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ABSTRACT

A study of the effects of color as used in presentation software on short-range (immediately following treatment) and long-range (one hour following treatment) memory retention was conducted. Previous studies have concentrated on color as cueing or coding mechanisms primarily in print media and have not explored the effect of individual colors as presented on CRT (Cathode Ray Tube) computer screens. Twenty-eight subjects were selected from 6th and 7th grade students enrolled in a public school. Subjects were shown a series of alphanumeric characters (three per slide times three slides, equaling nine total per color) using black text upon white, blue, and green backgrounds. The slides were prepared using presentation software. Slides were automatically timed for 10 seconds each. Subjects were given answer sheets and asked immediately (time 0) following treatment to write down what they remembered from the series. One hour later (time 1), the subjects were given another answer sheet and asked to write what they remembered. The white, blue, and green slides were presented at one week intervals using a different set of randomly selected alphanumeric characters upon each subsequent background. The answers were scored for number correct in order and sequence from all colors and time references and t-tests were conducted on the data. Results show a statistically significant memory loss from time 0 to time 1 at the .05 level in the trial using blue and in the trial using green. Additionally, in a comparison between mean number of correct responses, a trend may have been discovered which shows black text upon a white background to rank higher than both colors in both time 0 and time 1. Blue may rank second in time 0 and third (worst) in time 1 while green may rank third in time 0 and second in time 1. Recommendations for additional research are given. Several appendices provide information on specifics of the study. (Contains 37 references.) (Author/AEF)

A STUDY OF THE EFFECT OF COLOR IN MEMORY RETENTION WHEN USED IN PRESENTATION SOFTWARE

An Action Research Project Presented to the

Department of Teacher Education

Johnson Bible College

In Partial Fulfillment

of the Requirement for the Degree

Master of Arts in Educational Technology and Bible

by

Bruce Vernon McConnohie

August 9, 1999

APPROVAL PAGE

This Action Research Project by Bruce Vernon McConnohie is accepted in its present form by the Department of Teacher Education at Johnson Bible College as satisfying the Action Research Project requirements for the degree Master of Arts in Educational Technology and Bible

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May 5, 2000.
Date

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A study of the effects of color as used in presentation software on short (immediately following treatment) and long range (one hour following treatment) memory retention was conducted. Previous studies concentrated on color as cueing or coding mechanisms primarily in print media and have not explored the effect of individual colors as presented on CRT (Cathode Ray Tube) computer screens. Twenty-eight subjects were selected from 6^{th} and 7^{th} grade students who were enrolled in a public school. Subjects were shown a series of alphanumeric characters (3 per slide x 3 slides = 9 total per color) using black text upon white, blue, and green backgrounds. The slides were prepared using presentation software. Slides were automatically timed for ten seconds each. Subjects were given answer sheets and asked immediately (time 0) following treatment to write down what they remembered from the series. One hour later (time 1), the subjects were given another answer sheet and asked to write what they remembered. The white, blue, and green slides were presented at one week intervals using a different set of randomly selected alphanumeric characters upon each subsequent background. The answers were scored for number correct in order and sequence from all colors and time references and t-tests were conducted on the data. Results show a statistically significant memory loss from time 0 to time 1 at the .05 level in the trial using blue and in the trial using green. Additionally, in a comparison between mean number of correct responses, a trend may have been discovered which shows black text upon a white background to rank higher in both time 0 and time 1 than blue or green. Blue may rank 2^{nd} in time 0 and 3^{rd} (worst) in time 1 while green may rank 3^{rd} (worst) in time 0 and 2^{nd} in time 1. Suggestions of evidence to support additional research in this area are inferred.

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INTRODUCTION

Significance of the Problem

The relationship between human learning and technology is a complex issue. As society advances in its applications of technology it must also insure that technology is used to its best advantage. Multimedia capable computers and presentation software, such as PowerPoint®, present a new medium with which to explore the limits of this concept. While previous studies reviewed in this paper have involved themselves with various aspects of multimedia, such as motion, sound, color, and background, few if any, have examined any of these elements as a single entity to determine their relative effect on human learning (Chen, p. 431). These studies have concentrated on combinations of different elements and have inferred a positive influence on the learning experience, but they have not been specific as to which individual element had the most effect, and in which area. This current study seeks to isolate the single, yet complex, element of color and to explore its effect on the single, yet complicated, aspect of memory retention in 6th and 7th Grade students.

A Consideration of the Scope of the Problem

"Whenever the rainbow appears in the clouds, I will remember the everlasting covenant between God and all living creatures of every kind on the earth" Genesis 9:16 (NIV, p.9). The relationship between color and remembering has been an integral part of the human experience from the beginning. In this post-diluvian quotation from the Bible, God himself uses color as an instrument for recalling certain aspects of His relationship with mankind. The authorship of this reference is attributed to Moses, which might make this connection between color and memory dating from about the 14th century BC possibly the earliest mention of this topic available (McClintock, p.776). Throughout the subsequent eons, mankind has expressed or developed multitudes of various meanings, preferences, and applications for color. It is in the modern era, however, that we have begun to develop both the methods and the means to conduct an analysis of this previously elusive subject. Yet, this endeavor is not as simple as it may appear on the surface. Evidence of the difficulty of the task may be seen by considering each of the elements of color and memory as a separate entity.

Philosophers, psychologists, and many others have speculated, postulated, and hypothesized about the nature and construction of human memory. Aristotle, in his considerations "On Memory and Reminiscence (ca.350b.c.), related to the complexity of the relationship between an image and the associated mental process by stating: "a picture painted on a panel is at once a picture and a likeness: that is, while one and the same, it is both of these, although the being of both is not the same, and one may contemplate it either as a picture, or as a likeness" (Green, p. 3). He attempts to clarify the dilemma by stating: "Acts of recollections, as they occur in experience, are due to the fact that one movement has by nature another that succeeds it in regular order" (Green, p.4). He uses both color and alphanumeric character sequences as examples of possible memory triggers or methods of the quantification of memory functions (Green, p. 5).

It appears that no matter who makes the attempt to either qualify or quantify the workings of the human mind, the conceptualization escapes us. It may be that until current and future technologies, such as Positron Emission Tomography (PET) and beyond, allow us to precisely map the geography and operations of the human brain, we may be reliant upon external examinations of the processes involved. One such external method is found in Gestalt Psychology which attempts to study entire patterns of mental process rather than isolating the phenomena into single operations or sensations in order to deal with the utter complexity of the task (Bram, p.203). Whatever the method or the outcome of these examinations may be, several questions are raised. We must ask first, what is real? Secondly, we ask what does color mean? Eventually we ask, are colors perceived in exactly the same way by two different persons? Ultimately, the answers to these questions may still remain in the realm of the subjective or speculative. It may be possible, however, to describe certain aspects of mental activity, such as retention of information, in a reasonably accurate format. This approach has historically been accomplished by the use of a variety of tests, including written examinations, to determine the degree that a person remembers or recalls information on both a short-term and a long-term basis.

The element of color itself has also been an elusive target to either quantify or qualify. A method for describing the virtually limitless variations of the elements of color in precise terms has been sought for centuries. Such a method would permit more accurate experimentation and replication of color across fields as well as more complete descriptions of exactly which elements of color were used. For a description of color production see Appendix A.

The Problem

One of the most difficult problems in past color research has been that of precisely describing the attributes of particular colors. The researcher of the past has not been able to control for the differences in the descriptions and in the reproduction of various hues, shades, saturation, and etc. when either conducting primary research or in replicating the research of others. It is possible that, with the development of digital technologies, researchers may, at last, be able to utilize this digital format as a standardization toward a higher level of assurance of their results. One of the areas that needs to be examined is whether or not certain specific colors, or wavelengths of light, affect the process of the retention of information by the human mind. If, as it appears from prior research, some direct relationship does exist and can be found, continued research should be conducted to determine exactly which colors have an effect on mental activity. Exploration should determine what particular areas of human thought are involved with color. Once the relationship is established then it should be determined just how to apply these findings in the development of educational materials.

This study attempts to use the additive primary colors of blue and green, as available on a computer monitor CRT screen and as produced within a digital format on PowerPoint 95® presentation software, to determine whether either of these colors has an effect on the short-term and long-term memory retention of a series of unrelated alphanumeric characters by a group of 6th and 7th grade students. Additional descriptions will be seen in the Methods and Procedures sections of this paper. A detailed description of the hardware, software, and color values and descriptions used in this study are included in the Appendix B.

The Importance of the Study

The importance of this study extends beyond the results of this experiment. With the development of digital color media, researchers may eventually be able to consider the efficacy of the use of color in the educational environment. If, for example, it could be scientifically determined that a particular saturation level or hue of a color would actually improve or inhibit the retention of certain types of information, it could revolutionize the actions we take in presentations and in the perception of educational materials. Past work in color as associated with memory, as seen in this paper, has concentrated on combinations of different elements of multimedia which involved color, motion, sound, and background, and have inferred a positive influence on the learning experience. However, they have not been specific as to which individual element had the most effect, and in which area. Few, if any, of these studies have examined any of these elements as a single entity to determine their relative effect. This study seeks to isolate the single, yet complex, element of color and to explore its effect on the single, yet complicated, aspect of memory retention in 6th and 7th grade students.

Definition of Terms

Additive color mixing describes what occurs when colors of light overlap and add to each other. Mixing the additive primary colors, red, green, and blue, produce white.

Brightness or value refers to the lightness or darkness of a color as measured by the amount of light that the sample reflects or transmits.

CRT is an abbreviation used to refer to a Cathode Ray Tube used in current televisions and computer monitors, although the pixels are aligned differently in each. See Appendix E.

Dithering is the process used by software (i.e. a web browser) to mix intermediate colors from its common palette of 256 colors. See Appendix D.

Gamma (a greatly simplified definition) is a measurement derived by a mathematical formula which describes the relationship between the voltage input and the brightness of the image on a monitor (CRT) screen. See Appendix F.

Hexadecimal is a counting system analogous to the decimal system, but it uses base 16 instead of base 10. See Appendix C for additional information including descriptions of colors used in this study as expressed in hexadecimal terms.

Hue is the common term for a particular color, such as red, green, or blue.

Saturation or chroma is the degree of pure color in the sample, measured by the amount or strength of redness, greenness, blueness, and etc.

Subtractive color mixing describes what occurs within the solid pigment media of paint and ink. Mixing the subtractive primary colors, cyan, magenta, and yellow produce black.

Assumptions

It was assumed that the subjects used in this study understood the instructions and complied to the requests made of them to the best of their abilities.

Limitations

The limitations of this study include several considerations that are discussed below.

The use of a pre-set gamma in this current study could be seen as a limitation for reasons of accuracy in color reproduction. This current research used a PC computer system which had a pre-set and unchangeable gamma as opposed to a gamma corrected Macintosh ® or Silicon Graphics® system. The use of a gamma estimate of 1.6 on the equipment used in this study could be seen by some as a limitation because of subtle shifts in reproduction of color and intensity. However, a gamma of 1.6 was deemed by this researcher to be within acceptable parameters for accurate color production and display and for use in this research. A gamma closer to 1.8 or 2.0 might be slightly better but, as previously stated, those elements were pre-set and were not changeable on the equipment used in this study. The use of the computer system utilized in this current study was selected by the principal of the school and the selection of equipment was not under the control of the researcher.

The relatively small size of the sample of subjects involved could be seen as a limitation toward conclusive results. Out of the 28 students enrolled, sometimes only 23 were able to participate due to illness and absence. Attendance was not under the control of the researcher.

Another limitation could be seen in the lack of a pure randomization of the sample. The school used in this study was selected by the researcher because of proximity and because of a previously established rapport with the school. Selection of this particular sample group was made by the principal of the school not the researcher. The size of the class was controlled by the standard enrollment policies in conjunction with the class size limitation policies of Tennessee. Those students of appropriate age were assigned to the class by the principal as they arrived to enroll with the school. The sample is therefore not seen to be representative of all 6th and 7th grade students. Broader generalizations of the results of this study warrant additional research.

