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ABSTRACT

Intended to serve as a primer for future investigators, this paper surveys and analyzes research studies published between 1945 and 1980 which focus on the effect(s) of color on human cognitive learning. The question of whether or not color as a variable in the design of instructional materials enhances learning has been approached by researchers in a variety of ways, and this paper categorizes the conclusions drawn by the various researchers. For example, one category is devoted to the effects of using color in instructional materials designed to teach verbal tasks (in nonsense and meaningful word tasks), while another is devoted to the research done on the effects of color in instructional materials designed to teach visual tasks (in passive or active materials). Additional categories include the effects of color as it relates to information processing and memory systems, affective study of color, color in task tests, the relationship of color and time, and the efficiency of color. (LLS)

A COMPREHENSIVE AND CRITICAL REVIEW OF THE METHODOLOGY AND FINDINGS IN COLOR INVESTIGATIONS

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ABSTRACT

Purpose

The purpose of this paper was to present a comprehensive and critical review of the existing literature relating to the effect of perceptual stimuli containing color. The study will emphasize particularly the literature relating to cognitive processing and color as a cue or code strategy.

Perspective

Research during the instructional media era of the 1950's and 1960's was comparative in nature and sought to identify device usefulness rather than to identify the parameters impacting on elements of the message. In surveying the color literature, researchers have concluded that the significance of color as a message design variable has typically eluded researchers who have attempted to define its unique role rather than its possible interrelated role in the acquisition and retrieval process.

Furthermore while color has received considerable attention in perceptual research investigations, the findings appear to have contributed little as to a possible role of color in cognitive functioning. This lack of conclusive evidence has been attributed to either limited experimental designs or to the inability to develop experimental materials which would be unbiased.

Method

An exhaustive eight year review identifying several hundred references with respective findings were interpreted by selected decision criteria. The primary topics include verbal color applications (in nonsense and meaningful word tasks) and visual color applications (in passive or active materials) as they relate to cognitive functioning and perceptual processing. Additional topics related to the stated purpose include information processing and memory systems, affective study of color, color in task tests, the relationship of color and time, and the efficiency of color.

Discussion

The paper provides new insights into the probable interrelated value or limitations of color as a variable in perceptual stimuli design. Current research methodology was discussed in light of needed experimentation.

A Comprehensive and Critical Review of the Methodology and Findings in Color Investigations

Introduction

The increasing complexity of instructional development activities during the last decade has prompted numerous models of learning systems to be offered for the improvement of instruction. Each model has its unique emphasis on priorities, strategies, and methodology in the manipulation of the integral and viable components of resources, management, learners, and development procedures. However, each model relies on empirical evidence to specify criteria from which decisions can be made as to the effectiveness of one strategy over another for facilitating learning. Therefore, this review of the literature seeks to provide evidence of the effect of color cueing and coding on instructional and test materials. The paper is intended to serve as a primer for future investigators. The paper identifies the majority of studies investigating the interrelationship of color with cognitive processes.

Limitations to the Review

The primary focus of the surveyed and presented literature concerns the effect of color on human cognitive learning from both theoretical and applied experimentation. During the process of the literature search, investigative areas were identified which, while using color as a primary variable, have findings not directly related or interpretable to the purpose of this review. These investigative areas included:

(1) animal subjects,

(2) preferences for a color,

(3) physics or chemistry of color perception,

(4) aesthetics of color to art and literature,

(5) cultural differences,

(6) special learner populations, and

(7) special applications (i.e., therapy, symbolism, marketing, personality, etc.).

If interested in these areas, the reader is referred to Sheppard (1968), Hochberg (1971, pp. 395-474), Parks (1975), Parks and Architecture (1975), Carterette and Friedman (1975), Moore (1977), and especially Billmeyer (1977).

Color: A Message Design Variable

In attempting to identify message design characteristics, it is important to realize the tremendous variety of choices for production and dissemination of instructional material that a practitioner has available. However, historically there have been only a few design characteristics which have received major attention. One such design characteristic is color.

The significance of color as a design variable has typically eluded researchers who have attempted to define its unique role in the learning process. In previous surveys, Lamberski (1972), Berry (1974), and Chute (1978) found that the reported research was often contradictory or inconclusive, and in many cases lacking practical application. They concluded that researchers may have: (1) failed to analyze the interrelatedness of color as a variable to other components within a learning system; or (2) had research design flaws that prohibited meaningful interpretation of results. It is from these conclusions that the following historical perspective for examining the effects of color in message design is presented.

