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ABSTRACT

A study tested two alternative theories about the relation of color and visual learning: that realistic color serves to facilitate retention of instructional material and that all color functions only as a coding device which facilitates storage and retrieval of information. It also tried to discern an interaction between learner IQ and color function. Two hundred and twenty four students from Pennsylvania State University were divided into treatment groups. All groups received the same instructional presentation but different visual accompaniments--realistic color drawings, non-realistic color drawings, black and white illustrations, or no visual supplements. Achievement tests were administered and compared with IQ tests of the students. Findings showed interaction effects between IQ and visual stimuli. Lower IQ students did worse on non-illustrated and non-realistic color treatments; black-and-white illustrations reduced achievement differences between IQ groups; non-realistic color served to increase learning only for high IQ students. (KB)

INTERACTIVE EFFECTS OF COLOR REALISM AND LEARNER I.Q. ON VISUALIZED INSTRUCTION

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STATEMENT OF THE PROBLEM

The value of visual instructional materials in facilitating classroom instruction has been recognized for some time. Research has clearly established the need for carefully prepared and organized materials to effectively augment oral instruction. Research has been less conclusive, however, in identifying those design characteristics which contributed to improved learner achievement from visual materials as well as in examining the effect on the learning process of variations within each of those design factors.

A second, serious weakness lies in the fact that much of this research has failed to take individual learner differences into account.

It has been generally accepted that all individuals do not learn optimally from the same materials or at the same rate of speed. It would appear then, that a significant interaction would exist between an individual's mental abilities and the type of instructional materials which promote optimum learning.

The need for such research has become increasingly apparent in recent years. Numerous public agencies and private corporations now market great quantities of visual instructional materials and devices for the production of such materials. Teachers, instructional developers and graphic designers, however, have not been provided with a set of research-based guidelines for the use and manipulation of design factors such as color, complexity, contrast and realism in the design, selection and utilization of visuals for instructional purposes. The result of this inequity has, in many cases, led to the production of visuals which interfere with rather than aid instruction.

During the past fifty years, numerous studies have been conducted concerning the relative effectiveness of visual materials in facilitating student achievement. A serious limitation of these studies is that the visual materials were usually treated as entire units rather than as combinations of many distinct types of cues or stimulus elements. No attempts were made to systematically identify and examine those elements within a visual display which contributed to the improved learning. Rather, the practice of comparing instructional materials as entire units confounded any attempt to isolate and quantitatively define those characteristics which may have aided learning and those which impeded learning.

The use of color in instructional materials is one element which requires further investigation. Color has long been considered a significant factor in the design of visuals for instructional applications. Its use, however, has usually been determined by two considerations totally unrelated to its possible effectiveness as a facilitator of learning. These factors, the aesthetic appeal of color over black and white illustrations and the considerably higher production cost of color visuals have worked, although at opposite ends, to determine the instructional use of this variable.

One reason for this misjudgment of priorities has been the fact that the great majority of the research regarding color has been inconclusive. In a survey of a number of studies relating to the color variable, Otto and Askov (1968) concluded that "the cue value of color in learning is still essentially unclear."

Even more limited research has focused on variations within the color mode as a means whereby its effect as a cueing device may be more precisely stated.

The purpose of this study was to investigate the interaction between different types of color cueing techniques and the individual difference variable of learner I.Q. as evidenced by scores on five tests of learner achievement. Both immediate acquisition as well as delayed retention effects were examined.

BACKGROUND

Two theoretical orientations bear a close relationship to the role of color in visual learning and its associated research. These orientations both deal with the question of realism or complexity in learning from illustrations.

The first, a group of theories collectively referred to as "realism theories" by Dwyer (1967) include the iconicity theory of Morris (1946), Dale's (1946) cone of experience and the surrogate fidelity theory of Gibson (1954). All of these theories are predicated on the assumption that the more realistic an instructional device, the more effectively it will facilitate learning. This assumption is based on the notion that the more realistic materials will present more visual cues to the learner and thus, give him more information with which to work. Justification for this assumption is provided by the basic theory of stimulus generalization and the concept of cue summation.

A conflicting orientation, however, has also drawn wide support. This group of theorists and researchers has suggested that the "realism theories" do not accurately describe how visual instructional materials function in learning, and in fact, may be in direct contradiction to the true situation.