Delimitations

The delimitations of this study, or aspects not considered in this research, are listed in the following sentences.

Color as either a cue or as a coding mechanism in memory retention or search tasking was not considered in this current study.

The attributes of color in the subtractive medium of paint, ink, or other pigment upon a dimensional surface such as paper were not considered in this current study.

The attributes of color as part of an illustration, diagram, chart, or graph were not considered in this current study..

The preference of the subjects to a particular color was not considered in this current study.

Issues of acuity, contrast, or legibility were not considered in this current study.

The emotional, arousal aspects, or cultural meanings of particular colors (such as the color described as pure red which has been shown to evoke an emotional arousal response) was not considered in this current study.

The harmony or dissonance between combinations of colors (such as black characters and either white, blue, or green backgrounds) was not considered in this current study.

Issues of adaptation including general adaptation (moving from a light room to a dark one or vice versa), local adaptation (afterimages), or lateral adaptation (two colors viewed simultaneously)(Pett and Wilson, p. 20) were not considered in this current study.

Issues of a learning curve where subjects may exhibit increased abilities upon repeated administration of similar trial methodology were not considered in this current study.

Aspects of color in combination with factors such as other colors, motion, sound, integrity with content and context of a complicated background or life-like photographic or graphic image in either still or motion format multiples of these factors were not considered in this current study.

The effect of color upon the attention level of the subject was not considered in this current study.

Color when used in combination with verbal or audible responses was not considered in this current study.

Color as it may relate to field dependence of subject was not considered in this current study as field dependence issues are terms exclusively used in the results of an administration of the Group Embedded Figures Test® (GEFT). Subjects in this current study were not administered the GEFT nor were these issues explored in this current study. (Pett and Wilson, p. 27).

Human memory aspects of learning, association, reproduction, or philosophical meaning were not considered in this current study..

The relative increase or decrease of information retention when combined with various additional reinforcements over longer periods of time (beyond one hour) was not considered in this current study. Reinforcements could be understood as reward, punishment, or even the repetition of a single methodology.

A consideration of time-on-task was not seen as contributory to this current study and so was not calculated.

On-screen afterimage and its potential for effect on memory retention was not considered a factor in this current study.

No consideration of the conscious or unconscious involvement of either episodic, semantic (Jensen, p. 204), or a combination of both elements by the subjects was made during this current study.

No measurement or consideration of hormonal differences between individuals or between males and females were made during this current study.

No record of the sleep patterns or home environment of subjects was kept for this current study.

Neither individual brain hemisphere dominance nor breathing rate was measured for subjects in this current study.

Null Hypotheses

1. Students who receive information through presentation software which uses pure black text upon a pure white background exhibit no statistically significant difference in memory retention when tested immediately (time 0) following treatment when compared with students tested one hour (time 1) following treatment at the .05 level of significance.
2. Students who receive information through presentation software which uses pure black text upon a pure blue background exhibit no statistically significant difference in memory retention when tested immediately (time 0) following treatment when compared with students tested one hour (time 1) following treatment at the .05 level of significance.
3. Students who receive information through presentation software which uses pure black text upon a pure green background exhibit no statistically significant difference in memory retention when tested immediately (time 0) following treatment when compared with students tested one hour (time 1) following treatment at the .05 level of significance.
4. Students who receive information through presentation software which uses pure black text upon a pure white background exhibit no statistically significant difference in memory retention when tested immediately (time 0) following treatment when compared with students receiving the same type of information

using a pure black text upon a pure blue background when tested immediately (time 0) at the .05 level of significance.

5. Students who receive information through presentation software which uses pure black text upon a pure white background exhibit no statistically significant difference in memory retention when tested one hour (time1) following treatment when compared with students receiving the same type of information using a pure black text upon a pure blue background when tested one hour (time 1) at the .05 level of significance.
6. Students who receive information through presentation software which uses pure black text upon a pure white background exhibit no statistically significant difference in memory retention when tested immediately (time 0) following treatment when compared with students receiving the same type of information using a pure black text upon a pure green background when tested immediately (time 0) at the .05 level of significance.
7. Students who receive information through presentation software which uses pure black text upon a pure white background exhibit no statistically significant difference in memory retention when tested one hour (time1) following treatment when compared with students receiving the same type of information using a pure black text upon a pure green background when tested one hour (time 1) at the .05 level of significance.

Chapter 2

REVIEW OF RELATED LITERATURE

Historical Overview of the Concept and Methodology

The first modern contributions to the scope and the methodology of this study come from a review of the work of Hermann Ebbinghaus conducted in a number of trials during the years 1879-1890 and 1883-1884 (Green, p. 1). In his monumental work Memory: A Contribution to Experimental Psychology, he offers certain valuable realizations as well as establishing some important precedents for continued research. It must be noted at the outset, however, that, even though his work was meticulous, well calculated, and extensive, it was conducted upon only a single subject, himself. This fact, though admitted by Ebbinghaus, precludes any broad generalizations of his findings, particularly toward any specific application of his results. The Ebbinghaus study may provide some general principles for methodology in conducting research.

The first of these principles is the realization that it may be possible, by "methods of natural sciences," to obtain exact measurements, i.e., numerically exact ones, of the "inner structure of causal relations," and so, it may be possible to describe human mental activities, such as, retention of memories in an acceptably accurate manner. As a proof, Ebbinghaus offers that either a reproduction of memory takes place or else it does not. He proposes this fact as evidence of the relative nullification of most causal differences. Ebbinghaus also adds the integration of the time factor into the research model.

This is seen as the differentiation between memory that is recalled immediately following a treatment (short-term memory) and those memories recalled after a period of time (long-term memory) in addition to the individual time intervals that are used within the treatments.

In his study, Ebbinghaus used immediacy following the treatment as a short-term reference, 24 hours after the treatment as a long-term determinate, and a time interval of between 12.7 and 15 seconds pause between each series. By using a rhythm of 150 beats per minute (a selected segmentation of time used in the verbalization of syllabic utterances) for reading the nonsense syllables contrived for his study, he determines that each syllable would take between 0.4 and 2.1 seconds to read and or recall.

Ebbinghaus used alphanumeric characters which were arranged into a series and which were constructed into nonsense compilations. He makes note that he also used numerals, but that he eventually abandoned them for that of alphabetic characters because of their greater combined variety.

Ebbinghaus related the observation made in the 19th century by Sir. William Hamilton of the difficulty of viewing "at most seven marbles without confusion" indicating a consideration of the practical limitations of human memory in recalling items in a series. Another important contribution supplied by Ebbinghaus in the ability of humans to recall a number of syllables in a series is made by establishing a point beyond which the rate of probable error increases when the subject is exposed to more than a single repetition of the series. At this point a single exposure results in zero probable error (Coopersmith, p. 161).

Ebbinghaus established, albeit upon himself, that with seven (7) syllables in a series, there was a zero probable error in recalling the series after a single repetition. He also showed that when using 12 syllables in a series that there was a probable error in recalling them correctly, after 16.6 repetitions, of $\pm$ 1.1. Ebbinghaus also demonstrated that the use of seven (7) multi-character syllables (3 characters in each syllable = 21 individual characters) in a single exposure resulted in zero probable error. It must also be observed that the Ebbinghaus study involved the additional variable of repetition which is not germane to this research.

It should additionally be noted that, while Ebbinghaus briefly mentions the aspect of color, he does so only as it refers to the contemplations on the subject as were postulated by Aristotle, and as such, were not included as elements within his own studies. In retrospect, perhaps, one of the most important realities that was addressed by Ebbinghaus was the expression of a two-fold difficulty in the application of the "Natural Science Method" to issues of human mental or "psychical" processes. They are:

1. "The constant flux and caprice of mental events do not admit to the establishment of stable experimental conditions"; and
2. "Psychical processes offer no real means for measurement or enumeration"(Green, p.7).

In studies conducted at the Harvard University Psychological Laboratories by Miller (1958) (cited in Coopersmith, p.163) used the combination of alphabetic characters and numerals in which subjects were shown randomized lists of alphanumeric series and then asked to write down what they could remember. The Miller trial, again, demonstrates the acceptance of this methodology, although their study also included repetition as an element and excluded any connection to color. The concept of alphanumeric character use in research is additionally supported by Underwood (1964) (cited in Coopersmith, p. 155) in an article on Forgetting in Scientific American, March, 1964. In this article Underwood refers to the use of lists of words or non-words arranged in series of three (3) characters in a sequence, where the subjects are asked to observe and then report upon what they remember as a "standard procedure" (for research). Underwood also suggests a variant of the procedure in which the non-words are paired with something else, such as the word (or color) yellow and wherein the subject views both the non-word and the paired variable. The subject then views the first (of the paired items), and is asked to recall the item paired with it.

The inclusion of color names is not seen to be an inclusion of color as an element in Underwood's considerations. He does however, offer an important insight into another matter of interest to this study. Underwood suggests that there are important factors that may "determine the ease or speed with which one learns a list of items" (cited in Coopersmith, p. 155). He stated that there are, at least, two decisive variables. First, how meaningful they are, and second, the degree of similarity or non-similarity between the items (cited in Coopersmith, p. 155). He reports that, while dissimilarity may make the task of remembering more difficult, "the rate of forgetting is no higher for items of low meaningfulness than it is for highly meaningful material" (cited in Coopersmith, p. 156). This reinforces support for using dissimilar alphanumeric characters arranged into material of low meaningfulness (nonsense).

Underwood offers additional insight by recalling a study conducted by Peterson and Peterson (cited in Coopersmith, p. 156) of Indiana University in which subjects were shown a three (3) character nonsense syllable for one second and then were asked to recall them at various short intervals up to 18 seconds. Memory for the items was shown to decline in direct proportion to the lapse of time and that after 18 seconds 90 per cent of the students were unable to recall the nonsense syllables correctly. It was established, however, that such rapid forgetting occurs only after the subjects had been tested on several (number not given) successive items (over several different series). Miller, (cited in Coopersmith, p. 163) also established that it is "just as easy to memorize a list containing a lot of information as one of the same length containing less information". This current research assumes that three (3) sets of three (3) character nonsense syllables will not trigger a rapid decline in memory retention.

In his textbook on Neuropsychological Assessment Lezak indicates that the use of nonsense syllables "have been a popular medium for studying memory since Ebbinghaus first reported in 1885 on their use to explore retention and forgetting" (Lezak, p. 350). Lezak also notes that an interval of 10 seconds for exposure followed by an immediate response is used for both the Binet and the Wechsler memory Scales as well as by the Benton Visual Retention Test (Benton, 1963; 1974) (Lezak, p. 368). Additionally, to support the methodology of measuring retention based upon a single exposure of nonsense syllables, Rock, (cited in Coopersmith, p. 146) discusses his work in the area of using nonsense syllables to study memory. In the same article Rock, (cited in Coopersmith, p. 146) mentions an experiment done on students by Springfield at the New York School for Social Research. Rock reports that in the trials by Springfield (cited in Coopersmith, p. 146) the researcher pretended to be lecturing on memory and, as an example of syllables utilized by Ebbinghaus, held up a card containing a pair of nonsense syllables. After different intervals of time, he conducted tests and concluded that "virtually all of them (the subjects) had learned the syllables upon the single exposure" even though he had not asked them to do so (Coopersmith, p. 146). Rock, (Coopersmith, pp. 143-146) tested his subjects by showing them eight random pairs of nonsense syllables but used an associated-pairing of the syllables to determine whether subjects reshown the first syllable could then recall the second paired syllable. Rock's subjects were given a single exposure by which to learn the syllables. He also conducted similar trials using syllables comprised of letters and numbers with identical results. The combination of the conclusions and observations of past researchers is seen to support the methodology of this research in its use of timed, single exposure, short series, nonsense syllables and of the measurement of the subjects memory retention over two periods of time to assess both short-term and long-term retention of those syllables.