Historical Perspective

The research of the instructional media era of the 1950's and the 1960's was comparative in nature, and sought to identify carrier device usefulness rather than message elements. The research questions posed were to justify using media rather than to optimize learning through its use. Thus, the use of color in investigations was superseded by other variables. In most investigations the color variable was not properly isolated by experimental design to assess its relative effectiveness (Chute, 1978, p. 8). Lumsdaine (1963) summarized this early comparative color research by stating:

> No really definitive studies have been made on the specific way in which color may contribute to learning from instructional materials . . . All that can really be concluded from the evidence is that the effects, if any, of color were not large enough to show up as the significant difference that would be predicted . . . the evidence suggests that any general value of color for increasing learning through increased strikingness or attractiveness has probably been overrated. (p. 635)

Five years later, Kanner (1968), surveying the comparative literature in color and black/white television, stated:

> It should be pointed out that, while the literature on color as a subject matter is enormous, when you focus down to the topic of color and human learning a scarcity of information is encountered. (p. 1)

Kanner concluded from his survey that the use of color in instructional materials does not significantly improve cognitive learning. This was due primarily to the hypothesis that:

> . . . words or labels can be substituted for the actual perception of color by the learner. (p. 5) /Or/ . . . that the verbal coding or substitution of words for color more than compensated for not seeing the color. (p. 6)

In a comprehensive review of the literature on color-form-number preference of children, Otto and Askov (1968) made observations which marked the beginning of a transitional stage in the study of color as a secondary variable to a primary and manipulated variable. They described the problem:

> In general, no real attempt has been made to draw upon existing research and theory regarding the role of color in learning; instead, color has simply been used as an added information-bearing cue. (p. 161) . . . The salient implications of all the existing research on the role of color is fragile at best and apt to be superseded by more potent cues . . . to sum up, at the present time, the use of color cues in instruction has never had a truly fair trial. The reason for this appears to be that the relevant variables have not been identified and considered. (p. 163)

After several years of channel capacity research in which color was an embellishment in the visual channel, Travers (1970) concluded that:

> Color does not seem to add sufficient interest value or attention-getting value to a presentation to produce any measurable effect on learning. Perhaps the only general justification for the use of color is that it provided a more pleasing aesthetic experience than does black and white. The study of color versus black and white provided a useful kind of finding, but not one that has any great implications for solving any major and central issue related to the design of audio-visual material. (pp. 4-5)

These early attempts to define and question the value of color have since generated a wealth of research reviews and investigations on color as a perceptual and design variable. Table 1

Table 1. Selected Major Reviews of Color Research and Investigation.

Year	Investigators	Area of Color Interest
1967	Chu & Schramm	Film & Television
1968	Otto & Askov	Childhood Development of Preferences
1968	Kanner	Television
1969	Isaacs	Coding of Pictorial Stimuli
1972	Vollan	Description of Dynamic Content
1972	Lamberski	Cognitive Instruction and Testing
1972	Dwyer	Realism in Visualization
1973	Kauffman	Cartoons & Professional Background
1973	Rudnick, Porter, & Suydam	Pictorial Stimulus Variables
1974	Plack & Shick	Physical, Perceptual, & Emotional Responses
1974	Berry	Realism in Visualization
1974	Rudnick	Attention-getting & Perceptual Styles
1975	Christ	Visual Search in Target Acquisition
1975	Parks	Perception & Aesthetics
1975	Parks & Architecture	Perception & Aesthetics
1976	Puig	Television
1976	Spears	Television
1978	Chute	Film & Spatial Abilities
1978	Dwyer	Visualized Instruction
1980	Lamberski	Cognitive Instruction & Testing

presents some of the color literature reviews and research; it is apparent that the study of color is of current interest. In the time period covered by the present investigator's literature survey (from 1945 to 1980), individual research studies where color has been a primary experimental variable or a secondary variable number well in the hundreds. While this represents a staggering amount of research, only a limited number of interpretable or generalizable conclusions can be drawn from this body of data. Chute (1978) recently summarized the dilemma of color research:

> . . . the value of color as a stimulus variable was often overestimated because the color stimulus was not considered in relationship to other salient cues in the visual array. Color was studied as the unique and isolated stimulus variable. A major limitation of this approach was the difficulty of integrating the color research into the greater body of educational research investigating other stimulus variables. It seems apparent there is a need for a broader understanding of the functions colors can have in perception, human information processing, and learning in general. (p. 4)

To summarize, while color has received considerable attention in perceptual research investigations the findings appear to have contributed little as to a possible interrelated role of color in cognitive learning. This lack of conclusive evidence has been attributed to either limited experimental designs or to the inability to develop experimental materials which would be unbiased. In most color studies decision criteria or parameters were not clearly defined or the interrelatedness of those decision criteria evaluated.