Broadbent (1958, 1965) has described the human information processing system as a single-channel, limited capacity system which he refers to as the P-system. This system functions much like a filter in that, in times of high information reception, not all information perceived is immediately processed and stored. Rather, the P-system filters out all information beyond its capacity and holds this "overflow" for later processing. The overflow may possible block other incoming, relevant information. Jacobson (1950, 1951) further supported this contention and indicated that only a small percentage of all information perceived is effectively stored and utilized by the nervous system.

Working from the theory of Broadbent, Travers (1964) focused specifically on the question of realism in instructional materials. He suggested that, to deal with a complex environment, the nervous system must simplify inputs and perceptions. To achieve this end, Travers described a process known as "compression." In describing this phenomenon, he indicated that to maximize the instructional effectiveness of visuals, it may be necessary to discard some elements of a visual which contain little information. This position is supported by empirical research conducted by Cherry (1953), Attneave (1954), Spaulding (1956), Gorman (1972) and Dwyer (1972). The studies reported by Dwyer represent the single, most comprehensive group of studies in this area. He found strong evidence to indicate that the most realistic visuals are not necessarily the most effective in promoting student learning. The relevance of visual realism to the use of color is readily apparent. Color in a great many visual illustrations can represent a significant contribution to the realism depicted in those visuals.

Research related specifically to the use of color has, similarly, been inconclusive. In a number of studies investigating the use of color in instructional visuals (VanderMeer, 1952; Kanner and Rosenstein, 1960, 1961; Katzman and Nyenhuis, 1972) it was generally concluded that color has no significant effect on learner achievement.

More recent studies, however, have reported conflicting data. Color was found to be a significant design factor in research conducted by Bourne and

Restle (1959), Saltz (1963), Underwood (1963), Dwyer (1972) and Lamberski (1972).

The fact that learners vary considerably in mental abilities has been recognized for some time. It has similarly been acknowledged that different types of instructional materials are necessary to optimize learning by individuals who differ on organismic variables such as I.Q.

The need for research which explores the relationship between the individual differences of learners and the selection of appropriate instructional materials and strategies has been widely noted, most recently by Snow (1970). Snow has suggested the use of Aptitude Treatment Interaction Analysis (ATI) as a reliable means whereby this relationship may be studied. Specifically, ATI involves a situation in which the effects of different treatments (treatment variable) are related to aptitudes or attributes of the subjects (organismic variable). In this study, learner I.Q. was selected as the organismic variable since it is considered to be a valid indicator of learning ability.

SPECIFIC ORIENTATION OF THE PRESENT STUDY

When the results of those studies related to complexity or color are taken into consideration, it seems apparent that, as Otto and Askov (1968) indicated, the "cue value of color" is not clear. Limited research has focused on the effect of variations within the color mode of presentation as a means whereby the cue value of color may be more adequately investigated and described. The basic question, therefore, to which this study adressed itself was: In what manner does color function as an instructional variable?

Two alternative explanations appear possible. First, that color provides an additional dimension of realism which results in the learner attaining a more complete or realistic image of the event or object; or, second, color functions only as a coding or cueing device which facilitates storage and retrieval or the image or information. If the former alternative is true, then a realistic color visual should facilitate retention of material to a greater degree than a non-realistically colored visual. If the latter alternative is true, then all types of color visuals should function equally well in facilitating retention of material. Similarly, all forms of color could also be expected to be superior to black and white visuals in promoting the learning of material related to specific educational objectives.

The purpose of this study was to compare the relative effectiveness of two forms of color cueing, used in visual materials to facilitate the learning and retention of meaningful material by students possessing different I.Q. levels. Specifically, the two forms of cueing devices can be identified as realistic and non-realistic color. Realistic color being representative of the use of realistic colors which present the learner with a relatively realistic version of the object or scene described, and non-realistic color being representative of the artificial use of color solely as an additional visual cue which has no relation to the actual color of the object or scene.

A common problem in the literature deals with the task of designing equivalent materials to test the color hypothesis. The very nature of the color visual militates against attainment of equivalence. Specifically, the use of color in a visual adds a much greater number of visual cues to the display, resulting in a greater amount of available information. According to what the research has indicated, the greater quantity of information would appear to require more time to be perceived, processed and stored. This would perhaps explain why color effects appeared primarily in a number of self-paced studies reported by Dwyer.

