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ABSTRACT

Several theories in audiovisual education hold that learning from a visual illustration is directly related to the realism of the visual aid. In order to test this theory, five treatment groups were established. All groups were pretested, taught the same unit of instruction, and posttested. Four groups saw slide sequences in which were viewed illustrations with a different degree of realism: line drawing (black and white), line drawing (color), shaded drawing (black and white), and a shaded drawing (color). The fifth group saw a slide presentation with words only. The results of the study showed no significant difference among the five groups in learning achievement. The only significant difference observed was that the high IQ students who received the verbal-only treatment tended to score lower on the recognition test. (JY)

AN INVESTIGATION OF THE ROLE OF PICTORIAL COMPLEXITY IN VISUAL PERCEPTION

A Dissertation

Presented to

the Graduate School of Education

University of Virginia

In Partial Fulfillment

of the Requirements for the Degree

Doctor of Education

by

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Appreciation is expressed to my wife, Bonnie, who has spent hours proofreading and typing.

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CHAPTER I

THE PROBLEM AND DEFINITION OF TERMS

Introduction. Increasing attention is being given to visual literacy and its various ramifications. There is discussion about talking with pictures and creating taxonomies for classifying visual illustrations. An important aspect of this matter is the degree of complexity of detail that is desirable in a visual.

Much of the past theory and activity in the field of audio-visual education has been based on the realism theories. These theories, in general, have held that in a given learning situation maximum learning occurs when the situation is most real or life-like. They suggest a continuum of learning related to a continuum of experience. Figure 1 represents an example of the continuum of experience concept. Realism, as defined by the theorists, decreases by vertical movement from the base of the cone to the top. Maximum learning occurs in the direct, first-hand experience, and decreases through the subsequent stages of reality. Minimum learning occurs at the most abstract, least realistic, level in which verbal symbols alone are utilized.

The realism theories continue to determine practice in audio-visual education, but they have come into question in recent years. It has been suggested that there may be various continuums of learning within the over-all scale. If so, then learning may occur as indicated in Figure 2 on page 4. If not, then variations of experience within narrow limitations may be irrelevant as indicated in Figure 3 on page 5. It has, also, been suggested by some researchers that added detail may actually interfere with learning.

The present state of research in the area of visual literacy indicates the need for further research in which the three elements (learner, visual, and objectives) of a learning situation are carefully defined and studied in relation to each other. It has become essential to study these factors one at a time while holding constant the other two factors.

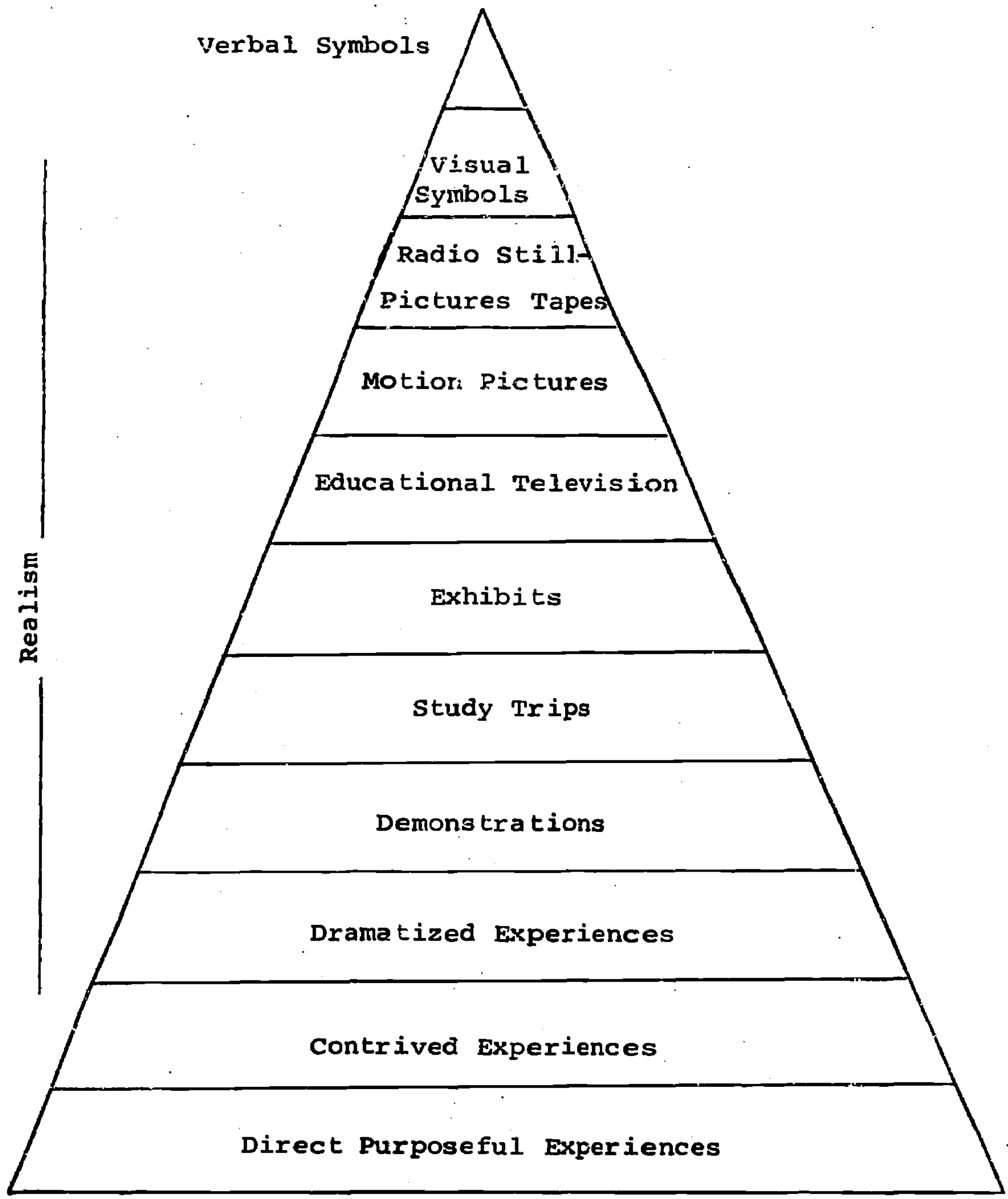

FIGURE 1

REPRESENTATION OF DALE'S (1969)
"CONE OF EXPERIENCE"