Verbal Color Applications

The application of color as a structuring device in verbal tasks has been both as a contextual cue (physical form within the stimulus) and as a contextual and associative code (physical form with meaningful value). Cue is defined as a verbal or visual strategy by which the perceiver's attention is focused upon perceptual information. A code is defined as a method of structuring perceptual and associative information for the purpose of facilitating learning, retention, and recall.

The application of color to verbal tasks may be divided into two areas: nonsense and meaningful word tasks, and prose tasks. For purposes of discussion, the literature will be separated into these two areas.

Color in Nonsense and Meaningful Word Tasks

The largest application of color within verbal investigations involves color being applied in or around printed trigrams, letters, words, shapes, and numbers. The cue value of color was either central (primary/relevant/intentional) or peripheral (redundant/irrelevant/incidental) to the learning of a concept.

The application of color in these nonsense word tasks may be subdivided into experimental categories; the first and largest category was that of paired associate tasks. Investigations in this category have indicated that color will enhance the recall of the paired associate, especially when matched with a nonmeaningful trigram, letter, number, or shape (Committee on Colorimetry, 1954; Weiss and Margoluis, 1954; Peterson and Peterson, 1957; Underwood, Ham, and

Ekstrand, 1962; Saltz, 1963; Berry, 1969; Goodman, 1975; Buchanan, 1975). Research further showed that the selection of color as the primary cue was enhanced if: (1) other contextual cues lacked physical form differences; (2) the associative value of words were difficult or low in meaning; (3) color was perceived as being useful; or (4) color was told to be of value (Isaacs, 1966; Swede and McNulty, 1967; Otto and Askov, 1968; Corballis and Luthe, 1971; Arnold and Bower, 1972; Bower, 1972; Newby and Young, 1972; Light, et al., 1975; Buchanan, 1975; Petrich and Chiesi, 1976; Winn, 1976; 1977).

Having learned concepts using a color contextual cue, the initial benefit did not necessarily transfer to similar tasks or benefit the learner when totally removed or altered in later testing (Saltz, 1963; Swede and NcNulty, 1967; Otto and Askov, 1968; Samuels, 1967; Washington, 1968; Goodman, 1975). Indeed the color cue superiority lost effectiveness rapidly unless practiced or reinforced (Randel and Havrda, 1968; O'Brien, 1971; Sabo and Hagen, 1973; Buchanan, 1975), overlearned (Gottlieb and Lindauer, 1967; Washington, 1968), or faded to some other non-color dimension (Allington, 1973; Goodman and Cundick, 1976).

A second category of experimentation has been in color-word interference tasks, or what has been termed the Stroop Test (Dyer, 1972; Nielsen, 1975), a test of recall of color names or nonsense words in conflicting color print. The Stroop Test demonstrated that several dimensions of information (verbal and visual) were acquired and retrieved by different but interrelated processing and memory structures (Majeres, 1970; Nealis, 1974; Harrison and Boese, 1976). The Stroop Test demonstrated that the use of color in printed meaningful words caused processing interference resulting in longer processing time.

A third category of experimentation has been that of color application in order to isolate central or peripheral concepts. Investigators (Sabo and Hagen, 1973; Sato, 1976) have found that the recognition of the intentional concept is (1) improved when the color cue differentiated the central from the peripheral stimuli, and (2) increased with development or age. This age enhancement of central stimuli appears to be more a function of encoding and rehearsal strategies of older learners rather than the younger learner's inability to disregard peripheral stimuli (Hale and Taweel, 1972; Sabo and Hagen, 1973). The recall of peripheral stimuli has been found to increase with multiple presentations of centrally color cued stimuli (Sato, 1976).