Color - Physics and Methodology

See Appendix G for an examination of the aspect of color as considered within this research including a discussion of : 1) the physics and the physiology of color perception within the eye; 2) disorders that effect color perception in humans; 3) common tests to determine those disorders; 4) measures taken to note the presence or absence of those disorders in the subjects of this research; and 5) a general overview of color research, particularly as it may involve memory retention.

Color Research

An overview of recent research that relates to color, with particular emphasis on studies pertaining to color as associated with memory retention, follows. By far the largest and most extensively considered studies on color and its relationship to human learning recently conducted have been those by Dwyer and by Lamberski. Dwyer and associates conducted over 100 experimental studies from 1965-1981 involving approximately 48,000 subjects. The studies, which were conducted at the Pennsylvania State University, are, to date, "the most comprehensive and systematic attempt to identify those variables which are most effective in increasing students information acquisition relative to specific learning objectives", according to Dwyer (Dwyer, 1982, p. 23). Dwyer offers extensive information and conclusions on the use of color in educational materials.

However, since the Dwyer studies, though massive, deal only with color as either a cueing or coding mechanism when used in printed (subtractive) colored diagrams, and, since all of Dwyer's subjects took the same trial of this single model, it is doubtful that most of the results and conclusions could be applied to this current study beyond broad generalizations. Dwyer does not study the single aspect of color nor does he attempt to describe the colors used in his study in any detail or by using any recognizable standard of description. Dwyer discusses the difficulties and realities that face anyone dealing with conducting research and with looking at previous studies upon which to base such studies. Several suggestions that arise from the Dwyer studies include the following realizations.

1. "Because of the lack of broad and specific studies of individual factors within the field of the relationship to color and human mental processes, educators have no real way of knowing whether or if any particular type of visual presentation is more or less effective than another in transmitting information;
2. Because of the paucity of studies which concentrate on the specific values of specific colors when used in specific mediums little can be concluded as to their direct effect on any specific area of human mental processes such as in that of retention;
3. Even though evidence shows that color plays an important role in memory retention when used as either a cue or as a coding device, more study is needed to determine whether individual colors or wavelengths of light themselves have any direct relationship to memory retention" (Dwyer, 1982, p. 24).

Dwyer's studies showed a clear advantage in retention to color coding (i.e. using colors to show blood flow in a diagram of the heart) of printed materials when compared to the same materials when presented in black and white (Dwyer and Moore, 1992, p. 195), and (Dwyer and Moore, 1995, p. 176).

Again, Dwyer points out that "the results . . . provide substantial evidence that colors, in fact, are a viable instructional variable," but he does not attempt to explore the subject beyond coding, cueing, and cognitive style (Dwyer and Moore, 1992, p. 195). Neither is an effort made by Dwyer to isolate particular colors as to their effect nor to determine the value of any individual color on this regard. It should be noted that 8,000 of the subjects in the Dwyer research were high school students who were from the ninth through the twelfth grades and could be seen as complimentary to studies on color and memory conducted on students below college age. Another individual who has recently studied the relationship between color and remembering is Pruisner. In these studies, conducted in 1993 (Pruisner, 1993, p. 1), and 1995 (Pruisner, 1995, p. 1), Pruisner examined the role of color as a coding mechanism in graphic (printed) materials as it might effect the recall of verbal material. Again, the obvious shortfall in contributions to a study in color and memory are as follows.

1. The use of color as a coding mechanism rather than as a single variable;
2. The use of color in a subtractive medium (printed form) rather than in an additive medium (CRT display); and
3. The use of color as an element that was a representative of realism in pictures relating to a Norse myth rather than a consideration of color as a single entity.

Also to be considered is, that in Pruisner's (Pruisner, 1993, p. 1), 1993 studies in remembering graphic information as in the recall of verbal material, certain elements such as: a) the use of systematic color coding in graphic presentations and b) the use of systematic color coding in the combination of color presentation and color assessment, were shown to be of a positive effect (Pruisner, 1993, p. 1), while "the 1995 study shows that the use of color did not have an effect on the recall and retention of verbal information" (Pruisner, 1995, p.1). These discrepancies present a conflicting view at best. Some contributions that Pruisner might be able to add, beyond generalized concepts and the suggested value of continued research, are in the sample of subjects studied. Pruisner used groups of 30 seventh grade students for the trials, and this would add to the justification of subject size and age for this research.

Additional support for subject age and methodology could be seen in a study done by Lo Bello where students from second to sixth grades were shown projected slides with nonsense syllables printed in back type using different colored backgrounds for a time interval of seven seconds per slide. The test was conducted with subjects who were dyslexic. Lo Bello found two important considerations. First, he indicated that he had found in his examination of the effects of colored backgrounds on the ability to pronounce pseudo-words that pronunciation was not effected by background color (Lo Bello et. al., p. 16). Secondly, he suggested that a "better strategy would be to use a computer program that can vary background color on a screen" (such as PowerPoint ®) (Lo Bello et. al., p. 19).

It should be noted that while the Lo Bello research showed that "background color is not significantly related to phonological processing ability," it did not consider, aspects of color as it may relate to memory retention (Lo Bello et. al., p. 19). Lo Bello also mentioned the relative cost effectiveness of conducting such studies using computer programs when compared with other media (Lo Bello et. al., p. 20).

In a study evaluating the differences in effect between alphanumeric, graphic, and color presentations on CRT displays, Tullis states that "the effects of graphics and color on human performance is highly dependent upon the complexity of the particular task" (Tullis, p. 542). It must be noted, however, that Tullis did not consider color as a single variable but only as broad element of the presentation type, i.e. if colored graphs were different in effect than the same information displayed using a text only format. Also to be considered is that the Tullis study was conducted prior to the mass acceptance of the increasingly popular Windows® graphic format in the interface (GUI - Graphic User Interface). Tullis was again using color only in a coding context and made no consideration for color contrast or conflict, readability, or user preference. This can be evidenced by some of the comments of his subjects who indicate, in their own words, "states of confusion, distraction, hardness on the eyes, and difficulty to read because of color" (Tullis, p. 548). These comments not only indicate his use of conflicting colors but also the importance of the need for continuing research in the discriminate use of color in presentations upon CRT display screens.

Another study that may contribute to this review was conducted by Pett (Pett and Wilson, p. 20). Their study was a meta-analysis of previous research and is an excellent source of insights on subjects related to color and learning. Additional conclusions from other studies that may relate to this review are included in the following list.

1. "The color of objects appears to be constant regardless of the energy distribution of the light source" (i.e. incandescent, fluorescent, natural, or mixed) (Pett and Wilson, p. 20).

2. The capacity of certain colors to physiologically arouse persons needs to be considered in research. According to Pett (Pett and Wilson, p. 21) it was found that the color red has been shown to produce higher anxiety rates and that it increases heart rate when compared to blue or green.

3. In many of the previous studies conducted on colors, the colors used have not been adequately specified, with the exception of those who have used precise Munsell color designations. (Pett and Wilson, p. 23). Again, this demonstrates the need for the use of a designation system for color description that is both precise and acceptable for replication such as the two (2) digit hexadecimal code. Note must be made that these previous studies utilized color as derived from the subtractive medium, such as in printed material, and that studies such as those mentioned by Pett and Wilson (Pett and Wilson, p. 31), which considered color as a reference on a CRT display, should, therefore, be continued.

4. Based on several studies, there appears to be a relationship between color used and memory retention but that the specific elements and their relationships need further study (Pett and Wilson, p. 26,27).

5. When used on CRT display there is apparently no strong relationship between the color used and the time interval used in the examination. The most

> important influence on preference appears to be that of saturation (low saturation of color is preferred). It also appears that black, for text color, provides the best contrast with most background colors (Pett and Wilson, p. 28, 29).

When reviewing the related research on the relationship of color to human learning, a threshold of practicality eventually arises because of the hundreds of studies conducted on the many variables and aspects of those subjects, whether combined or separate. It becomes impractical to examine completely every one of the hundreds of color related studies. A more efficient approach seems to be the examination of some of the larger overviews of the subject which were conducted over longer periods of time than those allowed for in this paper. Lamberski is, perhaps, second only to Dwyer and associates in contributing to the field of color research. Lamberski is noted both for his experimental research on color and for his extensive review of previous related research. Lamberski agrees with Dwyer on the basic problem of sorting out, from the myriad of studies, just how color research may effect the educational environment. Dwyer says, in his extensive review of research, "there is very little experimental evidence available as to how the addition of color to various types of visual illustrations will affect students achievement . . . and . . . guidelines for the use of color should be established as quickly as possible" (cited in Lamberski, 1975, p. 3). It should be noted that while this current study will not resolve the debate on the subject, it anticipates a contribution to the mounting body of evidence for the importance of the use of color in instructional media.

Most of Lamberski's work on color centered around color vs. black and white as a coding mechanism. An overview of his research provides an inconsistent conclusion as to the relationship of color coding to different elements in human learning, inferring that additional research is needed. In his eight year review of several hundred references on color research, Lamberski cites several others who themselves conducted reviews of related research. Lamberski's reviews, then, could be considered as a meta-review and, as such, he offers some important conclusions and observations. Perhaps the most relevant connections to this review are in the following list.

1. In spite of vast amounts of research, only a few generalizations about the specific role of color in the learning process can be made (such as color as a coding mechanism appears to enhance retention, and that some colors appear to increase aspects as legibility and contrast) (Lamberski, 1980, p.9).
2. Conclusions are difficult to correlate because of limitations in experimental design (Lamberski, 1980, p.9) (which include non-standardization of color descriptions).
3. "Color may have a direct, but difficult to determine, relationship between color and retention or recall in certain types of presentations" (such as when used as a coding mechanism in diagrams and charts which are presented using subtractive media) (Lamberski, 1980, p.10, 12).
4. Once encoded, color may "inhibit forgetting and facilitate delayed retention" (long-term memory) but, that "further investigations are necessary to substantiate, this proposition" (Lamberski, 1980, p.16).
5. "The questions of the value of color on retrieval tasks appears to have no simple answer" (Lamberski, 1980, p.21).
6. "The relationship of color to time remains unclear but, appears to be related to the perceptual task, code strategy, and required response" (Lamberski, 1980, p. 29).

In completion of this current review of related literature concerning research on the relationship of color to human memory learning and retention, it should be obvious that the conclusions are inconsistent across the field. There is also an admitted need by those in the field for further research and more precise methodologies (such as the use of CRT screens and hexadecimal descriptions for colors).

It should also be added that some type of learning machine has been utilized by humans throughout modern history. These machines and concepts include the ancient abacus, the punch cards of Jacquard, the considerations of the use of binary codes in memory research made by Miller, in 1956, the use of teaching machines by B. F. Skinner in 1961. The use of the advanced computer systems of today extend the need to understand the most effective ways to use and develop instructional materials for their application. This need for understanding the elements of human technology and education has remained constant.

Introduction to Current Memory Research

The related research material discussed in this paper has been included to provide, in general, an historical perspective for the understanding of classical research on both color and memory as it may relate to this current study. The reader should understand that memory research continues with the application of more technical methodologies than previously used. Advanced technologies should provide future researchers with a more thorough and explicit understanding of the relationship between external stimuli of the various senses and the operations of the human brain.

Overview of Current Brain-Memory Research

In an overview of current brain-memory research methodologies it appears that much of the observation of brain-based activity is being conducted on two main fronts. The first is in that of Psychology which often uses a behaviorist model of studying internal function by the observation of external stimuli and response. The second area of concentration is in the Biological or Physiological examination of the internal mechanics and mechanisms of the brain to deduce some measure of operation. The bulk of biological function research is currently being done through the use of the two main technologies of more sensitive Electroencephalography (EEG) and of Positron Emission Tomography scans (PET). EEG studies involve the examination of the electrical activity of the brain as registered through highly sensitive electrical leads attached to the scalp (McConnohie, interview, June, 1999). PET scans follow certain injected chemical tracers through the human brain during certain activities in order to image specific locations for brain activity (Jensen p.16).