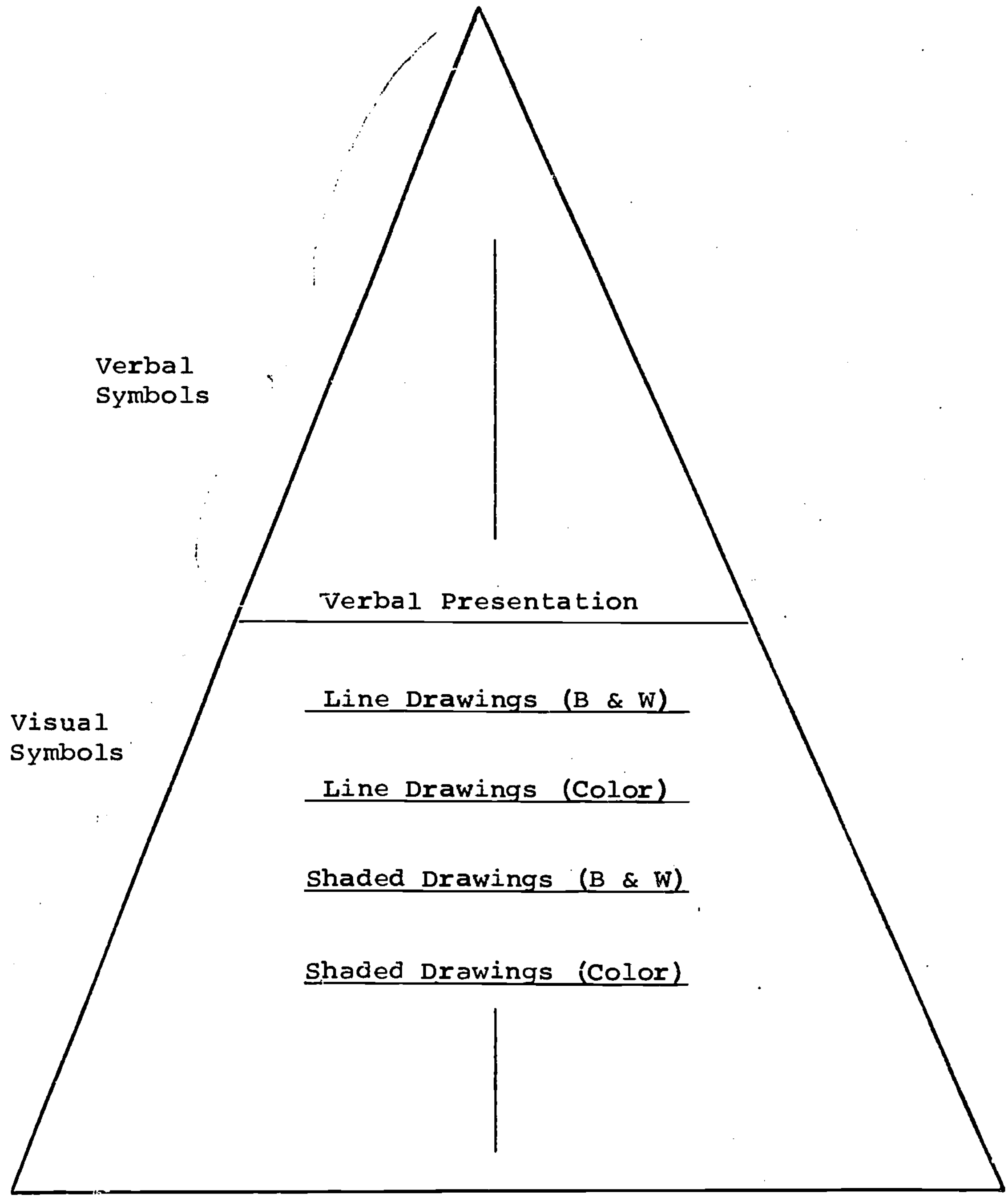

FIGURE 2

TOP TWO BANDS OF DALE'S (1969) CONE. ACCORDING TO THE REALISM THEORIES, LEARNING DECREASES AS ONE MOVES UPWARD THROUGH THE SCALE. TREATMENT GROUPS ARE SHOWN IN THEIR PROPER RELATIONSHIP TO THE SCALE.

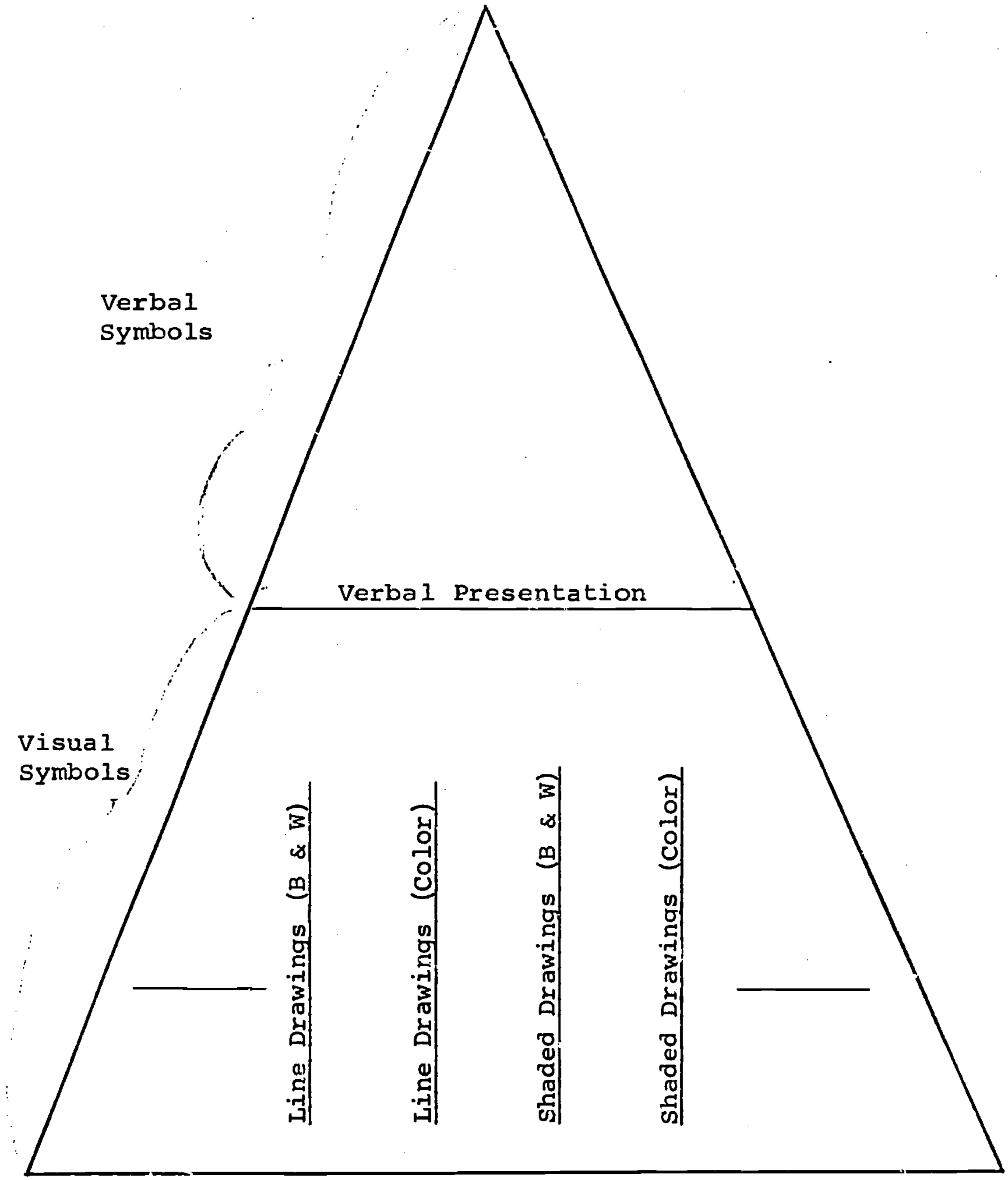

FIGURE 3

DIAGRAM SUGGESTING THAT LEARNING WITHIN A SPECIFIC BAND OF THE CONE MAY NOT INCREASE OR DECREASE VERTICALLY

<u>Statement of the Problem</u>. This experiment was designed to study the role of complexity of detail as related to learning. For the realism theories to be supported, two conditions must hold: a) that learning increases with complexity, and b) that learning increases in a continuum.

In order to study the possible existence of this realism theory five treatment groups were established each viewing a different sequence of visuals. All five groups were taught the same unit of instruction concerning the human heart. The cognitive elements in the learning experience included names of the specific parts and the operation of the heart through one complete cycle.

All groups received the same taped-word presentation. The treatment groups differed in the following ways:

(Group 1) The visual instruction was limited to a verbal presentation. The 2 X 2 slides had nothing but printed words on them. These words were identical to those used on the slides in the other sequences. However, in all of the other sequences there were these words plus visual illustrations on each slide.

(Group 2) The visual instruction consisted of simplified line drawings of the heart. The drawings were in black and white and were presented on slides.

(Group 3) The visual instruction consisted of simplified line drawings of the heart. The drawings were in color and were presented on slides.

(Group 4) The visual instruction consisted of shaded line drawings of the heart. The drawings were in black and white and were presented on slides.

(Group 5) The visual instruction consisted of shaded drawings of the heart. The drawings were in color and were presented on slides.

Students in all five groups were pretested and post-tested on cognitive information about the heart. The results of the instruction were measured by testing the student's recognition of parts of the heart, recall of terminology, and knowledge of operations of the heart. The student performance was recorded for each separate test and for a composite of the three tests.

Sexual differences and intelligence level differences on the Lorge-Thorndike Test were investigated to determine their possible relationship to learning within those visual symbol strata defined in Figure 2.

Purpose. The purpose of this study was to investigate relative effectiveness of the visual sequences on learning. Specifically, it was to investigate post-instruction factual recognition, recall, and knowledge of the heart and its operations.

This investigation was designed to determine support, for or against, the realism theory. The range of the continuum that was investigated is defined in Figure 2. The study was, also, designed to determine possible relationships between sexual differences and intelligence differences in learning based on specified stages of visual complexity.

<u>Objectives of the Study</u>. This study was designed to test the realism theory in terms of that portion of the cone shown in Figure 2. The test instruments included a Recall Test, Operations Test, Recognition Test, and a Composite of these three tests. Given these conditions, the following objectives were deemed appropriate:

1. To determine, if possible, the relative effectiveness of the five types of visual presentations as represented by the five treatment groups.

2. To determine, if possible, the existence or non-existence of a continuum of visual learning among the five treatment groups compared on the Composite Test.

3. To determine any possible differences in learning between the sexes.

4. To determine any possible differences in learning between students of varying score levels on the Lorge-Thorndike.

5. To determine any possible differences in achievement between sexual differences in terms of visual stimuli (i.e. do boys differ from girls in terms of learning from stimuli of one or more specific levels of visual complexity).