The present study attempted to eliminate the lack of equivalence by equating the actual number of visual cues presented while simultaneously altering the type of color cueing device. By photographically reversing the original color image of the visual, the exact number of color cues may be held constant, yet the resulting color still functions as a cueing or coding device.

It would appear, that since the task of assigning values to all color cues presented in a given visual could be virtually impossible, this means of controlling the number of cues would offer a fruitful means of investigating the effects of color as a cueing device.

Specifically, this study attempted to answer the following questions:

1. Are all types of instructional visuals equally effective in facilitating learning by individuals who differ in their level of I.Q.?

2. Are certain types of visuals more effective in reducing learning differences attributable to individual learner differences (I.Q. levels)?

3. Are certain types of instructional visuals most effective in facilitating learning by individuals at specific mental ability levels?

Based on the answers to these research questions, it should be possible to formulate useable guidelines for tailoring instructional materials to the needs of specific learners or groups of learners in such a way as to optimize the achievement of set instructional objectives.

INSTRUCTIONAL MATERIALS

The materials employed in this study consisted of six instructional programs on the human heart, its parts and its functions during the diastolic and systolic phases presented by means of slides and audio tape. This instructional unit was developed by Dwyer (1967) and has undergone extensive validation with over 5000 students. Each of these programs contained a series of visuals intended to complement the same oral script. Two sets of visuals were prepared in realistic color and two sets were produced in non-realistic color by means of photographic reversal. The remaining two sets were prepared in black and white and non-illustrated formats, respectively.

Photographic reversal was used as a means of producing visual materials in which the total number of visual cues were held constant while the degree of realism (color - realistic or non-realistic) could be manipulated.

In this case, all colors were systematically reversed to their opposite or complementary color, i.e. reds and browns were reversed to blues, grays and greens; yellows to violet and whites to black.

Measurement of achievement was accomplished by the use of five tests developed by Dwyer for the evaluation of student achievement in the areas of drawing, identification, terminology comprehension and total understanding.

EXPERIMENTAL PROCEDURE

The data for this study were obtained from 224 undergraduate college students enrolled in the Basic Instructional Media course at the Pennsylvania State University.

During orientation sessions to the course, all S's were requested to complete two pretest instruments, the Otis Mental Ability Test (Form FM) and a general pretest in the content area.

Subjects were randomly assigned to one of six treatment groups (treatment variable). These treatment groups received the same oral presentation; however, each of the six groups received their own respective type of visual illustration. These groups represented (1) non-illustrated; (2) black and white shaded drawings; (3 & 5) realistic color drawings; (4 & 6) non-realistic color drawings.

Immediately after participating in their respective instructional treatment, S's were administered the battery of achievement tests. Six weeks later students met again for the delayed posttest battery.

Based on scores obtained from the Otis Mental Ability Test (Form FM), three I.Q. levels were established. Cutoff points one-half standard deviation above and below the mean were selected to define the high, average and low I.Q. levels. (See Table 1)

All test data were normalized to T scores ($\mu = 50$, S.d = 10) to facilitate data analysis and comparison.

STATISTICAL ANALYSIS

Analysis of covariance was selected as a means of analyzing the data. Lindquist (1953) has indicated that the precision of an experiment may be increased considerably by use of analysis of covariance when the correlation between the adjusting variable (covariate) and the criterion variables is high. A Pearson Product moment correlation was conducted between each of the immediate and delayed achievement posttests and the general content area pretest measures. In all instances, the Pearson r correlation coefficient was significantly different from zero at the .01 level. Accordingly, this pretest measure was used as an adjusting variable in the analysis of covariance.

In those cases where a significant F-ratio at the .05 level was indicated by the analysis of covariance, further analyses were conducted between all possible pairs of adjusted means via the Scheffé method.

Analysis of both the immediate and delayed test scores by means of analysis of covariable produced two

TABLE 1

ASSIGNMENT OF STUDENTS TO TREATMENT GROUPS AND DIFFERENT LEVELS OF I.Q.