The fourth category of verbal color application has been in the use of color in meaningful word-visual association. Researchers (Wicker, 1970; Ernest and Paivio, 1971; Light, et al., 1975; Yurkiw and Gounard, 1975; Denis, 1976) found that colors, when used in association or to emphasize, have significantly enhanced the recall of pictures and facilitated the learning or recall of words; Ernest and Paivio (1971) attributed this enhancement of pictorial recall to stimulus concreteness found only in visual memory. It has also been suggested that color's usefulness in meaningful word tasks was apparently conditional on associative meaning (Deich, 1972; Gardiner, et al., 1976). Other concurring evidence suggested that the associative value of color with words or pictures may be more beneficial to concept attainment than the differences attributable solely to the physical form of color (Underwood and Freund, 1969;

Winn, 1976; 1977). Thus it appears that in this combined potential of stimulus concreteness and associative value, a color cue may become a valuable color code.

Color in Prose Tasks

A smaller investigative area involves meaningful prose materials in which color was used as a code having physical form (underlining, shaded areas, arrows, or printed words) and associative value (meaning). The instructional value of color in these incidences was mostly central (primary/relevant/intentional) acting as a strategy for concept attainment or improved performance.

Applications in this verbal area predominantly involved color codes in reading (Gattegno, 1962; Cruickshank, 1967; Jones, 1968) and phonic materials (Bannatyne, 1966; Knafle, 1974; Lyczak, 1976) which utilize color print to convey meaningful reading and pronunciation directions to the learner. Generally these researchers found that color coded materials were preferred by learners over other coding systems, and furthermore, learning rates and learner performance improved with the color coded materials. After investigating and validating learner reading achievement with color coded material, Hinds and Dodds (1968) have stated that the use of color:

> . . . gives the learner a stable and unchanging code of organization and sequence, which helps lend security in the learning process. Color, through its stimulation, rivets and holds the attention of the learner. (p. 46)

Visual Color Applications

In assessing the cue value of color in visualized learning materials, a separation of the literature can be made as to how color was applied. This separation of learning materials into two "carrier" categories, passive and active, has been suggested by Gropper (1976). Generally passive materials are normally not controlled by the learner (externally paced); examples of passive materials are film, television, and audio-slide presentations. Active materials are usually controlled by the learner (internally or self-paced); examples of active learning materials are programmed instruction and computer assisted instruction. The similarity between passive and active materials is that in most incidences the concepts are simultaneously presented with oral or verbal and visual information.

Color in Passive Materials

In reviewing color application in externally paced investigations, a variety of passive materials have been combined. These passive materials include television, film, pictures, charts, transparencies, and slides which were complemented by a synchronous narrative or complemented by a supplementary narrative on audiotape or live lecture. In most investigations the cue value of color is peripheral (redundant/irrelevant/incidental) to the learning of a concept.

Many researchers have concluded that color in passive materials was equal to or less than black/white materials for facilitating learner achievement (Long, 1946; Gibson, 1947;

VanderMeer, 1949; 1952; 1954; Zuckerman, 1954; Schwerin, 1957; May and Lumsdaine, 1958; Hudson, 1958; Kanner and Rosenstein, 1960; Rosenstein and Kanner, 1961; Link, 1961; Chu and Schramm, 1967; Kanner, 1968; O'Connor, 1970; Kaneko, 1971; Bretz, 1971; Reich and Meisner, 1973; 1976; Spears, 1976). For example, color was found to be inferior to black/white passive materials for different tasks and retention testings when used with college learners and adults possessing different educational backgrounds (Lamberski, 1972; 1975; Kauffman and Dwyer, 1974). Some researchers have suggested that color, since primarily peripheral, may distract the learner's attention from the important learning cues (Hoban and VanOrmer, 1950; VanderMeer, 1952; Chute, 1978). Other researchers have concluded that color will generally only enhance passive learning materials when it is used to emphasize relevant cues or aid in making discriminations (Norman and Rieber, 1968; Tolliver, 1970; Dwyer, 1972; Schramm, 1972; Brown, 1973; Rudnick, et al., 1973; Powers and Shrader, 1975).

When color does increase recall and recognition of passive materials, especially of peripheral stimuli, it is usually at the loss of the more relevant narrative information (Kumata, 1960; Deutschmann, et al., 1961; Chan, et al., 1965; Travers, et al., 1965; Schaps and Guest, 1968; Chute, 1978). Furthermore, it has been found that the effectiveness of color in passive materials appears more dependent on age or grade level with younger learners with generally higher performance being achieved with color materials (Travers, 1969; Booth, 1971; Casey, 1972; Miller, 1972; DeLucia, 1975). Given these supportive findings of color effectiveness, it has been suggested that once color <u>is</u>

encoded, it may inhibit forgetting of learned material and thereby facilitate delayed retention (VanderMeer, 1952; 1954; Lamberski, 1972; 1975; Kauffman and Dwyer, 1974; Scull, 1974; Hoban, 1975; Farley and Grant, 1976). However, further investigations are necessary to substantiate this proposition.