6. To determine any possible differences in achievement between intelligence levels in terms of visual stimuli (i.e. do students of varying intelligence levels differ from each other in terms of learning from stimuli of one or more specific levels of visual complexity).

Limitations. Dale's (1969) Cone of Experience starts with direct experience and moves vertically through verbal symbols (See Figure 1). This study was limited to visual and verbal symbols as indicated in Figure 2. Vertical movement was simulated by varying the degrees of pictorial complexity within the strata in Figure 2.

Materials used were those which were capable of providing optimum vertical movement within the chosen medium. The medium chosen was 2 X 2 projected slides accompanied by a standardized verbal presentation on audio tape.

The investigation was conducted among sixth-grade students within a single school.

Definition of Terms

Presentation. The projection of information was in one of five sequences: verbal presentation, simplified line drawings in black and white, simplified line drawings in color, shaded drawings in black and white, or colored drawings (see following definitions). The taped-word presentation is a modification of Dwyer's (1967b) Heart Script. The visual illustrations are variations of a drawing by the 3M company (1960).

Verbal Presentation. The taped-word message was presented on a tape recorder complemented by 2 X 2 slides with nothing but printed words on them. (The other four sequences each have these identical words plus visual illustrations of varying realism.)

Simplified Line Drawings (B and W). This was a taped-word presentation complemented by 2 X 2 slides with printed words plus simplified line drawings of the heart.

Simplified Line Drawings (Color). This was a taped-word presentation complemented by 2 X 2 slides with printed words plus simplified line drawings of the heart with color added to provide an element of realism.

Shaded Drawing (B and W). This was a taped-word presentation complemented by 2 X 2 slides with printed words plus drawings that used shading to add realism.

Shaded Drawings (Color). This taped-word presentation was complemented by 2 X 2 slides with printed words plus drawings of the heart using color to add realism.

Recognition Test. This test consisted of sixteen multiple choice items. Parts on the drawing of a model were numbered and the students had an answer sheet with corresponding numbers on which they selected the proper name for each part. This test was designed to test recognition of parts illustrated on the heart drawing by selecting the correct label for each part. The test was a modification of Dwyer's (1967b) Identification Test.

Recall Test. This test consisted of sixteen multiple choice questions evaluating recall of terminology (i.e. printed words used on the slides). This was a modification of Dwyer's (1967b) Terminology Test.

Operations Test. This test consisted of fifteen multiple choice questions designed to test knowledge of operational factors. Operational factors included direction and sequence of blood flow through the heart, operation of the heart valves, and contraction and relaxation of the heart through one complete cycle. The test was a modification of Dwyer's (1967b) Comprehension Test.

Composite Test. The scores for each individual on the three preceding tests were combined into a composite measure. This was a modification of Dwyer's (1967b) Total Criterion Test.

Pretest. The pretest was designed to determine prior knowledge of terms and operational factors concerning the human heart. The composite test was used as the pretest.

Complexity. For the purpose of this study, complexity was defined as an increase in the visual elements presented on the slides. This complexity ranged from the lowest level of black and white line drawings to the highest level of colored shaded color drawings. This is illustrated in Figure 2 on page 4. Complexity and realism are used synonymously in the study.

Realism. This term refers to elements within the visual illustrations which are shared with the real physical object (heart). A movement toward realism is synonymous with a movement toward increased complexity. (Refer to Figure 2.)

Knowledge. The term as used here reflects what Bloom (1956) refers to as: (1) "knowledge of specifics," and (2) "knowledge of ways and means of dealing with specifics."

Terminology. This includes the words indicating the specific parts of the heart and the functions of the heart as they appear on 2 X 2 slides.

Importance of the Study. If instruction is to approach the ideal of matching the visual--learner--objective, then further research is needed to investigate relevant aspects of all three elements. This study represents one step in a broad spectrum of needed research. The aspects of the elements included in this study are outlined in the following paragraphs.

The study included the investigation of aspects of the interaction of the learner and visual complexity. Sixth-grade students were chosen as the subjects of study because previous research had not tested the continuum theory at the elementary level. Students were randomly assigned to the treatment groups and the additional variables of sex and intelligence were investigated. Previous research has indicated that there is a need for investigating these last two variables. Therefore, since learning from a visual illustration seems highly individualistic, these variables were logical suspects for added dimension in this study.

The visual images were varied in complexity from line drawings in black and white to shaded drawings in color. This range parallels that of pictorial illustrations frequently found in textbooks.

Research suggests that individuals change in their reaction to visual complexity as they grow older. In general, small children desire simplicity in visuals while adults desire more complexity. This continual change in preference, which has been verified by research (Travers, 1970), suggests the existence of a spectrum of learner characteristics. This present study has concentrated on the sixth-grade level as one point within that spectrum.

The findings of this study should have relevance for educators in providing additional guidance for the selection of still pictures to be used in instruction at the sixth-grade level. The findings should, also, be of some assistance to the publishers of sixth-grade materials including slides, filmstrips, and various still pictures. This should be useful in planning the pictorial material. It should have value for those who buy and use this material, and for those who produce or select material not commercially produced for the immediate task.

CHAPTER II

SURVEY OF LITERATURE AND JUSTIFICATION

Broadbent (1958) suggests that the topic of perception has recently become far more closely related to the rest of behavior than it used to be. To study the varying aspects of perception, it becomes necessary to set the subject some objectively scorable task, and to find how performance on this task is affected by various stimulus situations.

Research studies regarding the comparative effectiveness of the various media have often proved to be contradictory. However, the illustrations used in the varying media have seldom been equivalent. The usual procedure is to compare one medium with another. In some comparisons, for example, illustrations projected on slides are compared with the same illustrations on 16mm films. This means comparing a still picture with a moving picture. A still picture is not equivalent to moving picture even if both project the same image. Most comparisons make a similar kind of mistake. It would seem that no valid comparisons could be made unless material equivalent in content appears in all of the media being compared (Dwyer, 1967). For this reason, several recent writers (Broadbent, 1958; Travers, 1964; Fleming, 1966; and Dwyer, 1967, 1969) are suggesting that controlled visual stimuli be isolated and studied for specific contributions to learning.

McCowen (1940), Vernon (1946), Hunt (1968), and others have found that visuals used to complement instruction do positively affect student achievement. Kopstein and Roshal (1954), and Treichler (1967) suggest that visuals used in conjuction with oral instruction improve instruction. The problem arises in the scarcity of evidence available indicating which types of visual illustrations best promote what types of student learning.

Visual Elements. The element of color in a visual used for certain instructional purposes is apparently still debatable. Color seems to make a visual more preferable to a learner, but according to Travers (1964, 2:55) "Research points to the conclusion that black and white is as effective as color for instructional purposes except when learning involves an actual color discrimination." Dwyer (1969) found that a detailed, shaded drawing presentation in color was more effective than the same drawing in black and white. Other presentations used in the same study rated below these two in effectiveness.

Vernon (1966) reports that test subjects find ways of utilizing only the amount of information called for by a perceptual task. Thus, in identification, classification, and learning tasks they will use only distinctive details of a figure.

Allen (1960) suggests that there is a need for further study of factors within illustrations that produce learning.

Literature Supporting Realism Theories. The realism theories (Morris, 1946; Dale, 1946; Carpenter, 1953; and others) have held to a continuum concept. According to these theories an increase in number of cues or an increase in realism in visuals or in the learning situation increases the probability of maximum learning. Finn (1953) indicates that audiovisual theories have oriented around the basic concept of concrete-to-abstract learning. Gibson (1954) and Osgood (1965) have expressed views that would be consistent with this thinking.

Dale's "Cone of Experience" is viewed by researchers as representative of the realism theories (See Figure 1 on page 3). It attempts to classify specific learning experiences as bands on a cone. Experiences move vertically from direct experiences at the base of the cone to verbal symbols at the apex (Dale, 1969). The realism theory holds that maximum learning occurs in the direct experience and minimum learning occurs when verbal symbols are used. The learning decrease between the two extremes occurs on a continuum.

Literature Contesting Realism Theories. Miller (1967) and Dwyer (1967) content that added cues do not increase learning by linear increment. Travers (1964) says that learners do not need highly embellished stimuli in order to recognize attributes of a visual or to identify objects or situations.

Recent evidence (French, 1954; Miller, 1956; Rappaport, 1957; Attneave, 1959; Travers, 1964) seems to indicate discrimination learning affected by additional stimuli may be limited by the information processing capacity of the brain. There seems to be an early peak in learning and then a diminishing effect with addition of cues.