	Experimental Treatment					
I.Q.	Oral/ Verbal	Black and White	Realistic Color I	Non-Realistic Color I	Realistic Color II	Non-Realistic Color II
High	13	15	10	10	9	16
Average	14	9	13	15	18	12
Low	7	18	13	10	11	12

interactions, significant at the $p < .05$ level as well as seven main effects. Of these, four were significant at the $p < .05$ level and three at the $p < .01$ level of significance. Six of the significant F- ratios occurred in the immediate posttests and three occurred in the delayed posttests. The significant F-ratios obtained are summarized in Table 2.

TABLE 2

SUMMARY OF SIGNIFICANT F-RATIOS OBTAINED

Test		F	P value
Immediate Posttest	Drawing Test Interaction	2.08*	.0275
	Identification Test Color Main Effect	2.74*	.0204
	Terminology Test Color Main Effect	3.21**	.0082
	Terminology Test I.Q. Main Effect	6.69**	.0016
	Total Test Color Main Effect	2.96*	.0133
	Total Test I.Q. Main Effect	6.17**	.0025
Delayed Posttest	Terminology Test I.Q. Main Effect	4.32*	.0145
	Comprehension Test Interaction	2.04*	.0310
	Total Test I.Q. Main Effect	3.28*	.0396

$*P < .05$ $**P < .01$

Tables 3 and 4 present the adjusted means and standard deviations for each treatment group and test for both the immediate and delayed testing situations respectively.

Multiple comparisons between adjusted means conducted by the Scheffé procedure are summarized in Table 5. No significant pair-wise comparisons were produced on the delayed posttests due to the inherent conservatism of the Scheffé test. It was employed, however, because it is exact rather than approximate for unequal group sizes.

IMMEDIATE POSTTEST FINDINGS

Based on the statistical analysis of the data, the following results become apparent:

Drawing Test:

1. Lower I.Q. students achieved significantly lower on both the non-illustrated, oral/verbal treatment and the non-realistic color I treatment.

2. The black and white and realistic color treatments reduced the achievement differences between individuals at all mental ability levels.

Identification Test:

1. No individual I.Q. level differed significantly from any other on the attainment of the identification objective as measured by this test.

Terminology Test:

1. Lower Level I.Q. subjects achieved significantly lower on both the non-illustrated, oral/verbal and the realistic color II treatment.

2. The high level I.Q. learners scored significantly higher than the average I.Q. learners on the non-realistic color II group.

TABLE 3

ADJUSTED MEANS AND STANDARD DEVIATIONS ON ALL IMMEDIATE ACHIEVEMENT TESTS BY I.Q. LEVEL

	Oral/Verbal Group		Black and White Group		Realistic Color Group I		Non-Realistic Color Group I		Realistic Color Group II		Non-Realistic Color Group II	
	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
Drawing Test												
High	47.31	6.60	47.95	11.40	54.95	10.55	54.07	9.80	54.52	7.97	54.10	10.37
Average	49.43	6.73	52.95	8.00	47.73	11.03	51.55	7.96	55.64	8.07	47.26	11.41
Low	41.57	9.38	46.94	9.16	47.91	7.12	43.42	10.93	48.07	10.22	53.85	9.62
Identification Test												
High	47.77	8.94	48.88	10.67	52.91	10.25	50.08	11.68	52.36	5.92	53.98	10.10
Average	47.78	7.54	53.79	9.18	44.22	10.73	49.41	7.19	56.22	8.54	49.64	9.18
Low	43.60	10.62	48.81	9.58	51.31	8.61	42.90	13.48	50.46	10.60	52.40	8.51
Terminology Test												
High	48.59	10.05	50.72	10.00	51.57	11.30	52.47	8.67	56.23	9.96	54.91	6.36
Average	48.56	14.03	50.57	6.93	48.76	7.76	51.09	7.57	54.11	11.13	46.64	11.72
Low	37.73	8.21	47.05	8.29	48.34	6.43	48.14	11.35	48.36	7.16	52.02	8.27
Comprehension Test												
High	52.53	10.24	51.29	10.11	49.18	12.35	52.61	11.85	50.47	13.03	53.53	10.55
Average	50.19	10.44	50.45	7.55	47.35	9.32	50.83	9.64	53.29	9.34	46.50	10.53
Low	46.35	7.06	49.40	5.77	47.98	11.85	47.33	7.22	47.84	9.76	49.77	10.28
Total Test												
High	48.28	7.18	49.79	10.10	51.83	11.57	52.98	11.25	54.11	9.31	55.07	9.57
Average	48.89	9.20	52.24	7.88	46.48	10.03	50.71	8.26	55.90	9.16	47.24	10.98
Low	39.77	7.20	47.69	8.19	48.33	8.61	44.78	11.00	48.56	8.74	52.49	9.16