When specific applications are noted, color has been found to facilitate learning from passive materials when used: in highly visual (spatial) tasks (Dwyer, 1972; Reich and Meisner, 1973; Shaw, 1975); in dramatic portrayal (Reich and Meisner, 1973); and in the perception of movement (Travers, 1969). These findings, in addition to other findings reviewed in this chapter, have made some researchers suggest that the color may have limited application to the learning of low level cognitive concepts and is of more value in the modification of attitude (Schweitzer, 1963; Caban, 1971; Field, 1972; Spangenberg, 1976; Chute, 1978).

Thus far, the reported investigations in passive materials have primarily used color as a physical form carrying no associative value. However, Lamberski (1972; 1975) did investigate the code value of color in verbal information with accompanying visualization. The results showed that learners who received a color code in instruction and testing materials had significantly inferior achievement than learners who received black/white materials for immediate retention tasks, and generally had less achievement than learners who received black/white materials for two-week delayed retention tasks. It was concluded that the difficulty of information acquisition and task retrieval requirements limited the potential of the color code; this was attributed to insufficient processing time brought about by the externally paced format. It was further concluded that learners who received the black/white instruction and testing materials had less distraction and therefore more time to attend to the more central acquisition and retrieval tasks.

Thus, the application of color as a cue or code to externally paced materials appears highly task specific and generally has been utilized inappropriately, particularly when the relevant information is contained in the oral narration or verbal labels.

Color in Active Materials

There is only a limited number of investigations that applied color to active materials. These internally or self-paced materials include posters, comic books, textbooks, programmed instruction, and photographs. The cue value of color in most of these surveyed investigations was peripheral (redundant/irrelevant/incidental) to the learning of a concept.

The surveyed research presents contradictory evidence for the value of color in active materials; at best the cue value of color is again highly task dependent. Some researchers have concluded that color does not facilitate the learning of concepts in active materials (Travers, et al., 1964; Scarpino, 1972; Dooley and Harkins, 1970; Scull, 1974). For example, Dwyer (1972), in a compendium of his research studies, found that programmed booklets complemented by color visualization were generally inferior to black/white materials for a highly visual task such as drawing, and furthermore were equal to programmed text material containing no visualization for a highly verbal task such as comprehension. Freed (1963), using color in self-paced training materials, has shown that color visualization will imapir transfer from training to real task application.

When color has been found to facilitate achievement in active materials, it has been for low perceptual tasks. These tasks include the recognition or discrimination of content (MacLean, 1930; Ibison, 1952; Davis, 1975), and the immediate recall of peripheral material (Katzman and Nyenhuis, 1972).

Most recently Lamberski (1980b) has conducted a study to assess the relative achievement effect of a verbal and visual color or black/white coding strategy. The coding was incorporated into self-paced instruction and test materials and was intended to facilitate student retention on different cognitive tasks. Major findings indicated that color coded self-paced instruction materials were superior to the black/white coded instruction materials for both immediate and six-week delayed retention and on all task tests (drawing, terminology, identification, and comprehension). However, the presence or absence of the color code in test materials had no significant effect on student achievement. Lamberski concluded that the effectiveness of the color coded instruction materials may reside in their ability to demand sustained student attention and interaction with the content along with their ability to be able to provide an enhanced associative memory structure. Results also indicated that the color coding had a more positive impact on tests representing visual tasks (drawing, identification) rather than the more verbal tasks (terminology, comprehension). Also noted was the drop in recall from immediate to delayed retention testing, which though statistically different, evidenced a similar percentage decline for both color coding and black/white instructional groups.

The Affective Study of Color

Having presented the findings of verbal and visual color application, several additional areas of color and perceptual research offer support for the potential value of color stimuli in instruction and testing materials. The first of these contains studies relating to the affective value of color.