Recently, PET scans have produced the greatest impact in understanding how the human brain functions. By tracing the flow of glucose mixed with an ionized tracer such as O^{15} as it travels through the brain during certain activities brain activity can be localized to a resolution of approximately 1 to 2cm (Luger, et.al., p.176). PET scans have greatly enhanced our understanding of the exact areas of the brain that are involved with particular activities and with diagnosing certain brain dysfunctions. One of the areas that is being explored is that of the parts of the brain involved with memory. It has been found that memory is more holistic (Jensen, p. 38) and involves more areas of the brain than previously thought. Human memory is linked to emotions in the amigdala, while formation and storage of memory involves the hippocampus. At the same time the thalamus and the hypothalamus regulate our emotions while the limbic portions give us a sense of reality to our experiences (Jensen, p. 28-29). The hippocanthus area of the brain is related to the most recent discoveries in memory research.

It is currently believed that the process of creating lasting memories begins when the neuron's endings, or dendrites, receive the initial signals of a particular stimulus. Those signals induce reactions involving protein kinase A, which in turn set off the cyclic amp-response element binding protein (CREB) activator in the nucleus. The CREB protein then activates genes in the cell's DNA. The genes are then converted into messenger RNA which is then used as a blueprint to produce proteins that secure a memory. This process takes place upon receiving a stimulus and apparently takes about an hour to recycle. The recycling is associated with long-term potentiation (LTP) in the establishment of long-term memories. LTP is the tendency of an activated synapse to lower its threshold. Lowering the threshold of the synapse makes it more likely to transmit a signal in the future and so effectively strengthens the connection (Creb and memory, 1997). Additional recent neuroimaging technologies that are being used in brain research and subsequently in memory research use magnetic fields and measurements of the electrical activity of the brain.

Electrical activity of the brain is most often measured using the venerable yet often more cost productive electroencephalogram (EEG). "The newer, more sensitive, computer enhanced EEG machines are still the mainstay in basic brain diagnosis and research for reasons of cost, relative ease of use, speed, availability, and lack of potential side-effects to the subject" (McConnohie, interview, June, 1999). The primary drawback of the EEG is its imprecision in detecting smaller locations of activity and direct relationships between brain areas when compared to more recent technologies. One technology that is gaining popularity in research is Magnetoencephalography (MEG) which detects the magnetic fields within certain populations of neurons in the brain. Since these magnetic fields are not diffused by either the skull or scalp greater resolution and detection of subcortical events can be obtained (Luger, p. 176).

Another new technology based on nuclear magnetic resonance is Functional Magnetic Resonance Imaging (F-MRI). F-MRI can detect changes in blood chemistry associated with the activation of brain regions and can compare those with images of resting states to analyze brain functions (Luger, et.al. p. 176).

Current Considerations in Memory Research and Theory

According to Luger and Johnson (Luger, et. al. p. 80) the technologies previously mentioned in this paper, as well as behaviorist models of research, are currently being used to develop understandings and applications for Cognitive Science. Luger discusses a brief history of recent methodologies used in memory studies from Tulving and Donaldson (cited in Luger, et.al. p. 77), who distinguished between episodic and semantic memories, to the most recent schema based approaches. The schema based view sees memory as being interconnected rather than compartmentalized in nature.

A schema based approach to memory research might also include such considerations as the current chaos model for seeking to describe complex processes. Comprehending the fractal nature of human mental activity in describable terms is not new, however. Aristotle struggled with the constant flux of mental caprice centuries ago. It is doubtful that even he could have guessed the degree of complexity involved in the world as we know it or that there is an apparent higher level of order within the seeming chaos. A schema based view could perhaps see that life exists in "a universe where order is found in patterns and processes of such scale and complexity that prediction and control are difficult or impossible" (Euster 1994) at current levels of technology and understanding. However, the researcher must not throw all hope to the wind for, in research, as in life, "there are those forces, strange attractors, that limit chaos, and patterns of order are apparent around these central tendencies" (Euster 1994).

Bringing a sense of order out of seeming chaos is, of course, the function of randomization, sampling of populations, minimizing variables, and other factors in the methodology of research. It could also be observed that any endeavor, particularly one involving more than a single subject, must fit both the deliberative and chaotic models or else they become stagnant. An example is found in the curriculum and the classroom. Both seek to establish a sense of order and structure but, are able to adapt to the differences in individuals and cultural applications over time and so exhibit fractal qualities (Goff, 1998). No research, even on a single human subject, such as Ebbinghaus, can eliminate all variables outside the study. Such work must rely on the precedents of scientific method, randomization, and proper sample size to approximate a conclusion in any research.

Another attempt to grasp the larger chaotic elements of understanding and research was expressed by the Gestalt approach as alluded to earlier in this paper. The Gestalt approach to memory study dictates that "the whole is qualitatively different from the sum of its parts" (Rock, p. 11). The Gestalt approach was not able to fully explain the stimulus perspective of human perception any more than the empiricist approach did and was eventually supplanted by those researchers working in the psychophysical tradition (Rock, p. 12). By the 1940's the psychophysical tradition lost its appeal and was replaced by a newer discipline of the information processing perspective of perception called Cognitive Psychology. Clearly, the complexity of human mental function mandates that hypotheses of research must continue to evolve until we reach an "adequate unified theory of all the phenomena of perception" (Rock, p. 12). In short, Rock says "while we cannot observe people's perceptions per se, we can confirm or disconfirm their generality and infer whether or not they actually occur" (Rock, p. 14) .

To illustrate how complex the study of the brain is and how little is actually understood about human mental potential, Jensen (Jensen, p. 37) cites a study conducted by Lorber (cited in Jensen, p. 37) who "found 150 adults with virtually no nerocortex (5% or less because of hydrocephalic disease). They had normal basal and limbic structures, but the neocortex area was 80% water . . . these 'brainless' people had IQs ranging up to 120. Many had advanced degrees, got along well with others, and had normal lives." (Jensen, p. 37).

Another example of the remarkable ability of the human brain is found in studies done by Sperling (Houston, p. 249) in iconic memory, where his subjects were shown a slide of 3 rows of letters with 4 letters in each row. The slide was flashed for 1/20th of a second and subjects were asked to recall what they had seen. Without special instructions they were able to report no more than 4 or 5 without error. The second phase of the experiment involved an audible tone that was produced immediately after viewing a second series of letters for 1/20th of a second. A higher pitched tone indicated that they should recall the top row of letters; a mid-range tone for the middle row; or a low tone for the bottom row. Sperling (cited by Houston, p. 249) reported that by using a tone subjects were able to recall any row with 100% accuracy.

While there are many names that are used describe and classify memory (e.g., short-term, long-term, positive and negative, surface and repressed, active and passive) the more recent descriptors are episodic and semantic or taxon memory. Episodic memory is contextual and is stored in relationship with a particular geographic location or circumstance. Semantic memory is thought to be based in content such as information found in a book, list, or a computer (Jensen, p. 204).

"Prior to the 1960s the two-factor theory of interference dominated the field of forgetting and retention" (Huston, p. 242). There are now many models of memory with more emerging frequently. While the Separate-Store Model developed during the 1960s and the Levels-of-Processing Model appeared in the 1970s, the Semantic-Network and Cognitive Science approach are currently in vogue. Terminology that runs across these various models and yet is not exclusive to any of them involves three known components of memory. The three components that describe our present understanding of memory are: encoding, storage, and retrieval. Murdock (1974) (cited in Houston, p. 242) defines encoding as "the process by which the nervous system develops a representation of an external stimuli" (Houston, p. 242). He goes on to define storage as "the persistence of encoded material over time" (Huston, p. 242) and retrieval as "the utilization of this stored material" (Houston, p. 242).

In relation to the Separate-Store Memory Model Houston (Houston, p. 244) states that, in terms of primary (short-term) and secondary (long-term) memory, "a string of dozens of digits (or letters) would be difficult to store in primary (working) memory but that most people can handle 5, 6, 7, 8, or 9 items without too much difficulty" (Houston,

p. 244). Houston (Houston, p. 67) also suggests that performance tends to increase with practice but, may relate to different types of learning tasks (e.g., word-list recall, classical conditioning, instrumental conditioning, discrimination learning, serial learning, paired-associate learning, free recall, priming in lexical decisions, concept formation, and problem solving) (Houston, p. 22).

According to current brain research certain long held methodologies of learning are counter-productive to the educational environment when considered against the holistic nature of the individual. Learning appears to take place best when approached using a pulse-style rather than a concentrated effort over a longer time span. Jensen (Jensen, p. 48) states that "learning is best when focused, then diffused, focused, then diffused. Constant focused learning becomes increasingly wasted over time. In fact, Jensen continues, the whole notion of 'time on task' is biologically wrong and educationally irrelevant" (Jensen, p. 48).

Another element in perception-memory research not previously discussed in this paper is that of afterimaging, both on the CRT and in the human body. Rock (1997) (Rock, p. 99) used the colors magenta and white as projected on a CRT for his studies. Geometric figures were produced with an interstimulus interval of 397ms for three-component figures and 251ms for four-component figures with an on-screen time of 67ms (Rock, p. 88). Since the residual energy level of the screen phosphors returned to the baseline black monitor background within 4ms, afterimages were considered not to be present (Rock, p. 104). Howard indicates that (Howard, p. 20) in some cases a mental afterimage was held in store after the stimulus had gone off. The mental afterimage of the 12 characters shown in the studies by Rock lasted long enough for the subjects to mentally scan each letter some 10 ms.

According to Jensen (Jensen, p. 42) there are a number of external and biological factors that effect human memory. Some of these factors include time of day, age, biological rhythms, and gender. Englund (cited in Jensen, p. 42) found that overall intellectual performance is greatest in the afternoon and that comprehension increases while reading speed decreases as the day progresses. Jensen (Jensen, p. 42) indicates that in general, short-term memory is best in morning and long-term memory is best in afternoon. Brewer and Campbell (cited in Jensen, p. 45) found the brain to be 15% more efficient for short-term memory from 9 - 11 AM while semantic cerebral process is generally more efficient in the afternoon and that a 2 to 4 hour variance between individuals can be expected. May (cited in Jensen, p. 46) found that young adults do better on memory recall in the afternoon while older people performed better in the mornings. Jensen (Jensen, p. 46) infers that no matter what time of day a topic is presented it is likely to be out of sync with about one-third of the learners but that more meaningful information is generally grasped better in the afternoon.

Jensen (Jensen, p. 42) indicates that natural human biological rhythms are also linked to brain function and memory. An interesting example of a biological rhythm associated with brain function is seen in cycles of breathing. According to Jensen (Jensen, p. 42) humans breathe through one nostril for three hours and then the body alternates to the other nostril affecting which hemisphere of the brain is used. Klein and Armitage (cited in Jensen, p. 43) found alternating periods of efficiency for brain hemispheres and that when spatial activity is high verbal activity is lower.

One additional consideration of biological influences on human memory and learning that may have some relevance is that of gender. Researchers say that the female brain is very different from the male brain with regards to function and perception (Jensen, p. 88). They indicate that females excel at verbal memory and process language earlier, faster, and more accurately (Jensen, p. 88). In addition, females are more sensitive to the red end of the spectrum, excel at visual memory and context, and can store more random and irrelevant visual information than males (Jensen, p. 89). Jensen indicates that studies have found that female learning and performance levels changed throughout the female cycle, varying with estrogen levels (Jensen, p. 49). In the study on hormonal influences on the brain it was found that estrogen, which promotes brain alertness, more active brain cells, and increases sensory awareness is found alone in the first 14 day half of the female cycle. During the second 14 day half of the cycle progesterone, which reduces cerebral blood flow, oxygen and glucose consumption, and which produces sluggish, unmotivated behavior, is introduced into the system (Jensen, p. 49). Concurrently, Jensen indicates that other studies found that, in males, when testosterone levels are lower spatial ability is higher and that male temperature cycles also affect attention and learning (Jensen, p. 50). Jensen (Jensen, p. 50) also mentions sleep and rest as influencing human brain function. He infers that "students from abusive families, overcrowded homes, or affected by divorce, death of a loved one, violence or poor nutrition are impacted" (Jensen, p. 50). Research in France (Jensen, P. 51) shows that a loss of even two hours of sleep may impair recall ability the next day.