TABLE 4

ADJUSTED MEANS AND STANDARD DEVIATIONS ON ALL DELAYED ACHIEVEMENT TESTS BY I.Q. LEVEL

	Oral/Verbal Group		Black and White Group		Realistic Color Group I		Non-Realistic Color Group I		Realistic Color Group II		Non-Realistic Color Group II	
	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
Drawing Test												
High	49.69	10.16	48.68	9.30	53.25	3.98	50.67	10.79	55.56	13.80	50.90	8.92
Average	50.90	9.32	53.70	8.56	46.95	3.95	49.10	6.74	54.28	10.13	48.07	12.38
Low	46.07	8.56	46.36	11.10	48.61	7.04	48.64	12.93	47.57	9.20	51.72	7.40
Identification Test												
High	50.98	10.73	52.02	8.57	52.23	10.69	51.02	10.23	50.83	8.44	49.61	9.65
Average	50.50	9.71	53.99	9.82	45.29	7.96	47.41	9.57	54.95	10.29	47.65	12.33
Low	46.74	11.28	46.35	8.55	51.75	7.77	48.09	12.69	50.27	9.53	51.03	10.71
Terminology Test												
High	49.28	11.05	51.40	10.13	52.88	11.03	53.39	10.51	53.99	10.07	52.18	9.84
Average	53.80	10.89	50.58	6.96	48.20	8.83	47.73	8.75	50.69	8.14	49.10	13.56
Low	44.52	9.89	48.67	6.40	46.94	9.15	46.31	12.69	48.03	7.70	51.80	8.15
Comprehension Test												
High	54.05	7.36	51.29	9.12	53.40	12.57	50.15	11.06	50.09	9.44	49.51	9.66
Average	49.53	10.36	45.74	5.63	51.56	7.65	50.72	9.06	55.44	6.58	46.73	12.33
Low	42.98	13.07	48.24	10.55	44.44	8.51	47.05	11.49	50.07	8.65	54.95	8.72
Total Test												
High	51.15	9.67	50.96	7.32	52.81	12.48	51.60	11.79	53.96	11.16	50.71	9.48
Average	51.34	9.84	51.17	8.33	47.45	9.31	48.57	8.29	54.87	8.15	47.62	14.10
Low	44.32	8.44	46.86	8.90	47.52	7.20	47.15	13.80	48.82	8.77	52.74	7.64

TABLE 5

I.Q. LEVEL MOST EFFECTIVE IN FACILITATING ACHIEVEMENT ON EACH IMMEDIATE POSTTEST

Achievement Test	Experimental Treatment					
	Oral/ Verbal	Black and White	Realistic Color I	Non-Realistic Color I	Realistic Color II	Non-Realistic Color II
Drawing Test	1 > 3 2 > 3			1 > 3 2 > 3		
Identification Test						
Terminology Test	1 > 3 2 > 3				1 > 3 2 > 3	1 > 2
Comprehension Test						
Total Test	1 > 3 2 > 3				1 > 3 2 > 3	1 > 2 1 > 3

1 = High I.Q. 2 = Average I.Q. 3 = Low I.Q.

3. Although non-significant at the .05 level, the low I.Q. level subjects achieved higher than the average I.Q. subjects in the non-realistic color II treatment group.

4. High and average I.Q. subjects in the realistic color II group and high I.Q. subjects in the non-realistic II color group achieved significantly higher scores than any other group or I.Q. level.

Comprehension Test:

1. No individual I.Q. level differed significantly from any other on the attainment of the comprehension objective as measured by this test.

Total Test:

1. Lower level I.Q. students achieved significantly lower on both the non-illustrated, oral/verbal and the realistic color II treatment.

2. High level I.Q. subjects scored significantly higher than average on low level subjects on the non-realistic color II group.

3. High and average I.Q. subjects in the realistic color II group and high I.Q. individuals in the non-realistic color II group scored significantly higher than any other group or I.Q. level.