An affective component of the learner, learner preference, has repeatedly been found to increase the recall of concepts presented in a favored verbal or visual mode (Ingersoll, 1970; Farr, 1971; Kalin, 1972; Lilly and Kelleher, 1973; Daniel and Tacker, 1974). These researchers have indicated that learner preference may influence learning by directly influencing attention. In this light there is conclusive evidence that color materials are preferred over non-color materials (Gibson, 1947; Malter, 1948; VanderMeer, 1952; 1954; May and Lumsdaine, 1958; English, 1961; Schweitzer, 1963; Travers, et al., 1964; Jones, 1965; Chu and Schramm, 1967; Dwyer, 1972; Lamberski, 1972; Katzman and Nyenhuis, 1972; Scarpino, 1972; Puig, 1976; Chute, (1978). Therefore a preferred color design strategy may contribute in facilitating cognitive learning in addition to enhancing learner attitude. Such preference for color has been suggested to increase attention and motivation (Schwerin, 1957; May and Lumsdaine, 1958; Birren, 1963; Dooley and Harkins, 1970; Dwyer, 1972; 1976a; Schramm, 1972).

However it has been found that the preference for color is <u>not</u> a necessary condition for learning; in fact, color preference does not seem to be correlated with concept achievement (VanderMeer, 1954; Dwyer, 1972; 1976b). Thus preference alone can not necessitate the use of color.

The Physiological and Developmental Study of Color

The second supportive research area involves the physiological and developmental study of color. The research findings in these endeavors indicate a meaningful role of color in human perception. Data indicates that color can cause physiological, perceptual, and emotional reactions and associations within the learner (Goldstein, 1942; Cheskin, 1948; Kouwer, 1949; Rudisill, 1952; Collier, 1957; Gerard, 1958; Smith, 1958; Birren, 1959; 1963; Schwartz, 1960; Roseheim, 1967; Child, 1968; Nourse and Welch, 1971). For example, the recognition of familiar or unfamiliar color stimulus affects heart rate, blood pressure, and perceptual judgments of size, weight, and distance in both infants and adults (Plack and Shick, 1974; Bornstein, 1975; Adkinson and Berg, 1976; Bornstein, et al., 1976). These intensified reactions and associations are perhaps related to the increased attention and motivation exhibited by learners with color materials.

Recent research in perception has provided the most influential findings for the advocacy of color coding. Findings indicate that once a stimulus is perceived, the retina and cortex categorizes the stimulus into color codes (Murch, 1974; Vidyasagar, 1976; Land, 1978). This physiological color coding of the stimulus has been found to be a function of the number of physical forms and processing time (Young, 1973; Galbraith, et al., 1975), luminance levels within the rods (Ambler and Proctor, 1976), and hemispheric brain properties (Meyer, 1975). The evidence suggests that we involuntarily process color into codes.

The study of human development has also supplied data which suggests that the value of visual attributes, like color, changes in the maturation process; it is generally viewed that this perceptual change parallels development of verbal skills with increasing reliance on associative strategies (Crowder, 1976; Estes, 1976).

For example, with older learners it has been reported that color as a visual cue becomes integrated with verbal information in the processing, encoding, and retrieval of concepts (Daehler, et al., 1969; 1976; Hale and Green, 1976). It has also been found that learners at any age are not necessarily deficient in the encoding of coded information during acquisition, but poor recall may be attributed to failure in using the acquired codes at the time of retrieval (Martin and Richards, 1972; Geis, 1974). Previously cited color research by Lamberski (1980b) supports both these contentions.

Color in Task Tests

The question of the value of color on retrieval tasks appears to have no simple answer. Frechtling (1970) and Dwyer (1972) have found that the significant retrieval value of color or other perceptual cues is highly dependent upon the instruction and testing tasks, the materials used, the complexity of the visualization, the age of the learner, the learner's attention and motivation, and the amount of interactive time. There is evidence suggesting that color presentation cues in passive materials facilitate recall in visual tasks more than in verbal tasks (Otto and Askov, 1968; Dwyer, 1972), but the application of color stimuli in testing instruments is limited.

The research evidence that is available has applied and evaluated color in low perceptual tasks. These low perceptual tasks include searching, counting, sorting, discriminating, locating, and recognizing. Schontz, et al., (1971) summarized color's usefulness in a low perceptual task by stating that color will facilitate retrieval if: (1) many categories of information have been coded; (2) the number of concepts per category is small; and (3) colors are highly discriminable.

In studies of more complex tasks, Saltz (1963) and Lamberski (1975) have found that once a color code has been integrated during the acquisition of a concept, the altering of the color code at retrieval may cause interference, having an adverse effect on learner recall. This trend was also noted by Lamberski (1980b) in self-paced materials, but failed to reach a meaningful significance level.