Broadbent's (1958) filter theory suggests that it is the filtering process within the central processing system which prevents much of the realistic stimuli from being actively received by the brain. He says that each stimulus is analyzed for certain relevant qualities and only these are passed on for further analysis. A related view held by Broadbent is that there is a perceptual defense. According to this view, features of the world which are repugnant to a particular person may not be perceived at all.

Writers from several fields (Jacobson, 1951; Broadbent, 1965) have developed models which do not support the assumption that increased realism leads to more effective learning. Recent research does not seem to dispute the existence of a realism continuum, but seems to suggest several visual continuums exist and that certain ones may be more useful than others in predicting student learning of specific objectives (Dwyer, 1969).

A brief examination of Dwyer's work is provided in Figure 4 which compares one of his earlier studies (1967) with one of his later ones (1969). His initial study involved: (1) oral presentation (with printed words on slide); (2) abstract linear presentation; (3) detailed, shaded drawings; and (4) realistic photographs of the heart. He later expanded this set of presentations to include colored illustrations and photographs of a heart model. His means of evaluation included a Drawing Test, Heart Model Test, Terminology Test, Comprehension Test, and a Total Criterion Test which was a composite of the other four tests.

Dwyer actually did a series of studies using these materials. These were done with students ranging from the ninth-grade up to and including college. The results of these various studies, like the two just cited, were not consistent. He concluded that "the same types of visuals are not equally effective in facilitating student achievement of identical educational objectives for students at different grade levels" (1969).

Having arrived at this point, Dwyer adds a dimension to the argument of Fleming (1966) who feels that visual illustrations should be studied for their specific contributions to specific educational objectives. Travers (1964) lends some support to the concept that complexity in visuals is related to learning. These writers collectively suggest a spectrum of learner/visual characteristics.

Total Criterion Test

(1967) Abstract linear and detailed, shaded drawing (equally good) oral presentation.

(1969) Detailed, shaded drawing (color detailed shaded drawing (B and W) oral presentation.

Drawing Test

(1967) Abstract linear and detailed, shaded drawing (equally good) oral presentation.

(1969) No significant differences among the nine types of presentation.

Heart Model (Identification) Test

(1967) Abstract linear presentation detailed, shaded drawing oral presentation and photograph.

(1969) Detailed, shaded drawing (color) oral presentation.

Terminology Test

(1967) Abstract linear and detailed, shaded drawing (equally good) photograph. (Oral presentation alone was as effective as any of the other presentations.)

(1969) Detailed, shaded drawing (color) detailed, shaded drawing (B and W) oral presentation.

Comprehension Test

(1967) All presentations equally effective.

(1969) Detailed, shaded drawing oral presentation

FIGURE 4

COMPARISON OF DWYER'S 1967 AND 1969 STUDIES

Summary. Combining these ideas (Travers, 1964; Fleming, 1966; Dwyer, 1967, 1969), it seems that visual complexity (including the presence or absence of color) is probably related to learning. This visual-learning relationship is modified by age, or grade level; and all of this is dependent upon the specific educational objectives. In other words, the role of a visual illustration in a learning situation is dependent not only upon the visual itself, but it is also dependent upon the individual learner and the specific educational objective. It is these relations that are being examined in more detail in the present study.

CHAPTER III

METHODS, MATERIALS, AND PROCEDURES

This chapter was designed to define the stimulus materials, test materials, population group, and to outline procedures by which the experiment was conducted.

Test Instruments. The following tests were included in both the pretest and the posttest: Recall Test, Operations Test, Recognition Test, and Composite Test.

Reliability. A trial presentation was run for the purpose of establishing the reliability of the test instruments. The trial was run at McIntire School in Charlottesville, Virginia. The school had three sixth-grade classes grouped by ability. This test involved the low group with twenty-six members and the high group with thirty-five members. Only the top group and the bottom group were used in this trial. One presentation, Line Drawing (B and W), was used and the posttests were administered and scored.

A Kuder-Richardson Formula (Ebel, 1956) was used with the composite test and each sub-test to determine reliability. Table I includes the means, variance, and the reliability.

TABLE I

PRETEST MEANS, VARIANCE, AND RELIABILITY

	Means	Variance	Reliability
Recall Test	9.11	4.10	.84
Operations Test	7.34	3.16	.71
Recognition Test	9.85	4.73	.90
Composite Test	26.31	10.97	.93

Validity. A chart of the pq scores used in the computation and a chart indicating content validity are furnished in the appendix (See appendices A and B).

Stimulus Materials. Stimulus materials were designed for sixth-grade students. From his previous studies, Dwyer (1969) found that learning sometimes increased with color. Therefore, color was included in this present study to determine its effect on learning.

These stimulus materials used one basic format for all sequences. Thus, the only differences between the sequences were those specifically designed for study purposes. For an example, the only difference between the line drawings in black and white and the line drawings in color was the actual color of the lines.

The visual stimulus materials were presented on 2 X 2 slides and the standardized oral program was presented via a tape recorder. There was an audible signal to indicate when each slide was to be changed. This insured uniform timing for each treatment group.

The slide projector was placed twelve feet from the screen in a darkened room. The students were seated on movable, folding chairs and were placed in positions providing comfortable viewing and listening for each student.

Population Sample. Students at the Washington-Reid School in Prince William County, Virginia were randomly selected, using Freund's (1967) table of random numbers, and randomly assigned to one of the five treatment groups. Those students not having complete data available in their records (IQ scores, etc.) were excluded. The school enrollment consisted of sixth-grade students exclusively.

The students in this population sample consisted of students living in a suburban area. Most of them came from a housing development that had been built within the five years previous to this study. Some were from low income areas. Many of these individuals had a rural or semi-rural background.

Treatments. The five groups received the following visual treatments:

(Group 1) The visual portion of the instruction was limited to a verbal presentation. The 2 X 2 slides had nothing but printed words on them. These words were identical to those used on the slides in the other sequences. However, in all of the other sequences there were these words plus visual illustrations on each slide.

(Group 2) The visual instruction consisted of simplified line drawings of the heart. The drawings were in black and white and were presented on slides.

(Group 3) The visual instruction consisted of simplified line drawings of the heart. The drawings were in color and were presented on slides.

(Group 4) The visual instruction consisted of shaded drawings of the heart. The drawings were in black and white and were presented on slides.

(Group 5) The visual instruction consisted of shaded drawings of the heart. The drawings were in color and were presented on slides.

Analytical Design. The design used in this study was a multiple linear regression design. This permitted the use of variables in both continuous and categorical vectors.

Vector Assignment

x^1 = vector of dimension n in which the elements are the corresponding pretest scores

x^2 = vector of dimension n in which the element is a 1 if the corresponding element in vector x^1 comes from a student who has an IQ of 94 or below; and 0 otherwise

x^3 = vector of dimension n in which the element is a 1 if the corresponding element in vector x^1 comes from a student who has an IQ of 95-110; and 0 otherwise

x^4 = vector of dimension n in which the element is a 1 if the corresponding element in vector x^1 comes from a student who has an IQ of 111 or up; and 0 otherwise

x^5 = vector of dimension n in which the element is a 1 if the corresponding element in vector x^1 comes from a student who is a boy; and 0 otherwise

x^6 = vector of dimension n in which the element is a 1 if the corresponding element in vector x^1 comes from a student who is a girl; and 0 otherwise

x^7 = vector of dimension n in which the element is a 1 if the corresponding element in vector x^1 comes from a student who is a boy in the Verbal treatment group; and 0 otherwise

x^8 = vector of dimension n in which the element is a 1 if the corresponding element in vector x^1 comes from a student who is a girl in the Verbal treatment group; and 0 otherwise

x^9 = vector of dimension n in which the element is a 1 if the corresponding element in vector x^1 comes from a student who is in the Verbal treatment group; and 0 otherwise

x^{10} = vector of dimension n in which the element is a 1 if the corresponding element in vector x^1 comes from a student who is a boy in the Line Drawing (B & W) treatment group; and 0 otherwise

x^{11} = vector of dimension n in which the element is a 1 if the corresponding element in vector x^1 comes from a student who is a girl in the Line Drawing (B & W) treatment group; and 0 otherwise

x^{12} = vector of dimension n in which the element is a 1 if the corresponding element in vector x^1 comes from a student who is in the Line Drawing (B & W) treatment group; and 0 otherwise

x^{13} = vector of dimension n in which the element is a 1 if the corresponding element in vector x^1 comes from a student who is a boy in the Line Drawing (Color) treatment group; and 0 otherwise

x^{14} = vector of dimension n in which the element is a 1 if the corresponding element in vector x^1 comes from a student who is a girl in the Line Drawing (Color) treatment; and 0 otherwise