Lastly, Jensen (Jensen, p. 55) states that "our brain responds faster to wavelengths of color, lightness and darkness, motion, form, and depth" (Jensen, p. 55). Jensen continues by suggesting that over 90% of all information that comes to our brain is visual and involves the spectrum of light which is seen in a range of between about 400 through 700 nanometers in length (Jensen, p. 55). Jensen also says that "we may want to be taking much better advantage of this capacity" (Jensen, p. 55).

Chapter 3

METHODS AND PROCEEDURES

Design of the Study

This study utilizes a traditionalist positivist paradigm. It operates under a modernist ontological assumption with a quasi-experimental, within-subject, passive design. It also uses a quantitative design in the collection and computation of data. For an amplified explanation of this terminology see Appendix J. Subjects in this current study were exposed to the stimuli of alphanumeric characters upon various colored backgrounds. Subjects were expected to mentally encode that stimuli using no external memory support systems (i.e. notes, sharing with other subjects, etc.) (Scruggs & Mast., p. 97) and then to retrieve the encoded stimuli immediately following each exposure and again after one hour. This action was used to determine the effect of various colors on the encoding-retrieval process over time (i.e. short-term and long-term memory). Analysis was conducted on the data gathered and results are reported in this paper.

This study utilizes the PowerPoint 95® presentation software for Windows 95® developed for the PC system. PowerPoint 95®, while not being the most technical in capabilities or descriptive properties, is relatively easy to use, widely accepted as a presentation medium, relatively inexpensive, accurate in color variation, productions, and descriptive qualities. PowerPoint® is also available for use on either PC or Macintosh® computer systems. All of this is both relevant to this current study and to those who might seek to replicate it.

One last consideration that must be made within this current study is the estimation of the gamma values of the monitor used within this and future research. Gamma is a measurement attained by a mathematical formula that reflects a relationship between electrical voltage input and the brightness of the image on a CRT monitor screen. Gamma values are important in order to accurately produce colors on a CRT screen and should be a consideration in all studies involving the use of CRT screens. Gamma values can be estimated by viewing a gamma estimate scale as seen on a particular monitor. See Appendix H for information regarding the scale used for this current study. In conclusion, there seems to be a need for more studies in the field of color as it relates to human memory retention. There also appears to be sufficient justification in the related literature for additional study and for the methods and procedures used within this current research project.

Subjects

Subjects include 28 students (eight boys and twenty girls) who were enrolled at a public school in Tennessee. Their ages varied from approximately 11 to 14 years. Students were placed into this classroom according to county, state, and school admission guidelines which allow for placement as enrolled on a first come basis. The number of students in the study was determined by random placement according to enrollment for the 1998-99 school year. The county in which the school is located has no current requirements or forms for approval of requests to do research in that county. This decision is left to the discretion of the individual principal to accept requests for research of this type. The principal approved the proposal for study and was responsible for selecting the class that would participate in the trial. The students were enrolled into regular programs and placed into a single, self-contained, 21st Century classroom. Subjects were comprised of students enrolled into a combined class of 6th and 7th grade students. The students were from moderately low to low income homes which are located in a rural, mountainous area of Appalachia.

Environment of Study

The school is located in a rural Appalachian community in eastern Tennessee. There was no carpeting on the floor of the classroom used in this study, and the flooring had a semi-gloss hard surface. The room was painted in neutral shades of off-white to gray and was lit by a combination of sunlight and fluorescent overhead lighting. The sunlight that was somewhat filtered by venetian blinds which were open approximately 60 percent. The fluorescent lighting was suspended from the ceiling to an approximate distance of ten feet above the work area. There were no bulbs unlit or missing in the double-tube plastic lens covered fixtures which were four feet in length. There were eight fluorescent fixtures, and they contained white or off-white bulbs.

The combination of sunlight and fluorescent lighting produced an acceptably neutral light source for observing color, particularly those produced by a CRT computer monitor. The PC platform computer and monitor used for this study was located in the west end of the room, facing the windows and within eight feet of the teacher's desk.

Because the subjects were placed facing the screen, with their backs to the windows, there was no detectable glare on the monitor screen as their bodies provided an adequate block against glare. The CRT screen continued to be lit with ambient light from the two independent sources. The display face of the computer monitor CRT screen was not in clear direct sight of those in the class who were not actively involved in the small sub-groups who participated in viewing the slides, in turn. Treatments were given between 11:00 A.M. and 3:00 P.M. during the regular school day.

Selection and Screening of Subjects

The selection of these subjects was not under the control of this researcher but may not represent a true randomization of sample or of a population. Subjects were screened prior to the study for color-blindness using a modified Ishahara Test. The Color Vision Guide®, as designed by Dr. Keith Nash and as accepted by the National Science Teachers Association, was administered to each subject individually to determine the presence of conditions of color blindness that would prevent any of the subjects from perceiving the colors used in this study. It was expected that, because of the high ratio of girls to boys in the sample, that there would be a low probability of color blindness within the sample. Any subjects that tested positive for color blindness were to participate in the study but would be excluded from the results. There were no instances of color blindness detected within the sample.

Time Interval Investigation

A pilot test was conducted to determine an acceptable time frame for each exposure of each slide to be used in the larger study. The pilot test was similar in construction to the methodology of the larger study but was conducted using white sheets of paper with black lettering rather than a CRT medium. In the pilot study 12 students of ages which were comparable to those subjects involved in the main study were selected at random from a different class. Subjects were shown three sets of paper cards with black characters on white backgrounds similar to the treatments in the main study. Subjects were shown one set of three cards at a time with a 10 minute delay between sets . A different time interval was used for each separate set of cards. The students were initially given twenty seconds per card to remember the characters and were asked to write down as quickly as possible, following viewing, what they recalled, in the order seen (i.e. the order on each card and in each set). This process was administered two more times with time intervals of ten seconds and five seconds accordingly. The answer sheets were collected and individually checked by the researcher for errors. The results indicated that twenty seconds was too long, allowing for almost complete recall of characters. It was also seen that an interval of five seconds per card was not sufficient for retention of the characters, with the most misses being observed. It was determined by the pilot study that a ten second time interval for viewing each card was adequate for measuring retention of the characters and for use on slides presented in the main study.

Preparation of Materials Used in Treatments

The slides used in this current study were produced on a PC computer system that was not the computer used for the treatments in this study. The use of different hardware to prepare the slides does not compromise this current study because of the nature of the presentation software used. PowerPoint 95® was selected for this current study for its accuracy in color production, ease of operation, wide range of colors, and for its ability to be installed via the "Pack and Go" feature onto any computer system that uses a Windows 95® operating system. The "Pack and Go" feature operates accurately regardless of whether or not the full version of PowerPoint® has been installed on that particular system. The slides used for this current study were prepared. The "Pack and Go" function was then utilized to save the both the presentation as well as the Presentation Viewer that would be needed to run and view the presentation onto 3.5 inch high density floppy discs. The presentation was taken to the school used for this current study and, with the permission of the principal and teacher, installed into a separate folder onto the hard drive of the computer that was utilized for the study. Color values for the slides were determined prior to installation by using the custom color functions within PowerPoint 95® and were checked for hexadecimal code description via an Internet website designed for that purpose. See Appendix I for location of a tool for describing color in hexadecimal terms. This researcher sees the use of three (3) slides with three (3) characters each (for a total of nine single characters for the series in each color variable) and for a single exposure for each color/character set as having an acceptable margin of probable error for this study. Cost and practicality were contributing factors that were considered in the selection of materials used for this current research both for the initial study and on behalf of those who might later replicate it.

<u>Treatment Used in the Study</u>

In the main study, the subjects were shown three sets of slides on three separate occasions. Subjects, who had been enrolled in the class as described, were chosen by the teacher to participate in each treatment and were assigned into five groups of no more than six subjects. Subjects were asked to position themselves from one to six feet from the computer monitor CRT screen so that there were no obstructions to clear vision. They were asked not to talk to others, not to share answers, and to listen to brief instructions concerning the treatment. In the instructions, the subjects were told that they would be shown three slides, that they would have ample time to memorize the information, and that they would be asked to write down what they remembered immediately following viewing. Writing instruments (Bic® pens) were in the control of the researcher until answers were to be given (to prevent writing answers during treatment and changing answers following initial reporting of items recalled). Answer sheets and pens were distributed immediately following treatment and were collected by the researcher when completed. Subjects were in close proximity to the researcher and were observed for compliance.

In treatment number one, the set of slides consisted of pure black, 200 point Lucida Sans Unicode/TrueType® alphanumeric characters upon a pure white background. Subjects were shown each of three slides for ten seconds. See Appendix L for example of font style, type size, and character selection. The time intervals of the slide presentation were not under the subject's control but was an automatic function of the presentation software and was determined and pre-set to ten seconds per slide by the researcher. To evaluate short-term retention of the information, subjects were asked, immediately after viewing the slides, to write down only what they remembered in the order and sequence of their appearance on each slide and series of slides. Answers were written on a prepared sheet of paper, on which was drawn a cube, which was divided into nine equal blocks arranged in three rows of three. Subjects were told that there were no passing or failing scores and no right or wrong answers (to diminish test anxiety i.e. there will be no negative effects for not remembering). Results were counted by determining the characters listed correctly both in order and sequence. To evaluate long-term retention, a second post-test was administered one hour after viewing the slides with the same instructions and a different sheet of paper, prepared and administered in a similar fashion. Writing instruments (pens) were distributed and controlled by the researcher and care was taken that answers were not shared between subjects by the use of blank cover sheets (which were checked at random for markings that might assist them in their answers).

The second treatment was administered at least one week following treatment one. Treatment two was comprised of a set of slides that utilized pure black alphanumeric characters of the same specifications as in treatment one on a pure blue background with each of the three slides being viewed for ten seconds as in treatment one. Testing for short-term and long-term retention was conducted as in treatment one.

The third treatment was administered one week following treatment two. The third treatment was comprised of a set of slides that used pure black alphanumeric characters of the same specifications as in treatment one upon a pure green background with each of the three slides being viewed for ten seconds as in treatment one. Testing for short-term and long-term retention was conducted as in treatment one.

Chapter 4

RESULTS

Statistical Analysis

Answer sheets were collected by the researcher following each test and remained under the control of the researcher for computation of the results. Answer sheets were examined by using a master list of the characters to check the order and sequence for each slide and set of slides. Correct answers were noted for both order on each slide and sequence for each set of slides in each of the three color groups. Characters that were out of order or out of sequence were scored as incorrect. Answers that were either in order but out of sequence or vice versa were not considered for the study. Correct answers were noted and entered into SPSS® for analysis. A mean score was determined from the scores and paired samples comparison t-tests were conducted on the means of the raw scores. All scores and results were double checked by the researcher and an independent source, (Cerrito).

Analysis of Data

There were three different trials labeled 1, 2, and 3 representing different color schemes. Trial 1 utilized a white background; trial 2 utilized a blue background; and trial 3 utilized a green background. All three trials utilized black as the color for the alphanumeric characters. There were two time values representing 0 time (immediately following treatment) and 1 hour following treatment. Each trial had a possibility of nine

(9) correct responses for each time reference (time 0/time 1). Each subject was scored using the number of correct (order and sequence) responses. All responses for all three trials and for both time references in each trial were entered into a MS Excel® spreadsheet for use in the SPSS® statistical software. In addition, there were 28 total subjects although not all subjects took all trials. 25 subjects took all three trials. One subject did not take trial 3 due to absence from the class. Three subjects were new students and so were absent for trials 1 and 2 but did participate in trial 3. The data were analyzed using t-tests and the results are discussed in the following paragraphs and tables.