Research has also found a trend that if color is added to the retrieval tasks, for learners who had received black/white instruction, interference will again occur (Dulsky, 1935; Lamberski, 1975). Again, this trend was noted by Lamberski (1980b) in self-paced materials, but failed to reach a meaningful significance level. Contradicting this finding Saltz (1963) indicates that color cues have facilitated retrieval when used only in the testing of concepts; Saltz attributed this effect to cognitive differentiation during testing conditions. 358

Further investigative research is needed to clarify these findings.

In the investigation of coded materials in testing, Bourne (1959) and Lamberski (1972) have both found that the administering of an immediate test after concept instruction will facilitate learner achievement at later delayed testing. This effect was apparently caused by reinforcement, rehearsal, and retrieval of the encoded stimulus during immediate testing making the acquired concepts more resistant to mamory and retrieval interference. However, the presence or absence of color in self-paced testing materials does not appear to be a significant factor for student achievement; rather, the presence of color coding during the acquisition of concepts appears to enhance learner achievement (Lamberski, 1980b). This enhanced learner achievement appears greatest for more visual tasks and diminishes as the task becomes more verbal.

The Relationship of Color and Time

The amount of time permitted for a task will partially determine the cue value of color or the cue value of other physical forms of the stimuli (Gordon, et al., 1967). Given unlimited time, color codes in some perceptual tasks have produced superior learner performance and speed for visual search or sort tasks (Jones, 1965; Harris, et al., 1964; Schioldberg, et al., 1973; Luria and Strauss, 1975). However, when time is limited, color has been found to impair learner speed and precise discrimination of objects (Jones, 1962), having a facilitating effect only in certain low perceptual tasks such as picture recognition (Fleming and Sheikhian, 1972; Berry, 1977) or reaction time (Samuels, 1967; Logan, 1976).

In more complex tasks, researchers have suggested that the use of color in materials will require more time to be perceived, processed, and stored (Dwyer, 1972; Berry, 1974). However, investigative evidence has found no clear support for the relation of color to learning time or retrieval time. In some investigations the data were inconclusive (Rust, 1967; Scarpino, 1972; Katzman and Nyenhuis, 1972), while in other studies color was found to reduce learning time (VanBuskirk, 1932; Funkhouser, 1968).

The lack of conclusive data on the effect of color in relation to acquisition and retrieval time prompted Berry (1974) to state that an investigation should be conducted utilizing color:

> . . . in an internally or self-paced format rather than externally paced. In this way, the time with which students interact with the visual materials could be examined as a significant variable contributing to the effectiveness of color as a cueing device. (p. 115)

In response to this need, a study was conducted by Lamberski (1980a) investigating the relationship of achievement to time with self-paced learning and test materials. Lamberski found that the mean time (minutes) that subjects required to work through a color coded instructional booklet was significantly greater than time needed to work through the instructional booklet in black/white. Lamberski further found a four-way interaction among presentation materials (color or black/white), evaluation materials (color or black/white), retention testing (immediate and six-week delayed), and type of task test (drawing, identification, terminology, and comprehension) when the dependent variable was the amount of time needed to interact with each task test. Most of this interaction appeared attributable to subjects who had received the color coded instruction and later received the color coded test materials; this was particularly evident for the more visual task tests.

Efficiency of a Color Code

In a new analysis area, researchers have attempted to analyze the relationship between learner achievement of concepts and the time needed to interact with color materials. The rationale is that the message should be designed not only for its achievement effect but also for the message efficiency. Efficiency, defined as achievement per unit of time, has been expressed in several different formulas. Lamberski and Roberts (1979) have observed the relationship using achievement divided by instruction time, achievement divided by test time, and achievement divided by instruction and test time. Lamberski (1980a) has observed the relationship using achievement gain (post-instruction achievement minus pre-instruction knowledge) divided by total time (time on instruction plus time on test). The observed results of these formulas have generally favored subjects who received self-paced color coded instruction material and self-paced black/white evaluation material. However, these exploratory analyses have not been statistically analyzed.

Recently, Lamberski and Myers (1980) conducted a study to assess the efficiency (achievement gain per instruction time) of a verbal and visual color or black/white code when used in self-paced learning and test materials. By accounting for the guessing and prior knowledge of the subjects, and by accounting for the different time necessary for processing information at acquisition for each treatment condition, it was shown that color and black/white coded materials produce similar efficiency results.

They concluded that the unlimited time allowed by the self-paced instructional materials benefited the students who received the color coded instruction by permitting necessary and sufficient rehearsal time. However, the acquiring of these concepts was time consuming, causing efficiency means comparable to subjects who received the black/white materials.