x^{15} = vector of dimension n in which the element is a 1 if the corresponding element in vector x^1 comes from a student who is in the Line Drawing (Color) treatment group; and 0 otherwise

x^{16} = vector of dimension n in which the element is a 1 if the corresponding element in vector x^1 comes from a student who is a boy in the Shaded (B & W) treatment group; and 0 otherwise

x^{17} = vector of dimension n in which the element is a 1 if the corresponding element in vector x^1 comes from a student who is a girl in the Shaded (B & W) treatment group; and 0 otherwise

x^{18} = vector of dimension n in which the element is a 1 if the corresponding element in vector x^1 comes from a student who is in the Shaded (B & W) treatment group; and 0 otherwise

x^{19} = vector of dimension n in which the element is a 1 if the corresponding element in vector x^1 comes from a student who is a boy in the Shaded (Color) treatment group; and 0 otherwise

x^{20} = vector of dimension n in which the element is a 1 if the corresponding element in vector x^1 comes from a student who is a girl in the Shaded (Color) treatment group; and 0 otherwise

x^{21} = vector of dimension n in which the element is a 1 if the corresponding element in vector x^1 comes from a student who is in the Shaded (Color) treatment group; and 0 otherwise

x^{22} = vector of dimension n in which the elements are the corresponding Recall Test scores

x^{23} = vector of dimension n in which the elements are the corresponding Operations Test scores

x^{24} = vector of dimension n in which the elements are the corresponding Recognition Test scores

x^{25} = vector of dimension n in which the elements are the corresponding Composite Test scores

x^{26} = unit vector of dimension n

x^{27} = vector of dimension n in which the element is a 1 if the corresponding element in vector x^1 comes from a student who has an IQ of 94 or below and is in the Verbal treatment group; and 0 otherwise

x^{28} = vector of dimension n in which the element is a 1 if the corresponding element in vector x^1 comes from a student who has an IQ of 95-110 and is in the Verbal treatment group; and 0 otherwise

x^{29} = vector of dimension n in which the element is a 1 if the corresponding element in vector x^1 comes from a student who has an IQ of 111 or up and is in the Verbal treatment group; and 0 otherwise

x^{30} = vector of dimension n in which the element is a 1 if the corresponding element in vector x^1 comes from a student who is in the Verbal treatment group; and 0 otherwise

x^{31} = vector of dimension n in which the element is a 1 if the corresponding element in vector x^1 comes from a student who has an IQ of 94 or below and is in the Line Drawing (B & W) treatment group; and 0 otherwise

x^{32} = vector of dimension n in which the element is a 1 if the corresponding element in vector x^1 comes from a student who has an IQ of 95-110 and is in the Line Drawing (B & W) treatment group; and 0 otherwise

x^{33} = vector of dimension n in which the element is a 1 if the corresponding element in vector x^1 comes from a student who has an IQ of 111 or above and is in the Line Drawing (B & W) treatment group; and 0 otherwise

x^{34} = vector of dimension n in which the element is a 1 if the corresponding element in vector x^1 comes from a student who is in the Line Drawing (B & W) treatment group; and 0 otherwise

x^{35} = vector of dimension n in which the element is a 1 if the corresponding element in vector x^1 comes from a student who has an IQ of 94 or below and is in the Line Drawing (Color) treatment group; and 0 otherwise

x^{36} = vector of dimension n in which the element is a 1 if the corresponding element in vector x^1 comes from a student who has an IQ of 95-110 and is in the Line Drawing (Color) treatment group; and 0 otherwise

x^{37} = vector of dimension n in which the element is a 1 if the corresponding element in vector x^1 comes from a student who has an IQ of 111 or up and is in the Line Drawing (Color) treatment group; and 0 otherwise

x^{38} = vector of dimension n in which the element is a 1 if the corresponding element in vector x^1 comes from a student who is in the Line Drawing (Color) treatment group; and 0 otherwise

x^{39} = vector of dimension n in which the element is a 1 if the corresponding element in vector x^1 comes from a student who has an IQ of 94 or below and is in the Shaded (B & W) treatment group; and 0 otherwise

x^{40} = vector of dimension n in which the element is a 1 if the corresponding element in vector x^1 comes from a student who has an IQ of 95-110 and is in the Shaded (B & W) treatment group; and 0 otherwise

x^{41} = vector of dimension n in which the element is a 1 if the corresponding element in vector x^1 comes from a student who has an IQ of 111 or above and is in the Shaded (B & W) treatment group; and 0 otherwise

x^{42} = vector of dimension n in which the element is a 1 if the corresponding element in vector x^1 comes from a student who is in the Shaded (B & W) treatment group; and 0 otherwise

x^{43} = vector of dimension n in which the element is a 1 if the corresponding element in vector x^1 comes from a student who has an IQ of 94 or below and is in the Shaded (Color) treatment group; and 0 otherwise

x^{44} = vector of dimension n in which the element is a 1 if the corresponding element in vector x^1 comes from a student who has an IQ of 95-110 and is in the Shaded (Color) treatment group; and 0 otherwise

x^{45} = vector of dimension n in which the element is a 1 if the corresponding element in vector x^1 comes from a student who has an IQ of 111 or up and is in the Shaded (Color) treatment group; and 0 otherwise

x^{46} = vector of dimension n in which the element is a 1 if the corresponding element in vector x^1 comes from a student who is in the Shaded (Color) treatment group; and 0 otherwise.

Full and restricted models were defined to test each hypothesis. These models are recorded, along with resulting probabilities, in chapter four.

Multiple Linear Regression. This is a research design which permits the formulation and analysis of two distinct possibilities in one distinct application. Comparison of the results of the studies of each of the two possibilities usually gives answers to the research questions being investigated.

These two possibilities are stated in terms of models. The first is the full model and the second is the restricted model. The full model represents an attempt to predict criterion values from a linear combination of the stated vectors. The restricted model attempts to predict the criterion values without taking the previously stated vectors into consideration. In other words, the full model suggests the existence of differences between the stated vectors and the restricted model suggests the nonexistence of differences between the stated vectors (it completely omits the vectors being questioned). The results of the study of the full model are compared to the results of the study of the restricted model. On the basis of this comparison, a probability may be determined. Numerous additional questions can then be investigated by formulating additional models.

The research questions being investigated in this study are stated in the form of null hypotheses. That is, the null hypotheses suggest that there are no differences (significant at the .05 level) between the vectors in question. Therefore, if a resulting probability is more than .05, the null hypothesis is accepted. Likewise, if the probability is less than .05, the null hypothesis is rejected.

The test results are used as the criterion values in this study. These test results are represented by vector designations x^{25}, x^{22}, x^{23}, and x^{24}.

Bottenbert (1963) was used as the design reference.

<u>Hypotheses</u>. The null hypotheses were tested with a Recall Test, Operations Test, Recognition Test, and a Composite Test which consisted of a combination of the other three tests. Given these means of evaluation, the null hypotheses were as follows:

(H_1) There are no differences in learning achievement among students viewing visual illustrations with varying amounts of realism.

(H_2) There are no differences in learning achievement between sexual differences.

(H_3) There are no differences in learning achievement between students of varying intelligence levels. Intelligence levels were derived from scores on the Lorge-Thorndike Test.

(H_4) There are no differences in learning achievement between sexual differences in terms of visual stimuli as represented by treatment groups. That is, boys and girls learn essentially the same at each stratum of visual complexity (Figure 2, page 4).

(H_5) There are no differences in learning achievement between students of varying intelligence levels in terms of visual stimuli as represented by treatment groups. That is, students of varying intelligence levels learn essentially the same at each stratum of visual complexity (Figure 2, page 4).

In chapter four the data from this experiment will be analyzed.

CHAPTER IV

DATA ANALYSIS

Pretest. Each treatment group was given a pretest. This was followed immediately by the formal presentation and the posttests. The pretest scores were examined to determine any possible initial differences between the five treatment groups.

A full model was designed to study the possibility of pretest score differences among the five treatment groups.* A restricted model was designed to study the possibility of no pretest score differences among the five treatment groups. The models were:

Full $x^1 = a_9x^9 + a_{12}x^{12} + a_{15}x^{15} + a_{18}x^{18} + a_{21}x^{21} + a_{26}x^{26} + e$

RSTR $x^1 = a_{26}x^{26} + e$

Probability = .15 ($p > .05$)

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*See page 27 for vector assignment.

A comparison, by computer, of the studies of the two possibilities resulted in a probability that was greater than .05. Therefore, any initial differences among the five treatment groups were not significant at the .05 level. This determined that the treatment groups were essentially equal at the beginning of the experiment.

<u>Hypothesis One</u>: There are no differences in learning achievement among students viewing visual illustrations with varying amounts of realism.