Consideration of Hypotheses

Hypothesis one is retained as the results show no statistically significant difference at the .05 level of significance in memory retention between time 0 and time 1 when using black text upon a white background (trial 1). 26 subjects took this trial and had a mean difference between scores from time 0 to time 1 of (.4615) which resulted in a significance of (.143) which is not statistically significant at the .05 level. See Table 1.

TABLE 1

TABLE OF COMPARISON BETWEEN TIME 0 AND TIME 1
WHEN UTILIZING A WHITE BACKGROUND (TRIAL 1)

Groups	N	Mean	Mean Difference	Std. Error of Means	t-ratio	Sig. 2-tailed
White T/0	26	7.6923				
			.4615	.3050	1.513	.143*
White T/1	26	7.2308				

*Not Significant

Hypothesis two is rejected as the results demonstrate a statistically significant difference at the .05 level of significance in memory retention between time 0 and time 1 when using black text upon a blue background (trial 2). 26 subjects took this trial and had a mean difference between scores from time 0 to time 1 of (.9615) which resulted in a significance of (.034) which is a statistically significant loss of memory over time at the .05 level. See Table 2.

TABLE 2

TABLE OF COMPARISON BETWEEN TIME 0 AND TIME 1
WHEN UTILIZING A BLUE BACKGROUND (TRIAL 2)

Groups	N	Mean	Mean Difference	Std. Error of Means	t-ratio	Sig. 2-tailed
Blue T/0	26	7.5385				
			.9615	.4278	2.248	.034*
Blue T/1	26	6.5769				

* Significant < .05

Hypothesis three is rejected as the results demonstrate a statistically significant difference at the .05 level of significance in memory loss between time 0 and time 1 when using black text upon a green background (trial 3). 28 subjects took this trial and had a mean difference between scores from time 0 to time 1 of (.5357) which resulted in a significance of (.045) which is a statistically significant loss over time at the .05 level. See Table 3.

TABLE 3

TABLE OF COMPARISON BETWEEN TIME 0 AND TIME 1
WHEN UTILIZING A GREEN BACKGROUND (TRIAL 3)

Groups	N	Mean	Mean Difference	Std. Error of Mean	t-ratio	Sig. 2-tailed
GreenT/0	28	7.3214				
			.5357	.2545	2.105	.045*
GreenT/1	28	6.7857				

* Significant < .05

Hypothesis four is retained as the results show no statistically significant difference at the .05 level of significance in memory retention between time 0 when using black text upon a white background and time 0 when using black text upon a blue background. 26 subjects took these trials and had a mean difference between scores from time 0/white to time 0/blue of (.1538) which resulted in a significance of (.703) which is not statistically significant at the .05 level. See Table 4.

TABLE 4

TABLE OF COMPARISON BETWEEN TIME 0 USING A WHITE
BACKGROUND AND TIME 0 USING A BLUE BACKGROUND

Groups	N	Mean	Mean Difference	Std. Error of Mean	t-ratio	Sig. 2-tailed
White T/0	26	7.6923				
			.1538	.3988	.386	.703*
Blue T/0	26	7.5385				

* Not Significant

Hypothesis five is retained as the results show no statistically significant difference at the .05 level of significance in memory retention between time 1 when using black text upon a white background and time 1 when using black text upon a blue background. 26 subjects took these trials and had a mean difference between scores from time 1/white to time 1/blue of (.6538) which resulted in a significance of (.207) which is not statistically significant at the .05 level. See Table 5.

TABLE 5

TABLE OF COMPARISON BETWEEN TIME 1 USING A WHITE BACKGROUND AND TIME 1 USING A BLUE BACKGROUND

Groups	N	Mean	Mean Difference	Std. Error of Mean	t-ratio	Sig. 2-tailed
WhiteT/1	26	7.2308				
			.6538	.5052	1.294	.207*
Blue T/1	26	6.5769				

* Not Significant

Hypothesis six is retained as the results show no statistically significant difference at the .05 level of significance in memory retention between time 0 when using black text upon a white background and time 0 when using black text upon a green background. 25 subjects took these trials and had a mean difference between scores from time 0/white to time 0/blue of (.6400) which resulted in a significance of (.137) which is not statistically significant at the .05 level. See Table 6.

TABLE 6

TABLE OF COMPARISON BETWEEN TIME 0 USING A WHITE BACKGROUND AND TIME 0 USING A GREEN BACKGROUND

Groups	N	Mean	Mean Difference	Std. Error of Mean	t-ratio	Sig. 2-tailed
WhiteT/0	25	7.8000				
			.6400	.4159	1.539	.137*
GreenT/0	25	7.1600				

* Not Significant

Hypothesis seven is retained as the results show no statistically significant difference at the .05 level of significance in memory retention between time 1 when using black text upon a white background and time 1 when using black text upon a green background. 25 subjects took these trials and had a mean difference between scores from time 1/white to time 1/green of (.7200) which resulted in a significance of (.185) which is not statistically significant at the .05 level. See Table 7.

TABLE 7

TABLE OF COMPARISON BETWEEN TIME 1 USING A WHITE BACKGROUND AND TIME 1 USING A GREEN BACKGROUND

Groups	N	Mean	Mean Difference	Std. Error of Mean	t-ratio	Sig. 2-tailed
WhiteT/1	25	7.4800				
			.7200	.5276	1.365	.185*
GreenT/1	25	6.7600				

* Not Significant

For an explanation of what may appear to be discrepancies between mean scores from analysis across trials see Appendix K.

Chapter 5

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Summary

A study of the effects of color as used in presentation software on short (immediately following treatment) and long range (one hour following treatment) memory retention was conducted. Previous studies as discussed in the related literature have concentrated on color as cueing or coding mechanisms primarily in print media and have not explored the effect of individual colors as presented on CRT (Cathode Ray Tube) computer screens. 28 subjects were selected from 6th and 7th grade students who were enrolled in a public school. Subjects were shown a series of alphanumeric characters (3 per slide x 3 slides = 9 slides per color = 27 slides total) using black text upon white, blue, and green backgrounds. The slides were prepared using the "Pack and Go" feature of Microsoft® PowerPoint® presentation software. Slides were automatically timed for ten seconds each. Timing for the slides was determined by information gathered during a pilot study on similar subjects from another group.

The 28 subjects in the main study were given answer sheets following exposure and were asked immediately (time 0) following treatment to write down what they remembered from the series. One hour later (time 1), the subjects were given another answer sheet and asked to write what they remembered. The white, blue, and green slides were presented at one week intervals using a different set of alphanumeric characters upon each subsequent background. The answers were scored for number correct in order and sequence from all colors and time references and t-tests were conducted on the data. Comparisons were only made to determine differences between blue and white and between green and white. No relationship between blue and green was considered as the focus of the study was to determine differences between certain colors when compared to a white background.

Results show a statistically significant memory loss from time 0 to time 1 at the .05 level in the trial using blue and in the trial using green. Additionally, in a comparison between the mean number of correct responses, a trend may have been discovered which shows black text upon a white background to rank higher in both time 0 and time 1 than blue or green. Blue may rank 2nd in time 0 and 3rd (worst) in time 1 while green may rank 3rd (worst) in time 0 and 2nd in time 1. Suggestions of evidence to support additional research in this area are inferred.

Conclusions

When based on the evidence taken from this study some inferences may be suggested. While the ability to generalize is limited because of sample size the information gathered in this paper may indicate a trend that may suggest a need for additional research using a larger sample size. It appears that in a comparison between mean number correct in time 0 and time 1 of the three colored backgrounds used (white, blue, and green which are all described as pure) the white background provides the best result in memory retention. The results indicate the highest scores for white backgrounds in both immediate recall (time 0) with a mean number correct of (7.6923) and in long-term recall (time 1) with a mean number correct of (7.230). A white background therefore ranks 1st (highest) for memory retention in both immediate and long term recall. The blue background ranks 2nd in time 0 with a mean number correct of (7.5385) and ranks 3rd (lowest) in time 1 with a mean number correct of (6.5769). The green background ranks 3rd (lowest) in time 0 with a mean number correct of (7.3214) and 2nd in time 1 with a mean number correct of (6.7857). See Table 8.

TABLE 8

TABLE OF COMPARISON OF THE MEAN OF NUMBER OF CORRECT RESPONSES IN TIME 0 AND TIME 1 OF WHITE, BLUE, AND GREEN

Trial Background Color	Time 0	Time 1
	Mean of Number Correct	Mean of Number Correct
White	7.6923	7.2308
Blue	7.5385	6.5769
Green	7.3214	6.7857

It should be noted that trial 2 appears to have larger differences than the other two trials. In the analysis it was also noted that some of the subjects scored higher on time 1 than time 0. A second analysis was conducted eliminating the three values with a difference less than –1, (those who scored better after one hour) under the possibility that those students were employing creative enhancement measures. Results were computed including these scores and again excluding these scores however, the results remained the same and so the second analysis is not included in this paper. Only the scores that include all subjects that participated in each trial are shown in this paper.

This paper may demonstrate evidence to support additional study of the topic of color as it relates to memory retention. It must be stated however, that these results are only for the specific colors as described in this study. There may be other colors or variables that were not considered here that would provide other conclusions. It also appears that white backgrounds with black characters may provide the best short (immediate) and longer range (one hour) memory retention when used in presentation software. This information may also have some relevance when applied to the development of web pages for use on the Internet although this issue was not directly addressed here.

It would appear that if either pure blue or pure green were considered for use in presentation software for information that is to be immediately recalled, pure blue might be better than pure green. If a longer term (one hour) memory retention is desired and if either pure blue or pure green is chosen, then pure green appears superior to pure blue. It might also be of interest to the researcher to explore longer and/or shorter time intervals of memory retention than those utilized in this study.

It was also noted previously in this paper that there were several subjects who actually scored higher after a time interval of one hour (time 1) than immediately following treatment (time 0). There are several possible explanations for this inconsistency. It is possible that the subjects disregarded instructions and discussed the answers with other subjects between time intervals. It is possible that the subjects utilized some form of creative enhancement (i.e., writing answers down, rehearsal, or improvising some shared memory strategy with other subjects) to improve their answers.

It is also possible that in the interval between time 0 and time 1 some form of testing anxiety was relieved whereby the subject could genuinely remember information that was blocked by time constraints or other factors during time 0. Considerations of improved scores after one hour were not explored here but, should be examined or corrected for in future studies. Subjects were not under the direct control of the researcher during the interval between time 0 and time 1. The analysis of the data in this study was not effected by either inclusion or exclusion of those scores.

Another issue mentioned previously in this paper is that which is associated with learning over repeated measures and with the potential for an increased performance curve upon continued exposure (Jensen, p. 76). In such cases prior exposure led to quicker responses and learning while recall also increased when subjects were pre-exposed to a pattern (Jensen, p. 76). Increased performance over repeated exposure issues were not considered in this current study however, subjects did not appear to exhibit characteristics which are consistent with such an understanding. If increased performance upon continued exposure is true in all occurrences, subjects could be expected to do better in retention with each successive exposure. Increased performance over repeated exposure was not supported as subjects in this current study did best during the first exposure and alternated T0 and T1 performance on exposures two and three. It should be understood that only the methodology remained constant across trials as each slide contained new information as well as different colors within each slide set.

Recommendations

Considering the results of this study it would appear that additional research is suggested. If replication of this study is anticipated several considerations should be made. The first consideration is in that of sample size and homogeneity. By the use of a larger sample size, perhaps an expanded or different conclusion may be drawn than shown here. While homogeneity was not considered a factor in this study it might be of interest to the researcher to compare responses of males to females, grade level to grade level, or age level to age level.

Studies of larger sample sizes over longer periods of time (i.e., 6th grade students from several schools studied in succession over a period of several years) might also be considered. Additional consideration should also be made to insure the isolation of subjects between time intervals if the study is replicated. This would explore inconsistencies in individual scores to determine if issues such as relief of time pressure or limiting contact between subjects alters the results.

