGEST, STRONGEST, AND MOST MUSCULAR SECTION OF THE HEART. WHEN THE LEFT VENTRICLE IS FILLED WITH BLOOD, IT CONTRACTS RESULTING IN PRESSURE OPENING THE AORTIC VALVE. THE AORTIC VALVE IS SIMILAR TO THE OTHER FLAP LIKE VALVES; THE VALVE STOPS THE BACKWARD FLOW OF BLOOD TO THE LEFT VENTRICLE AND OPENS FOR THE FORWARD FLOW OF BLOOD TO THE AORTA.

THE AORTA IS THE LARGE ARTERY WHICH CARRIES THE BLOOD AWAY FROM THE HEART BACK TO THE VARIOUS PARTS OF THE BODY.

Figure 1. Sample page within the instructional booklet.

Shape, length, and position of these focus cues were the same in all treatment conditions. One version of booklet presented all learning material in black and white. A second booklet was identical, except that six color inks (red, blue, green, purple, brown, and gold) were used to color code. For example, in the color coded version of Figure 1, gold was used for the verbal label AORTA, the arrow leading from the word aorta to the aorta structure, the shaded aorta area, and the word AORTA mentioned twice in the text on that page. Gold was also used on other pages where the aorta was a central theme, but not when the aorta was not a central interest. The intent was to use color to emphasize the concept being emphasized, create smaller category groups, distinguish different concepts, and associate related words and structures.

Tests. After learning, students took a test of eighty questions, either multiple-choice or drawing based on the information in the instructional booklet. One version had similar color codes as were in the instruction. For example, a test question based on Figure 1, used gold color for the word AORTA, while the other words had different colors that matched their colors in the instruction booklet (Figure 2).

ITEM:	When the blood leaves the heart through the pulmonary artery, it is also simultaneously leaving the heart through the a. TRICUSPID VALVE c. AORTA b. PULMONARY VEINS d. PULMONARY VALVE
CODING SCHEME:	The above test item represents a multiple choice item where the question stem and item choices are black type for the black and white coded testing materials. However in the color coded testing materials the item choices are color coded: TRICUSPID VALVE (Green); PULMONARY VEINS (Brown); AORTA (Gold); and PULMONARY VALVE (Purple).

Fig. 2. Example test question to illustrate how multiple-choice answers were color coded.

There were four types of test questions. **Terminology**: 20 multiple-choice questions measured knowledge of specific facts, terms, and definitions of the human heart. **Drawing:** students made a drawing from memory to illustrate 20 concept words. **Identification:** 20 questions tested students ability to use visual cues to distinguish heart structures and to associate structures with their corresponding word labels. **Comprehension:** 20 multiple-choice questions measured student understanding of the simultaneous functions of different heart areas during contraction and relaxation phases.

Experimental Design: Subjects were assigned to four treatment groups. The first two groups used color coding for either instruction or testing or both. The other two groups used black/white instruction booklets, but one group received color-coded tests.

Treatment 1: one-fourth of the students received the color-coded instruction booklet and similar color-coded tests. Treatment 2: one-fourth received color-coded instruction booklets and black/white tests. Treatment 3: one-fourth received black/white instruction booklets and color-coded tests. Treatment 4: one-fourth received instruction booklets and tests in black and white.

Thus the factors involved in data analysis that compared different subjects was the type of coding (black/white or color) used in instruction (***Presentation***), the type of coding used in testing (***Evaluation***). This yielded four different combinations for between-subject factor comparisons.

There were also two within-subject factors based on "before and after" test scores within each subject. For example, one factor was a comparison of test scores (***Retention***) at two different times, one immediately after completion of the instruction booklet and the other six weeks later. The other factor was based on the type of test (***Task***)—drawing, identification, terminology, or comprehension.

In all situations, the dependent variable was the number of correct answers on each test immediately after learning or six weeks later.

Procedure. Students were randomly assigned to one of the four treatment groups. Each treatment group went to a different room to complete their assigned self-paced instruction booklet. All students started at the same time but could take as much time as they needed to complete the booklet. Immediately after completion, students took the appropriately coded tests. Six weeks later, they returned to the same room in which learning had occurred and re-took the same tests. Tests were not time limited.

Results

Test reliability was established by an established measure (Kuder-Richardson 20 formula).[1] Respective values for immediate and delayed testing were as follows: terminology, .81, .77; drawing, .88, .84; identification, .82, .80; comprehension, .81, .74.