The hypothesis was investigated by designing a full model to study the possibility of differences among the treatment groups and a restricted model to study the possibility of no differences.

A comparison of the two studies was made using the Composite Test scores (x^{25}) as the criterion value. The comparison was then repeated using Recall Test scores (x^{22}), Operations Test scores (x^{23}), and Recognition Test scores (x^{24}) as the criterion values.

The models and the resulting probabilities were as follows:

$$\text{Full } x^{25} = a_9x^9 + a_{12}x^{12} + a_{15}x^{15} + a_{18}x^{18} + a_{21}x^{21} + a_{26}x^{26} + e$$

$$\text{RSTR } x^{25} = a_{26}x^{26} + e$$

Probabilities

$x^{25} = .17$ ($p > .05$) accepted at the .05 level

$x^{22} = .22$ ($p > .05$) accepted at the .05 level

$x^{23} = .23$ ($p > .05$) accepted at the .05 level

$x^{24} = .02$ ($p < .05$) rejected at the .05 level

There were no significant differences found at the .05 level when the Composite Test, Recall Test, and Operations Test scores were used as the criterion values. Thus, the hypothesis was accepted in terms of these criteria.

When the Recognition Test scores (x^{24}) were used as the criterion values, the probability was less than .05. This indicates that the differences were significant at the .05 level. The null hypothesis, as it related to Recognition Test scores, was rejected.

In order to investigate the cause for this difference, the means for each treatment group were examined. The following table consists of the means, for each treatment group, of the Recognition Test scores.

TABLE II

TREATMENT GROUP MEANS

Verbal	6.52
Line Drawing (B & W)	8.44
Line Drawing (Color)	8.28
Shaded Drawing (B & W)	8.08
Shaded Drawing (Color)	8.44

An examination of this table reveals a lower mean score for the Verbal treatment group.

In summary, there were no differences, significant at the .05 level, among the treatment groups when the Composite Test, Recall Test, and Operations Test scores were used as the criterion values. When the Recognition Test scores were used as the criterion values, differences significant at the .05 level were found. An examination of the means revealed that the Verbal treatment group had a lower mean score.

The Verbal treatment group did not see visual illustration, and did not respond as well when the test called for labeling parts on a drawing.

Hypotheses Two and Four. Hypothesis two: There are no differences in learning achievement between sexual differences.

Hypothesis four: There are no differences in learning achievement between sexual differences in terms of visual stimuli as represented by treatment groups. That is, boys and girls learn essentially the same at each stratum of visual complexity (Figure 2, page 4).

A full model was designed to study the possibility of differences in learning achievement between the sexes. A restricted model was designed to study the possibility of no differences in learning achievement. The two studies were compared using scores from the Composite Test and each of the sub-tests as criterion values. The models and the resulting probabilities were as follows:

Full $x^{25} = a_5x^5 + a_6x^6 + a_{26}x^{26} + e$

RSTR $x^{25} = a_{26}x^{26} + e$

Probabilities

$x^{25} = .87$ ($p > .05$) accepted at the .05 level

$x^{22} = .50$ ($p > .05$) accepted at the .05 level

$x^{23} = .41$ ($p > .05$) accepted at the .05 level

$x^{24} = .85$ ($p > .05$) accepted at the .05 level

There were no differences, significant at the .05 level, found in terms of any of the criterion values. Therefore, hypothesis number two was accepted.

Since there were no significant differences in learning achievement found between boys and girls (hypothesis two), it was concluded that there were no significant differences in learning achievement between boys and girls in terms of individual treatment groups (hypothesis four).

Hypothesis two and hypothesis four were both accepted.

<u>Hypothesis Three</u>: There are no differences in learning achievement between students of varying intelligence levels. Intelligence levels were derived from scores on the Lorge-Thorndike Test.

Intelligence levels were determined from scores on the Lorge-Thorndike Test. Three categories were established for this study. The first group consisted of those having scores of 94 or below (x^2), the second group had scores of 95-110 (x^3), and the third group had scores of 111 and above (x^4).

A full model was designed to study the possibility of differences in learning achievement between the three intelligence levels. A restricted model was designed to study the possibility of no differences in learning achievement between the three levels. The two studies were compared in terms of the Composite Test and each of the sub-tests. The models and the resulting probabilities were as follows:

Full $x^{25} = a_2x^2 + a_3x^3 + a_4x^4 + a_{26}x^{26} + e$

RSTR $x^{25} = a_{26}x^{26} + e$

Probabilities

x^{25} = .00000000003 rejected at the .05 level

x^{22} = .0000007 rejected at the .05 level

x^{23} = .00000005 rejected at the .05 level

x^{25} = .0000000003 rejected at the .05 level

The resulting probabilities for each of the criterion values were all less than .05. Therefore, the hypothesis was rejected at the .05 level of significance.

The following table provides a comparison of mean scores, as related to criterion values, of the three levels of intelligence.

TABLE III

MEANS FOR THREE INTELLIGENCE LEVELS

Criterion Values	x^{25}	x^{22}	x^{23}	x^{24}
111 and Above	29.12	10.42	8.37	10.40
95 to 110	22.25	8.28	6.57	7.40
94 and Below	16.03	6.11	4.85	5.06

Mean scores, for all criteria, increased as intelligence increased. This was true in terms of each of the four tests.

These mean scores are consistent with what would be be expected of varying intelligence levels. However, they are helpful in that they ascertain the expected differences and provide the basis for further investigation in hypothesis number five.

<u>Hypothesis Five</u>: There are no differences in learning achievement between students of varying intelligence levels in terms of visual stimuli as represented by treatment groups. That is, students of varying intelligence levels learn essentially the same at each stratum of visual complexity (Figure 2, page 4).

For the purpose of investigating this hypothesis, the test scores were separated and each intelligence level was studied by itself.

<u>Intelligence Level 94 and Below</u>. First, all test scores for students on this level of intelligence were pulled by treatment groups.

A full model was designed to study the possibility of differences in learning achievement among the five treatment groups. A restricted model was designed to study the possibility of no differences in learning achievement among the five groups. These two studies were compared using test scores from the Composite Test and each sub-test as criterion values.

The models and the resulting probabilities were as follows:

$$\text{Full } x^{25} = a_{27}x^{27} + a_{31}x^{31} + a_{35}x^{35} + a_{39}x^{39}$$
$$a_{43}x^{43} + a_{26}x^{26} + e$$

$$\text{RSTR } x^{25} = a_{26}x^{26} + e$$

Probabilities

x^{25} = .25 ($p > .05$) accepted at the .05 level

x^{22} = .22 ($p > .05$) accepted at the .05 level

x^{23} = .87 ($p > .05$) accepted at the .05 level

x^{24} = .46 ($p > .05$) accepted at the .05 level

All of the resulting probabilities were greater than .05 and. therefore, were not significant at the .05 level.

The null hypothesis was accepted for students at this intelligence level. Students having an IQ of 94 or below achieved essentially the same in each treatment group, thereby achieving essentially the same at each stratum of visual complexity.

Intelligence Level 95-110. This procedure was repeated for the other two levels of intelligence. The scores for those students having an IQ of 95-110 were pulled next. The models used and the resulting probabilities were as follows:

$$\text{Full } x^{25} = a_{28}x^{28} + a_{32}x^{32} + a_{36}x^{36} + a_{40}x^{40}$$
$$a_{44}x^{44} + a_{26}x^{26} + e$$

$$\text{RSTR } x^{25} = a_{26}x^{26} + e$$

Probabilities

$x^{25} = .50$ ($p > .05$) accepted at the .05 level

$x^{22} = .21$ ($p > .05$) accepted at the .05 level

$x^{23} = .45$ ($p > .05$) accepted at the .05 level

$x^{24} = .69$ ($p > .05$) accepted at the .05 level

Again, there were no significant differences at the .05 level among the resulting probabilities.

Therefore, the null hypothesis was accepted for this intelligence level. Students having an IQ of 95-110 achieved essentially the same at each stratum of visual complexity. That is, they achieved essentially the same in each treatment group.

Intelligence Level 111 and Above. Scores for this level were pulled and models designed. The resulting probabilities were:

$$\text{Full } x^{25} = a_{29}x^{29} + a_{33}x^{33} + a_{37}x^{37} + a_{41}x^{41} + a_{45}x^{45} + a_{26}x^{26} + e$$

$$\text{RSTR } x^{25} = a_{26}x^{26} + e$$

Probabilities

$x^{25} = .02$ $(p < .05)$ rejected at the .05 level

$x^{22} = .13$ $(p > .05)$ accepted at the .05 level

$x^{23} = .09$ $(p > .05)$ accepted at the .05 level

$x^{24} = .01$ $(p < .05)$ rejected at the .05 level

There were no significant differences, at the .05 level, among the treatment groups when scores from the Recall Test (x^{22}) and the Operations Test (x^{23}) were used as criterion values. The null hypothesis was accepted as it related to these criterion values. That is: students having an IQ of 111 or above achieved the same on the Recall Test and Operations Test at each stratum of visual complexity (in each treatment group).