Another consideration would be to explore what material and complexity level of material or task was assigned to the subjects between time intervals. In this study the subjects resumed their regular schedules of in-class work that included mathematics and science. It was not a consideration in this study whether the resumption of a study of mathematics had any effect on the retention of alphanumeric characters. An additional consideration in the comparison of the mean number of correct scores to evaluate a trend might be to determine whether the actual difference between scores (i.e., one-half point) would be sufficient to facilitate incorporation of the result into an expanded curriculum.

Simply, is the difference found in this project great enough to matter in the particular area in which it is being considered for application?

If a conclusion could be drawn from such a study as this one there would be the possibility of excluding certain colors when using presentation software and perhaps in website designs if memory retention of information is a factor. Application in the public sector might include product identification and retention of pertinent related information for longer or shorter periods of time. In the educational field, there might be the possibility of enhancing the learning experience or even of improving test scores. Though not explored here, there may be some benefit in the use of color in presentation software for students with certain learning disorders. Additional study could provide a more complete understanding of the role of color in learning and of the process of human memory retention. A more complete understanding of the role of color in memory might be obtained by replicating this current study utilizing a combination of the methodology used for this current project and the current technologies (e.g. PET, MEG, and F-MRI) discussed in this paper. Finally, the expanded development of the topic could provide for the potential of a more efficient and effective use of technology in education.

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APPENDICES

APPENDIX A

Color Production

What we know as color is derived from the portion of the electromagnetic spectrum that is both visible to the human eye as light and perceivable by the human mind. Color is, in essence, an analog medium determined by wavelengths of visible light on a segment of a continuum with an essentially limitless number of variables. Just as there is a theoretically infinite number of numerical values between any two whole numbers, there are, in practical terms, a virtually limitless number of variations of colors that exist between two colors. Describing those variables in precise terms is a daunting task. The production of color is accomplished in at least two ways, which are described as additive and subtractive mixing. Additive color mixing occurs when colors of light overlap and add to each other (Exploratorium (additive), p. 1). Mixing the additive primary colors, red, green, and blue, produce white. This additive color mixing is the phenomenon that most closely approximates that which is produced by a cathode ray tube (CRT) in televisions and computer monitors. These devices utilize the three additive primary colors, red, green, and blue, to produce an approximation of most of the other colors, as received by the eye and perceived by the mind. Subtractive color mixing, conversely, occurs within the solid pigment media of paint and ink. In subtractive color mixing, paint is perceived as a particular color because it subtracts or absorbs colors from the white light hitting it (Exploratorium (subtractive), p. 1). The unabsorbed color reflects and reaches the eyes. In effect, what we see is all of the colors except what we name it because the pigment absorbs or subtracts all of the other colors away from what reaches our eye. The primary subtractive colors are cyan, magenta, and yellow, which can be combined in varied proportionate amounts to produce any other color, or, when mixed at full value, to produce the color black.

APPENDIX B

Description of Hardware, System Properties, and Color Values

Computer: Noblis ® by Equus ® with Pentium "r" ® processor.

Monitor: Sampo ® "Alpha Scan 411 with Plug & Play / Energy Star compliance.

Hard drive size: 3Gigabytes.

Random Access Memory: 64 MB RAM

Keyboard: (No brand name available) Standard 101/102 Key or MS Natural properties English (U.S.) with U.S. 101 layout.

Mouse: (No brand name available) Standard serial mouse with right handed configuration.

Modem: NobleLink ® K56 Flex PC Plug & Play voice modem / set on COMM Port 2 (maximum speed 57600 bps.).

Connection: Data bits = 8 ; stop bits = 1; parity = none; phone connection = ISDN.

Performance (status): System resources 88% free; file system 32 bit; virtual memory 32 bit; disk compression not installed; PC cards (PCMCIA) no (p) sockets installed.

Graphics: (advanced settings) Hardware acceleration (full).

File system: Role = desktop computer; read-ahead optimization (full).

Display properties: True Color® Color Palette (32 bit) / desktop area = 640x480 pixels.

Adapter/Driver: Matrox Millenium II Power Desk ® by Matrox Graphics ® / features = DirectDraw version 4.0 @ optimal refresh rate.

Internet Browser: Netscape 3.0

Color values: (expressed in hexadecimal terms)

<u>White</u> = Hex FFFFFF; decimal 255 (pure red), 255 (pure green), 255 (pure blue); at a percent value of 100 (red), 100 (green), 100 (blue). Used in background one.

<u>Black</u> = Hex 000000; decimal 0 (zero red), 0 (zero green), 0 (zero blue), at percent values of 00 (zero red), 00 (zero green), 00 (zero blue). Used for font color on all treatments.

<u>Blue</u> (pure) = Hex 0000FF; decimal 0,0,255; percent 00,00,100. Used in background two.

<u>Green</u> (pure) = Hex 00FF00; decimal 0,255,0; percent 00,100,00. Used in background three.

<u>Red</u> (pure) = Hex FF0000; decimal 255,0,0; percent 100,0,0. Not used in this study. Included for reference.

APPENDIX C

Hexadecimal System

In a hexadecimal numbering system, instead of counting from 1 to 10 before changing decimal position (a position represents units, tens, hundreds and so on in the decimal system), the counting is done from 1 to 16 before changing position (and then positions represent powers of 16: 16, 256, 4096). As there are no digits available beyond 9, the first 6 letters of the Latin alphabet (or of any alphabet if the Latin script is not used) are used to represent the extra hexadecimal "digits" 10 (A), 11 (B), 12 (C), 13 (D), 14 (E), 15 (F). In this international standard, hexadecimal numbers are used to refer to the UCS, the hexadecimal coding of which is considered as equivalent to a catalog numbering system to select characters. Hexadecimal notation exists as a shortcut to represent groups of 4 bits (there are 16 combinations possible with permutations of 4 digits whose values can be either a zero or a one); it also takes less characters to express a number in hexadecimal than in decimal.

See Appendix B for an example of colors as expressed in hexadecimal terms.

APPENDIX D

Dithering

The CRT screen only has red, green, and blue (RGB) so, software must approximate certain hues by changing the value and chromas of the additive primaries (RGB) in a process called dithering. Currently only 216 colors are common to all Web browsers.

APPENDIX E

Color on a Cathode Ray Tube (CRT)

A color CRT uses three individual electron guns to electronically stimulate either of three colored phosphor dots on the inside surface of the glass screen. The colors are (RGB) red, green, and blue. The object of this study was to isolate each color from the other colors and to investigate its relative effects on human memory retention.

APPENDIX F
Gamma

When expressing a color (RGB), gamma is used to specify the amount of light which will be emitted from each phosphor, as a fraction of full power by specifying the voltage which will be applied to each electron gun. An effective gamma rating will deliver true colors and a good range of light, middle, and dark tones. Generally, gamma measurements range from 1.0 to 3.0. Macintosh ® and Silicon Graphics ® based systems have built in gamma correction while most PC and Unix systems do not. This correction is accomplished by the operating system and/or the graphics card, particularly in PC machines. A more complete understanding, including tests to approximate gamma, are available on the World Wide Web at the following URLs (as of May, 1999): <http://www.lava.net/~colorcom/comput.html (also follow links). Also see: <http://www.cgsd.com/papers/gamma_colorspace.html>

A corrected gamma of 1.8 is produced from a Macintosh ® or Silicon Graphics ® system running NeXTStep ®. The gamma estimate for the equipment used for this study was determined to be 1.6 by using the tests mentioned above. An approximate gamma of 1.6 falls within the parameters of corrected gamma with a range from 1.0 to 3.0 and mean of 2.0. Windows 95 ® has some gamma correction and was the operating system used for this study. Netscape 3.0, which accurately reproduces colors, was also used as a web browser for this study. Additional information on the efficacy of using the Netscape browser, as well as, a tool for identifying the hexadecimal codes of colors may be seen at: <http://the-light.com/netcol.html> and <http://the-light.com/colclick.html> (May, 1999).

APPENDIX G

Physics, Physiology, and History of Color

Physics (general)

What we call "color" is relative to the small part of the electromagnetic spectrum known as visible light. Because visible light is a segment of a continuum, it is inherently in an analog format. There are then a theoretically infinite number of variables within and between those values that we describe as individual colors. This presents an immediate problem to the researcher of color and its effects. The problem is that of describing an exact color and of replicating that exact color across additional research. Previously, this problem has been dealt with by using various color scales in an attempt to standardize the description of various hues and their relative values. The problem is exacerbated by the reality that color exists on a three-dimensional scale and, as such, cannot easily be described using a two-dimensional format. This difficulty is evidenced by the work of Albert Henry Munsell (1859-1918), an American artist, who did extensive work in standardizing the descriptions of colors by the use of a base 10 scaling system. Munsell eventually developed a three-dimensional solid to describe the various vectors used in the study of color, which became known as colorimetry. Those vectors are derived from the variables that he described as "hue" (what we call the color, i.e. blue, red, green), "value" (the relative brightness) ,and the "chroma" (the saturation or purity of color). Munsell observed that this solid representation did not form a perfect sphere, as he supposed, but rather, a shape that was more like an onion with one side extending to a blunt point toward the red, and somewhat indented toward the center in the green-blue segment of the spectrum. Munsell's system has become adopted by the United States Bureau of Standards since shortly after its publications in 1905, in spite of its shortcomings when attempting to describe additive light as produced on a CRT screen. Some of these shortfalls may be resolved by the acceptance of the digital description of color vectors using a hexadecimal coding system. This study assumes the efficacy of digital coding to be true and describes the vectors used within the study in two (2) digit hexadecimal terms which should be helpful in describing or replicating this study.

History

A brief review of the history of work in color theory and standardization follows. Early color systems were based on astronomy and used the "planets" (which included the Sun and Moon) to represent primary "colors" (Taramasso, p.1). Another early system associated each of the four "elements" of fire, earth, air, and water with a different color. Proponents of this method included Josephus and the cultures of Hindu, Greek, and Chinese people. These systems were the accepted norms until the Renaissance. Pythagoras (582 - 507BC) is thought to be the first to associate color to solid shapes while maintaining their connection to elements and the planets. Aristotle (384-322BC) contemplated the nature of color and some of his misconceptions, i.e. that all colors could be obtained by mixing black and white, prevailed for almost eighteen centuries. During the Renaissance, when art began to flourish, painters, who had to mix their own colors for paints, began to study light and color. Two early experimenters with the description of color were Alberti and Cennini but their work was not of a scientific nature.

Leonardo da Vinci was, perhaps, the most scientific in his studies of color theory, naming six primary colors including black and white. In 1666, Sir Isaac Newton (1642-1727) conducted his experiments using prisms and light which demonstrated the visible spectrum contained within white light. The difference in the wave-length of the light caused the light to be refracted at different angles within the prism, resulting in a differentiation in the various "colors". Newton was the first to arrange these elements into a color "wheel". His work resulted in the standard color theory of physics based on wave length radiation, now known as colorimetry.

The next notable person to express views on color theory was not a scientist but rather a poet named Johann Wolfgang von Goethe (1749-1832). Goethe repudiated Newton by stating that color was made by mixing light and darkness. In Goethe's color wheel, he instigated one of the more persistent misteps of modern color theory (Taramasso, p.1). He selected red, yellow, and blue as his primary colors and purple, green, and orange as secondary colors. The error comes when mixing Goethe's primaries in a subtractive medium (pigment). The resultant color is muddy brown rather than black if corrected. Black is produced only when using the true subtractive primary colors cyan, magenta, and yellow. This error is persistent and is still taught today (Taramasso, p.1).

Next to study color theory was Albert H. Munsell (1859-1918) as mentioned earlier in this paper. His work was later developed into a color vision test called the "Farnsworth-Munsell 100-hue and Dichotomous Test for Color Vision" by Farnsworth in 1943 (Lezak, p. 276). Munsell's work has been updated in 1929, 1943, 1950, with a glossy version being developed in 1958 and a Nearly Neutrals Collection® which was released in 1990.