A formal statistical test, repeated measures analysis of variance (ANOVA) measured the variation of data between and within subjects. Effects were considered statistically significant if the analysis indicated less than a 5% chance that the presumed treatment effect was due to chance.

The coding of instruction booklet (color or black/white) produced a significant main effect.

Students with color-coded instruction booklets had greater mean test scores than those using black/white booklets. Subsequent analysis (so-called post-hoc test) revealed that

[1] Test consistency is usually measured by one of two standard statistical tests: "Chronbach's alpha," which is used especially when the data are continuously varying and this "Kuder-Richardson" formula when data are not continuous (dichotomous). A maximum desired coefficient value is 1.0. Reliability does not imply validity. That is, a reliable measure that is measuring something consistently may not be measuring what you want to be measuring.

this main effect was created by two interactions. One significant interaction was the presentation material and time of testing for retention (Figure 3).

Post hoc testing indicated an interaction between type of presentation and retention testing. That is, students who received color-coded instruction booklets had higher mean test scores than those with black/white booklets at both testing times. The third hypothesis that color-coded instruction would produce a more lasting memory (that is, less decline in score over time) was not supported. Students with color-coded instruction actually had lower test scores at six weeks than those with black/white instruction.

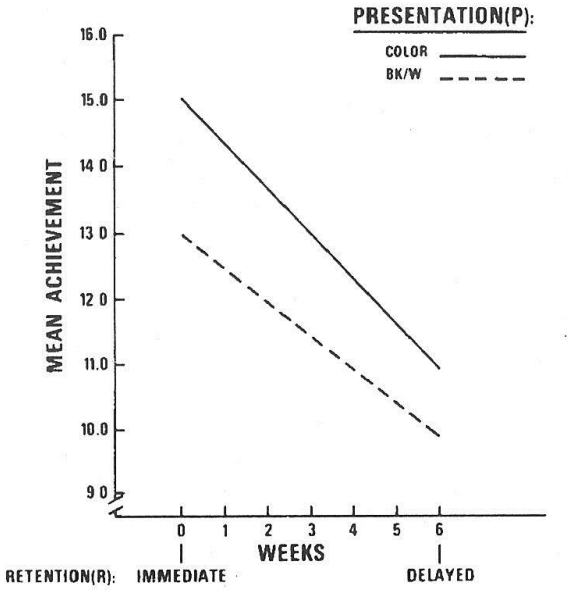
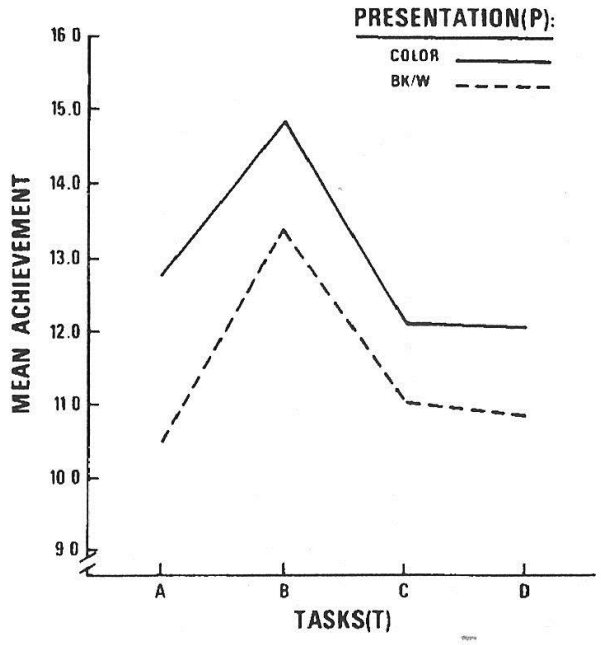


Fig. 3. Test scores showing that students with color-coded instruction booklets had greater mean test scores than those using black/white booklets.

There was also a significant interaction involving the presentation material and each of the four types of tests (drawing, identification, terminology, and comprehension) (Figure 4).



Note. Tasks: A = Drawing; B = Identification; C = Terminology; D = Comprehension.

Fig. 4. Data showing that higher scores resulted from color-coded instruction on all four types of tests.

Post hoc testing of the data in Figure 4 revealed that higher scores resulted from color-coded instruction on all four types of tests. Also, immediate testing produced higher scores than re-testing at six weeks, as expected.

A final significant interaction involved the test type and retention testing (Fig. 5).