There were significant differences at the .05 level, among the treatment groups when scores from the Composite

Test (x^{25}) and the Recognition Test (x_{24}) were used as the criterion values. The null hypothesis was rejected as it related to these criterion values.

Having determined that there were differences among the treatment groups in terms of these two criteria, the mean sc es of each treatment group were examined. The following table consists of the mean scores for each treatment group.

TABLE IV

MEANS FOR INTELLIGENCE LEVEL 111 AND ABOVE BY TREATMENT GROUPS

Criterion	x^{25}	x^{24}
Verbal	22.15	7.14
Line Drawing (B & W)	33.19	12.17
Line Drawing (Color)	31.10	11.66
Shaded Drawing (B & W)	29.41	11.08
Shaded Drawing (Color)	31.31	11.08

An inspection of this table reveals lower mean scores for the Verbal treatment group on the Composite Test (x^{25}) and on the Recognition Test (x^{24}). Those in the Verbal treatment group did not achieve mean scores on these two criterion values as high as those students in the other treatment groups.

An examination of mean scores revealed that it was the Recognition Test scores that decreased the Composite Test scores downward (there were no significant differences) on the other two sub-tests).

Thus, it was concluded that students having an IQ of 111 or above did not achieve as well on the Recognition Test if they were in the Verbal treatment group.

In summary, there were no significant differences in learning achievement among students of varying intelligence levels when they were viewing stimuli containing visual illustrations of varying complexity. That is, when each intelligence level was considered separately, each level reflected no significant differences among the four treatment groups which viewed sequences having visual illustrations. Those students in the two lowest groups scored essentially the same (as others on their respective intelligence levels) in all five treatment groups. Students in these two intelligence levels scored essentially the same, as others on their level, in all five strata of visual complexity.

Those students having the highest level of intelligence achieved significantly lower on the Recognition Test when they were among those in the Verbal treatment group (that treatment which provided no visual illustrations). In chapter five these results will be discussed further.

CHAPTER V

SUMMARY AND RECOMMENDATIONS

This experiment was designed to investigate the role of complexity of detail in a picture as related to learning. For the realism theories to be supported, two conditions must hold: a) that learning increases with complexity, and b) that learning increases in a continuum.

In order to examine the realism theory, five treatment groups were established for this study, each viewing a different sequence of visuals. The five sequences included the following presentations: Verbal (words only), Line Drawing (Black and White), Line Drawing (Color), Shaded Drawing (Black and White), and a Shaded Drawing (Color). All five groups were taught the same unit of instruction concerning the human heart. The cognitive elements in the learning experience included names of the specific parts and the operation of the heart through one complete cycle.

Students in all five groups were pretested and post-tested on cognitive information about the heart. The effects of the instruction were measured by the student's recognition of parts of the heart, recall of terminology, and knowledge of operations of the heart. Student performances were recorded for each separate test and for a composite of the three tests.

Sexual differences and intelligence level differences (Lorge-Thorndike scores) were investigated to determine their possible relationship to learning within those visual symbol strata defined.

The data collected in this experiment did not indicate any significant differences, at the .05 level, among the five treatment groups--except when Recognition Test scores were used as the criteria. A comparison of the mean scores of the five treatment groups revealed the Verbal treatment group as the one having lower scores on the Recognition Test.

Investigation of intelligence levels indicated significant differences on the Composite Test and each sub-test. However, when each of the three categories of IQ scores (94 and below, 95-110, and 111 and above) were investigated separately, significant differences were found only with the top group. The significant differences found with this group related to the Recognition Test. A comparison of the mean scores between treatment groups, again, revealed the Verbal treatment group as having lower scores. To sum up: those differences found were limited to the upper intelligence level of the Verbal treatment group.

The Verbal treatment group saw 2 X 2 slides with words only. The Recognition Test contained a drawing similar to the ones used in the slides shown to the other treatment groups. Therefore, it appears that the Recognition Test was evaluating a skill which required the use of the visual in the presentation.

There were no significant differences in learning achievement between boys and girls on the Composite Test or any of the sub-tests.

Conclusions. The results of this experiment did not reveal any differences, significant at the .05 level, between treatment groups viewing visual illustrations of varying complexity. When the visual illustration was completely omitted from a slide sequence, those students in the highest intelligence level viewing that sequence scored lower on the Recognition Test. Students in all treatment groups scored equally well on the other tests (Recall Test and Operations Test).

TABLE 18 (Continued)

Source	df	MS	F	Percentage of the sum of squares for overall trend
53.49 PERCENT (PROFILE B)				
Overall trend	3	1081.39	50.42*	
Linear	1	3228.01	107.73*	99.50
Quadratic	1	16.06	.91	.49
Cubic	1	.01	.01	.003
Between individual trends	51	21.45		
Linear	17	29.96		
Quadratic	17	17.70		
Cubic	17	16.68		
72.09 PERCENT (PROFILE C)				
Overall trend	3	743.13	48.10*	
Linear	1	2165.80	64.06*	97.15
Quadratic	1	62.35	9.03*	2.80
Cubic	1	1.23	.22	.05
Between individual trends	51	15.45		
Linear	17	33.81		
Quadratic	17	6.91		
Cubic	17	5.63		
83.75 PERCENT (PROFILE D)				
Overall trend	3	741.83	44.97*	
Linear	1	2136.47	69.50*	96.00
Quadratic	1	86.68	8.85*	3.89
Cubic	1	2.34	.26	.10
Between individual trends	51	16.50		
Linear	17	30.74		
Quadratic	17	9.80		
Cubic	17	8.95		

*$p < .01$

The linear components of each of the four profiles in Fig. 6 were significant. The quadratic components of profiles A, C and D were significant but not the quadratic component of profile B.

CHAPTER V

Discussion and Conclusions

Hue Contrast

The obtained result that the discrimination accuracy of color normals, deuteranopes and protanopes increased as a positive function of the amount of hue contrast supports experimental hypothesis 1.

Although Bishop (1966) and Cavonius and Schumaker (1966) used methods which were quite different from those of the present study, there seems to be considerable agreement between their findings and the present writer's with regard to the fact that color normals exhibited rather high discrimination accuracy with stimuli involving medium to large amounts of hue contrast. The present study indicated that deuteranopes were also able to discriminate on the basis of hue contrast to a considerable extent and protanopes to some extent. Protanopes' mean percentage correct responses at each amount of hue contrast was much lower than that of color normals and deuteranopes. Further, at 180° of hue contrast, which is the maximum amount of hue contrast obtainable in the Munsell Hue Circle, their mean percentage correct responses had the same value as that of color normals at 36° and was lower than that of deuteranopes at 72°. Further, variance among the individual trends for protanopes was larger than that for color normals and deuteranopes, as shown in Table 6. Thus, not only did protanopes on the average show poorer discrimination on the basis of hue contrast and less increase in their discrimination accuracy as the amount of hue contrast was increased, but performance was more variable from one S to another than in the case of color normals and deuteranopes. Further, as will be recalled, while the linear component of the profiles for color normals and deuteranopes was significant, that of protanopes was not significant. Thus, protanopes' discrimination accuracy cannot be described as a linear function of the amount of hue contrast.

As will be recalled, the significant ranges in the simple main effects of hue contrast were different from one type of color vision to another. They seem to indicate that color normals are able to use hue contrast more effectively for making accurate visual discrimination than deuteranopes and protanopes. This seems to be true because color normals' significant ranges were in the low-to-medium hue contrast of 36° to 108° and their discrimination accuracy reached almost its highest value at the hue contrast of 108°. Deuteranopes' discrimination accuracy did not show a significant increase until hue contrast was increased to the medium range of 72° to 144°, and their discrimination accuracy required a rather high hue contrast of 144° in order almost to reach its highest value. In other words, color normals' discrimination accuracy started to show a significant increase at a hue contrast which was lower than the hue contrast at which deuteranopes started to show a significant increase; and color normals' discrimination accuracy approached its highest value at a hue contrast which was less than that at which deuteranopes' discrimination accuracy approached its highest value. The significant range between 72° and 180° for protanopes seems to indicate that protanopes, being less sensitive to hue contrast, required a hue contrast which was greater than that required by color normals and deuteranopes to show a significant increase in discrimination accuracy.