Wilhem Ostwald (1853-1932) was the first to include numerals for various wavelengths on his color wheel, as technology had been developed to measure wavelength. Ostwald has been popular, with mathematics researchers. He used as his primaries, red, yellow, green, and blue, placed equidistant apart on the color wheel. In 1931, the Commission Internationale de L` Eclairage created its color model known as CIE. This scale forms a somewhat elongated triangular shape that is straight across the bottom and rounded at the upper most points (green). This system plots three (X,Y, & Z) tristimulus values that were initially devised to approximate the three primary color values thought to be perceived by the human eye, although these receptors were not fully known until the 1950s. The CIE scale was slightly updated in 1964. Its odd shape is owed to the fact that when measured from white, the color green is higher in comparative wavelength than any other color, making pure green more saturated than all others. In 1976 the table was revised again to adjust the pure white to appear more to the center, yet this was after the CIE had been accepted as a standard. Since then, the CIE L*a*b color system has been created as the first attempt to solve for the problem of differences between images shown on different computer monitors. The "L" stands for "luminance," the "a*" for the red/green balance, and the letter "b*" for the blue/yellow balance. Theoretically, the CIE L a*b* color model can produce any color visible to the human eye and is used in most current professional image editing programs (Taramasso, p. 1).

Additional understandings associated with color theory show that ". . . the colors of the spectrum can be found both in the color of light and in pigment colors" (Parramon, p.20). According to current color theory the spectrum of light is made up of at least the colors of magenta, red, yellow, green, cyan blue, and dark blue. The primary colors of light are red, green, and dark blue while the secondary colors of light are yellow, cyan blue, and magenta. The secondary colors are produced by combining two of the primary colors. Yellow is made by combining green and red, cyan blue is made by combining dark blue and green, and magenta is made by combining red and dark blue (Parramon, p.20). According to Shibukawa (Shibukawa and Takahashi, p.64) "blue hues are perceived as giving impressions of cool/cold" and is usually associated with serenity, cleanliness, and intellect (Shibukawa and Takahashi, p.64). They also indicate that "as blue moves closer to green it is perceived as more refreshing than cold" (Shibukawa and Takahashi, p.64).

A final consideration in the visual impact of color and images may be found in the use of various font styles and sizes. There may be an effect known as "appearing size" (Livingston and Livingston, p. 16) where there is a perceived difference in the size of letters from different typefaces but, with the same point size. This effect results from the variation in x-height of the ascender and the descender of the letters or numbers. Point (pts.) size is understood here to be the Anglo/American standard of typographic measurement where one point equals 0.351mm and 72 pts. equal one inch (Livingston and Livingston, p. 158). While only one type face (Lucida Sans Unicode) and one font size (200 pt) was used in this current study, because of the use of both alphabetic characters and numerals, there could have been some perceived differences between appearing sizes but, these differences were not seen to effect the outcome of the study.

All of the previous information combines to add support for the use of a hexadecimal code for describing the colors used in this study. With so many different standards in use, the hexadecimal system simplifies the description and is translatable into virtually any standard by those who might seek to describe or to replicate this research. As a matter of reference, the wavelengths of the colors known as red (R), green (G), and blue (B) are approximated as: R=575nm, G=535nm, and B=445nm. It is additionally noted that by using a two (2) digit hexadecimal number for each primary color (RGB), over 16 million colors can be produced. This is accomplished, on the CRT monitor, by a process called "dithering" whereby the equipment approximates colors by rapidly shifting between the red, green, and blue phosphors in combination with variations in the X,Y, and Z values (or the values represented by La*b*). The efficiency of using a binary coding system to conserve energy and to increase the amount of information represented was noted by Miller (1959) (cited in Coopersmith, p. 160) in an August, 1959 article in Scientific American. The hexadecimal code is an extension of or analogous to a binary code that allows for better processing in 16 bit and higher machines. This is further support for using hexadecimal descriptions when differentiating between the theoretically infinite combination of values within the analog nature of color. It is agreed that there is a mathematical limit that theoretically exists between two numbers that are in a digital format as described in two digit hexadecimal terms (i.e. that there may be colors or units that exist between any 2 digit descriptions that are not expressible by those two descriptors). However, in the case of this study, the difference interval between the two hexadecimal delineations is minute and, is neither practical to consider, able to be produced by current technologies, nor perceivable by the human eye to a degree to resolve the issue to that extent and, as such, will not be seen to exert a statistically significant influence upon this study.

Physiology

A simplified explanation of the physiology of human color perception begins within the eye. The retina of the human eye contains two types of elements, rods and cones. There are approximately 130 million of these elements with a ratio of 18 rods to each cone. The rods are responsible for night vision, dim lighting circumstances, and shades of gray (variables of black/white). The cones each contain pigments that are sensitive to one of three wavelengths of light. One sees red, one sees green, and one see blue. All color that is visible to the human eye is accomplished through an operation of mixing between these three colors. Each of the three types of color receptors (cones) within the eye are named by Greek terms which mean “first”, “second”, and “third”. The receptor for red is called protos, green is deuteros, and blue is tritos. People with various dysfunctions of this system are commonly referred to as color blind although complete color blindness, where the subject sees only black, white, and shades of gray (monchromatic), occurs in only 1 in 30,000 of the population.

One of the earliest descriptions of color blindness was made by John Dalton in the late 1700s. The condition eventually became known as Daltonism in France (Bridges, p. 1). Dr. Keith Nash, who produces the Color Vision Guide ®, a simple tool to detect color blindness, stated that approximately 8% of males and 0.4% of females are color blind to some extent. The subjects that were used in this study were of a high ratio of females, but the Color Vision Guide ® test for color blindness was administered to each individual prior to the trial. There were zero detectable incidences of color blind individuals within this study. Lezak indicates that the accepted protocols for color blindness testing are the Ishihara (1954) test and the Dvorine (1958) screening test and that both are considered satisfactory (Lezak, p. 276). He mentions a third more extensive diagnostic tool called the H-R-R Pseudoisochromatic Plates that screen for two rare forms of color blindness in addition to those identified by the Ishihara and Dvorine tests.

The stimulus for all three of these tests are cards that are imprinted with dots of different colors which form figures or numerals that are easily distinguishable to the normal eye. Nash indicates that 75% of color blind people have poor green, with 24% in red, and 1% in blue. The Color Vision Guide ® is a modified, or simplified, Ishihara test, and as such, should be considered adequate and acceptable for this study. Subjects were screened for their ability to distinguish the colors used within this trial, i.e. blue and green. No anomalies were detected within either the subjects or the researcher.

APPENDIX H

Gamma Settings Information and Sources

The scale used for the estimation of the gamma settings on the equipment used in this study is available over the Internet at the following URL address (as of January 1999): <http://www.vtiscan.con/~rwb/gama.html>. Additional information on the importance of determining the monitor gamma is also available at this website and by following the related links. Gamma will effect the brightness and color correction on a CRT monitor screen. B. Villados, at <www.lava.net>, infers that the Windows 95® operating system, used for this current study, has certain built-in gamma correction capabilities and, as such, are not controllable by this researcher and has qualities that are considerable acceptable for use in this current study (Villados, p. 1). It is incumbent, however, to note that the observed estimate of gamma which was taken using the scale noted above, and which was viewed using the Netscape 3.0 Internet Browser, was noted at 1.6 on a scale ranging from 1.0 (low) to 3.0 (high) and having a mean of 2.0. This was understood to be within an acceptable range, between 1.6 and 2.2, for accurate color production. In addition, according to V. Engle, the Netscape Browser is recognized for its accuracy of color representation and so the use of Netscape 3.0 was not only the preferred browser used by the school in this study, it is also deemed acceptable for accurate color production for the hue, saturation, and values used within this study (Engel, p. 1).

APPENDIX I

Determination of Color Values in Hexadecimal Terms

The tool for determining the hexadecimal descriptions of colors is located at the following URL address: <http://the-light.com/colclick.html> (as of May, 1999). This online tool allows for the determination of the relative values of the colors available on a CRT by moving the mouse around the palette. The color values are automatically displayed in hexadecimal terms.

APPENDIX J

An Amplified Explanation of the Terminology Used to Describe the Design of This Study

"Traditionalist" describes this current study as one that approaches reality by the numbers. It accepts that reality exists and that it can be somehow measured. The term "positivist" is closely associated with a traditionalist approach in the realm of quantitative studies and refers to the oldest and most widely used approach to both natural and social science. Positivism accepts that reality exists apart from the researcher and that there is nothing that the researcher can do to change it. Positivist research prefers quantitative data, seeks exacting measurement, and tests hypotheses by the analysis of numerical information derived from the measures. Positivism often uses experiments and statistics to use in consideration of the outcome of the research. The term "paradigm" indicates a basic orientation to theory and research and is descriptive of a system of thinking. "Modernist" refers to a reliance upon logical reasoning involving basic beliefs, values, and assumptions that have been long accepted such as, the existence of a measurable reality. Modernism opposes the "postmodern" philosophy which rejects relative truth and which suspects all forms of empirical data or meanings derived from such considerations. Modernism holds that there are standards of truth which most people can agree upon. An "ontological assumption" is an approach to research that seeks to study the nature of existence as understood within a particular reference such as modernism.

"Quasi-experimental" is used to describe studies which seek to discover causal relationships and which also involve groupings that are not truly random. A "within-subject" design refers to studies using the same subjects which are assigned different treatments. A "passive" design for a study is one where the subjects do not have any control over the treatment. In the case of this current study the alphanumeric characters and the timings for the individual slides were pre-set by the researcher using automatic timing settings and were not alterable by any of the subjects during any of the trials. A "quantitative" design uses the collection of empirical data from experimental trials in the collection and computation of data. Quantitative designs are those studies which primarily utilize experimental methodologies and differ in approach from studies which use a qualitative design.

APPENDIX K

An Explanation of What May Appear as Discrepancies Between Mean Scores Across Trials

Upon a closer examination of the analyzed data there appears to be a discrepancy between the mean scores. The reason for the differences between information presented in tables 1 through 3 and between information found in tables 4 through 7 is attributed to the differences in sample (N) sizes in the three trials. In the trial using a white background there were 26 subjects. In the trial using a blue background there were 26 subjects and in the trial using a green background there were 28 subjects. In comparisons between time 0 and time 1 in the three trials the N sizes and mean scores remain constant. The anomaly occurs when a paired samples t-test is computed. The SPSS ® software uses only those datasets that are in common between the compared subsets. Different mean scores are generated because only those samples that are common to both subsets are used in the comparison. The t-tests utilized in this project were conducted under the instruction of the professor in oversight of this paper. The numbers contained in this project are correct as presented. The most relevant considerations in this study are, in the opinion of the researcher, those found between time 0 and time 1 across the three color trials.

APPENDIX L

Example of Type Style, Font Size and Characters Used in This Project

(Characters shown in 100 point print to accommodate paper format - 200 point font example seen below)

Q3K

A

APPENDIX M

Permission Letter

September 9, 1998

Dr. Chris Templar
Chair, Teacher Education Department
Johnson Bible College

Dear Dr. Templar, et. al.

This letter is to serve as an acceptance for research as required in your Graduate program. As there is no official form supplied or required for such a study by the Cocke County Board of Education, this notice will suffice.

We, at Smoky Mountain School, Cosby, TN., accept the proposal for research by Mr. Bruce V. McConnohie to be conducted, at my suggestion, with Mr. Kelly's 6^{th} and 7^{th} grade class. The proposal is for *A Study of the Effect of Color in Memory Retention When Used in Presentation Software*. This study will be conducted on site during the 1998-99 school term.

We look forward to a continuing relationship with Mr. McConnohie and with Johnson Bible College and therefore remain

Sincerely,

Mr. Paul Cogburn
Principal
Smoky Mountain School

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