These findings support previous research (Hock and Egeth, 1970; Dwyer, 1972; Young, 1973; Berry, 1974; Galbraith, et al., 1975) which concluded that the increased attention, motivation, preference, code switching, processing interference or rehearsal with accompanying physiological changes associated with the use of color may be detrimental or produce no significant achievement effects unless appropriate pacing or time is allotted. It is this quality and quantity of interactive time which has been suggested as the most important of all learning variables (Bloom, 1974).

It should be noted that in this (Lamberski & Myers, 1980) and in previous studies (Lamberski, 1980a; Lamberski & Roberts, 1979), a wide range between individual students was noted for processing time on instruction and task tests suggesting further replication or extension of the interactive materials themselves.

In Conclusion

The purpose of this review was to provide evidence of the effect of color cueing and coding on instruction and test materials. Specifically the studies, categorized and presented within selected interrelated criteria, were intended to provide a literature framework for future investigations. Weaknesses of past research have been a limited survey of the literature and a lack of conceptualization of the interrelated variables which determine color's effectiveness. These weaknesses were usually found reflected in the use of biased experimental materials or in the use of inappropriate research design methodology to control or explain these biases. However, given the vastness of the literature base, several conclusions may be derived. The reader is encouraged, since these conclusions are derived acrossed the categorized criteria, to refer back to the specific literature for more detailed descriptions of the research findings.

The instructional value of color appears highly dependent upon the complexity of the task in the materials and perceived response requirements by the learner. It is known that color is preferred in learning materials and can be used to focus attention and provide motivation. Furthermore, color has been shown to have a physiological basis in the coding of perceptual stimuli. This color advantage has particularly been shown to facilitate discrimination in perceptual situations where complexity or quantity may preclude the use of other cues.

Color was found to be of value in non-meaningful tasks, especially if other perceptual cues lacked physical form differences or were low in associative value. The application of color to meaningful tasks appeared related to the interaction between learner and materials. In externally paced materials (passive), color appeared to be secondary to other salient features. If the task in passive materials became confusing, especially in simultaneous audio and visual materials, the learner selectively attended to a preferred mode as the functional stimulus; in most adult learners this preferred mode is verbal though in some incidences an integrated verbal and visual strategy may be utilized. Thus, if color was central to concept instruction, and if it was selected, color facilitated learning.

The literature surveyed also reinforces that unless structuring strategies like color were perceived to be or told to be important, the learner may have filtered out relevant information. Thus, in unstructured situations, older learners are found to be in a highly favorable position to learn from purely auditory or print materials negating the relevant visual code. In structured situations, however, older learners appeared to have the encoding and rehearsal strategies necessary to use an integrated code system like color. Younger learners generally have been found to benefit from color cues in passive materials due more to motivational than identified cognitive functions.

Color codes have been found to be ineffective in passive materials, apparently due to insufficient learner-material interactive time. However, color codes have had more success in facilitating verbal (reading and phonic) performance in self-paced materials (active) and recently their application to more complex cognitive learning has been evidenced in the literature.

The value of color in retrieval tasks again appears highly task related. Color cues appeared to facilitate recall of low perceptual tasks which were highly visual, while the facilitating value of color cues in more verbal tasks was not supported. However, color codes have been found to facilitate achievement in complex cognitive self-paced tasks, particularly with the more visually requiring tasks.

It has also been stated that color should inhibit forgetting, particularly when an immediate post-instruction test is administered.

However, there is research which suggests that the value of color in testing materials is only for low perceptual tasks, having no significant effect in more complex tasks.

The relationship of color to time remains unclear; at best the relationship was dependent upon complexity of the perceptual task, selected code strategy, and required response. Color may reduce time in low perceptual tasks depending on limited or unlimited time given to the learner; but the relationship of color in more complex tasks is highly dependent on the interrelatedness of several variables. Hock and Egeth (1970), speaking on time in complex color-word interference tasks, suggested that increased time for color "... should appear in tasks which involve the cognitive apparatus rather than in 'low-level' perceptual tasks" (p. 302). This appears supported for concept acquisition but findings for concept retrieval are still in need of further investigation.

Lastly new methods such as efficiency analysis or certain learner aptitudes (Chute, 1979) appear to offer design methodology which may further explain the cognitive functioning and processing of color stimuli. However, the base of this research needs further expansion and replication.

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378

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44