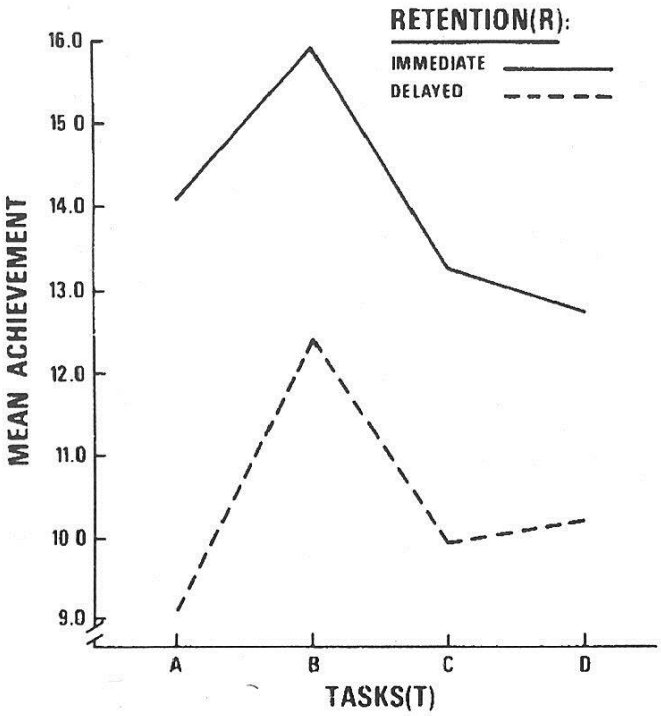


Fig. 5. Data showing that tests requiring more visual recall (drawing) revealed more decline in scores at six weeks than tests relying on verbal recall (comprehension).

Post hoc testing of Fig. 5 data indicated that tests requiring more visual recall (drawing) revealed more decline in scores at six weeks than tests relying on verbal recall (comprehension).

The data (omitted here) that were not statistically significant suggested that students who received a different code in testing material than in the instruction booklet had similar mean test scores on the immediate and delayed retention tests.

Discussion

The authors argued that their test design answered some of the critics of earlier studies on the effects of color on learning and memory. They believe this present study controlled variables better than previous studies.

In support of the first hypothesis, that color-coding instruction should be beneficial, the data here support the notion that color coding helps learning and memory when the coding is integrated (verbal and visual) in structured, self-paced learning situations.

Not supported was the second hypothesis of a benefit of color-coding both instruction and tests at both times of testing. This conflicts with results of previous reports, but is explained by the combined effect in this present study of the enhancing elements of color code in meaningful tasks and the rehearsing elements allowed by self-paced learning.

The authors suggest that color is attention-grabbing and learning enhancing when it is structured to have association value. This could explain that lack of a color effect in another lab's study, in which the color had no association value.

Previous literature indicated that learners prefer colored materials. Because color can directly influence attention or motivation, we should expect color to affect learning. Other investigators had predicted the color coded learning material would produce an interference effect on learning because by distracting from important learning cues. But these present results suggest that the kind of color coding used here is beneficial.

These authors suggest that the main beneficial effect of color-coding instruction is that it provided a structure to distinguish physical elements and associative meaning in self-paced instruction. Learning may not be enhanced by color if the color is a poorly related cue or when color is not used as a coding strategy to emphasize the central learning elements in self-paced instruction.

The authors speculate that similar beneficial effects of color-coded instruction could occur in older people.

The pattern of mean scores did not support the third hypothesis that color-coded instruction would preserve memory at delayed testing better than black/white materials (27% decline in scores versus 24% decline). The authors speculate that color's benefit occurs at the encoding and may actually interfere with memory preservation. Some previous investigators have suggested that memory rehearsal is needed to preserve any benefit of color-coded learning. In this study, there was no traditional post-learning drill or practice, and the rate of memory decline was similar for both color-coded and black/white instruction.

Long-term memory research by others indicated that older learners benefit primarily from visual codes and rehearsal strategies, and at times learn independently from any verbal codes. This seems consistent with the present observation that color is a visual cue that enhances learning without reducing the decline in retention about the same as black/white instruction.

The authors cite other work showing that both verbal and visual codes effect on learning and memory depends greatly on task demands. Verbal cues may not be as helpful as color cues in more spatial or visual tasks. The opposite may be true for verbal tasks. Thus, it may not be surprising that the data of the present study support the fourth hypothesis that the best effects of color-coded instruction would be on tests that depend more on visual than verbal recall.

The terminology task was an exception in that it too benefitted from color coding. Perhaps this task has more of a visual component that expected. Future research should explore this point.