DELAYED POSTTEST FINDINGS

Although a significant interaction (Comprehension Test) and I.Q. main effects (Terminology Test and Total Test) were indicated, no pair wise comparisons were found to be significant ($P < .05$). The reason for this finding apparently lies in the fact that the Scheffé procedure is extremely conservative. This test was employed because of the existence of widely differing n's.

RESULTS

Based on the above findings, a number of summary statements can be made:

1. The use of visualization in instructional materials tends to facilitate student learning.

2. Not all types of instructional visuals are equally effective in promoting learner attainment of various educational objectives.

3. Extreme realism in instructional visuals does not appear to aid learning by students at lower I.Q. levels.

4. The use of black and white visuals reduces the achievement differences due to the individual difference factor of learner I.Q.

5. Stylized or unrealistic coloring of instructional visuals serves to increase student learning only at higher I.Q. levels.

6. The realism hypothesis is generally supported as a descriptor of visualized learning by high and average I.Q. individuals when color is used as a realism dimension.

7. The realism hypothesis does not appear to be a valid predictor of performance by lower I.Q. learners when visuals are used to augment verbal instruction.

8. Neither the degree of color realism nor individual mental ability differences appear to be significant factors in facilitating the retention of material after a period of six weeks.

DISCUSSION

The findings of this study seem to indicate that the "realism theories" do not, in all cases, serve as a descriptor of how individuals learn from visualized instruction. Rather, it would appear that an interaction exists between the degree of visual realism in terms of color and individual mental ability differences. This interaction has the following specific implications.

Lower I.Q. students appear to achieve equally well under different types of color or black and white visuals. Any type of visualization which accompanies verbal instruction, however, appears to improve learning by these individuals. It would seem that the visuals provided "basic" or "relevant" information necessary for learning of the material. The use of visuals possibly supplied a "spatial" relationship between each of the parts or locations discussed in the verbal instructional material. The fact that the additional information provided by color did not further improve learning would seem to indicate that this information was perhaps perceived and processed, but not actually needed or used in making the required discriminations or forming necessary concepts.

Learners of average level I.Q. appear to have made further use of the color cueing device in the case of realistic color visuals. These learners apparently used the visual to supply not only a spatial structure, but used the additional realism as a device whereby they could categorize parts and locations for future recall. It should be noted however that non-realistic color did not in all cases aid this group. This fact may be indicative of confusion resulting from an unfamiliar (and therefore difficult to categorize and recall) stimulus array.

The high I.Q. level students were able, in some cases, to make use of the non-realistic color as easily as other students used realistic color cues. Apparently the unfamiliar coloring did not confuse these students as it may have with other I.Q. levels. Conversely, this form of cueing technique did not appear to produce the most effective learning. The differential effects of these materials on varying levels of I.Q. does not appear significant after a period of six weeks. It would seem that the spatial structure of the visual is most important, with color adding only a secondary series of cues. Apparently these cues are given a lower priority in memory storage and are therefore forgotten first. Since most learning is intended to be of a long term nature, this finding would have significant implications for the design of most instructional materials.

The results of this study indicate that a significant interaction does exist between an individual's level of mental ability (I.Q.) and the type of instructional visuals most effective in facilitating learning by the individual. Several specific conclusions are readily apparent:

1. The use of visuals to augment verbal instruction tends to improve learning.
2. The use of relatively simplified visuals containing no irrelevant color cues tends to reduce differences in learning attributable to individual mental ability differences.
3. The use of realistic color visuals to supplement verbal instruction appears to improve learning by upper and average I.Q. learners, but not by lower I.Q. learners.
4. The "realism" hypothesis is supported with regard to average and above average I.Q. students, while the "information-interference" approach appears to apply to lower I.Q. individuals.
5. The differential learning effects of various types of materials are only temporary and cease to be of any significance after a period of several weeks.

This study has provided strong evidence to support the contention that instructional materials must be designed to meet the needs of individual learners.

Designers of such materials should give close attention to analyzing the needs and characteristics of the intended audience before proceeding to design or produce a particular instructional package incorporating visual materials. Attention should, however, also be given to the nature and purpose of the material to be learned. If it is necessary that it be retained for long periods of time, the added expense of visuals may not be warranted. This question of retention over long periods of time should be further explored, in greater depth than has been done thus far.

Additional research should focus on the effects of different types of visualization techniques and color cueing in particular, on specific types of human learning.

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