As will be recalled, there were eight different orientations of the gaps in the targets. Thus, the probability of making a correct response by guessing is one out of eight or 12.5 percent. It is rather obvious that protanopes were making responses at the chance level at a hue contrast of 36°. This fact probably accounts for the significant increase in protanopes' discrimination accuracy between 36° and 72°.

Illuminant Intensity

The obtained result that the discrimination accuracy of color normals, deuteranopes and protanopes increased significantly as the illuminant intensity was raised from 25 to 100 fc. supports experimental hypothesis 2.

Since the stimuli had approximately 30 percent reflectance, the luminance range of stimuli in the present study was approximately 25 to 100 mL. As will be recalled, Konig's data replotted by Hecht (1934) indicated that the visual acuity of average observers increased only slightly when the luminance of achromatic stimuli was increased from 10 to 100 mL. The critical difference between Konig's experimental conditions and those of Part I of the present study seems to be that Konig used stimuli having brightness contrast, while there was hue contrast but no brightness contrast in Part I of the present study. The implication of the difference in the results of Konig and those of the present study seems to be that, for color normals, when discrimination is based on brightness contrast, raising the luminance above 10 mL. has little effect; whereas, when discrimination is based on hue contrast, raising the luminance even above 25 mL. has considerable effect.

Seagers (1963, p. 68) recommends 70 fc. for tasks such as reading and typewriting which require discrimination of letters. This level of illumination seems also adequate for discrimination of chromatic stimuli such as those used in the present study. Increasing illuminant intensity beyond 75 fc. to 100 fc. did not affect the visual discrimination of Ss having either of the three types of color vision.

As will be recalled, color normals' discrimination accuracy increased steadily as a positive linear function of illuminant intensity within the range of 25 to 100 fc. This was not the case for deuteranopes and protanopes. Further, under the illuminant intensity of 100 fc. deuteranopes' mean percentage correct responses was approximately equal to that of color normals at 50 fc. Protanopes' highest mean percentage correct responses, obtained under 75 fc. and 100 fc., was still much lower than the mean percentage correct responses of color normals and deuteranopes at 25 fc. A result like this seems to indicate that the advantages for deuteranopes and protanopes of raising illuminant intensity within the range of 25 to 100 fc. is rather limited. This seems true especially for protanopes.

Type of Color Vision

The result obtained in Part I that color normals' discrimination accuracy was significantly higher than that of deuteranopes which in turn was significantly higher than that of protanopes supports experimental hypothesis 3.

Since Ss having different types of color vision had approximately equal visual acuity, as shown in Table 2, the obtained result seems attributable to type of color vision. However, it seemed desirable to determine whether visual acuity might have been inadvertently confounded with the variable of type of color vision. A one way analysis of variance for independent measures was applied for testing the significance of the differences between the mean visual acuity of _Ss_ having each of the three types of color vision. The value of _F_ was 1.19 (_d.f._ = 2, 15) which was not significant. Accordingly, differences between the mean percentage correct responses presumably were due to the differences in type of color vision.

Brightness Contrast

The result obtained in Part II that with a brightness contrast of 30 percent or greater there were no longer differences between the discrimination accuracy of color normals, deuteranopes and protanopes supports experimental hypothesis 4. In other words, at high brightness contrasts, deuteranopes and protanopes were able to discriminate as accurately as color normals.

It will be recalled that Ludvigh (1941) found that visual acuity increased very little when the brightness contrast of achromatic stimuli was increased beyond about 30 percent. This was not the case in the present study. As will be recalled the discrimination accuracy of color normals and deuteranopes increased significantly each step as the brightness contrast was increased from 30 percent to 72 percent. Protanopes' discrimination accuracy increased significantly as the brightness contrast was increased each step from 30 percent to 84 percent. The implication of the difference in the results of Ludvigh and those of the present study seems to be that increasing the brightness contrast in achromatic stimuli beyond about 30 percent has little effect on visual discrimination but increasing the brightness contrast in chromatic stimuli beyond about 30 percent has considerable effect on discrimination accuracy.

In view of the result obtained in Part II of the present study the critical amount of brightness contrast on the basis of which deuteranopes and protanopes can make a visual discrimination of chromatic stimuli which is as good as color normals' could be less than 30 percent. This is true because as pointed out above, at a brightness contrast of 30 percent there was no difference between the discrimination accuracy of the three groups of Ss. A brightness contrast of approximately 27 percent can be obtained by using Munsell colors with the brightness of 8/ as targets and those with the brightness of 7/ as surrounds. However, Munsell colors with the brightness and saturation of 8/6 are not available in 5BG, 5B, 5PB and 5P. They are available in the brightness and saturation of 8/4. But Munsell colors with the saturation of /4 are considerably desaturated and hence may not be adequate for studying the effects of hue contrast.

As will be recalled, the linear trend and quadratic trend of the profile of the main effects of brightness contrast were significant. The significant quadratic trend of this profile and the relatively small amount of increase in discrimination accuracy at the high brightness contrast range as shown in Fig. 4 seem to indicate that the Munsell Value [Brightness] Scale may not be exactly scalar at the upper part of its scale or more likely that the difference between the obtained result and what might have been expected on the basis of the Munsell Value Scale was due to the difference in the method used in the present study for measuring the effect of brightness contrast and that used for determining the Munsell Value Scale.

Viewing Distance

The result obtained in Part II does not support experimental hypothesis 5. Color normals', deuteranopes' and protanopes' discrimination accuracies all decreased linearly to the same extent as the viewing distance was increased from 5 to 8 m. Thus, viewing distance within the range of 5 to 8 m., or more accurately, the angular subtence of chromatic stimuli within the range of 26' to 1°8', seems not to be a critical variable in experiments which are intended to test the effect of type of color vision. As was shown in Table 2, the visual angle subtended by the surround was larger than 20° in all conditions of observation so that the effect due to the tritanopia of the central fovea presumably did not affect the obtained result.

Interaction between Brightness Contrast and Viewing Distance

Inspection of the data in Table 18 and the profiles in Fig. 6 reveal that while profiles C and D each had a significant quadratic component reflecting their being concave downward, the quadratic component of profile B was not significant. Further, the significant quadratic component of profile A reflected its being somewhat concave upward. However, it appears that this characteristic of profile A is an artifact due to the fact that the expected value of mean percentage correct responses if Ss were simply guessing the orientation of the gap is 12.5. The value in the case of profile A at a viewing distance of 8 m. would have had to be of the order of zero if the profile were not to be concave upward. This artifact may account for the interaction's being significant.

Recommendation

On the basis of the evidence obtained in the present study it is recommended that a brightness contrast of 30 percent or more be provided in colored instructional materials so that color deficients can discriminate important aspects of the materials as accurately as color normals.

CHAPTER VI

Summary

The primary purposes of the study were a) to investigate the effect of hue contrast, illuminant intensity, brightness contrast and viewing distance on the discrimination accuracy of color normals and color deficients, and b) to investigate the extent to which the discrimination accuracy of color deficients improves, as compared with that of color normals, as a function of brightness contrast in chromatic stimuli.

Six each of color normals, deuteranopes and protanopes having approximately equal visual acuity were paid to discriminate the orientation of the gap in chromatic rings presented on chromatic surrounds. Observations were made under a certain level of light adaptation. Subjects' responses were made orally and guessing was encouraged.

The surround was a circle of 60 mm. diameter. The target was a ring with an outside diameter of 6 mm., and a thickness of 2 mm. and a gap of 2 mm.

In Part I of the study, the amounts of hue contrast were 36°, 72°, 108°, 144° and 180° on the Munsell Hue Circle. The illuminants were approximations of the ICI Source "C" with intensities of 25, 50, 75 and 100 fc. The viewing distance was fixed at 3 m.

In Part II of the study, brightness contrast has four values between 30 and 80 percent, with a perceptually equal difference between each value. The viewing distances were 5, 6, 7 and 8 m. The illuminant intensity was fixed at 50 fc.

The discrimination accuracy of color normals, deuternaopes and protanopes increased significantly ($p < .01$) as a positive function of hue contrast, illuminant intensity and brightness contrast and decreased significantly (linearly) as the viewing distance was increased. Color normals' discrimination accuracy was higher than deuteranopes' and deuteranopes' accuracy was higher than protanopes' when hue contrast was the only cue for discrimination. Deuteranopes' hue contrast function was similar to color normals'. Protanopes' hue contrast function was somewhat different from that of other subjects. But once a brightness contrast of 30 percent or more was provided in chromatic stimuli, then there was no longer a difference in discrimination accuracy among the three groups of subjects.

The data from color normals suggest that some modification of the Munsell Hue Circle needs to be made in order that it be appropriate for specifying the amount of hue contrast, defined in terms of discrimination accuracy, between any two Munsell hues.

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