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ADULT PREFERENCES FOR COMBINATIONS OF COLORS USED IN THE DESIGN OF COMPUTER DISPLAYS

by

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research for acceptance, a thesis entitled ADULT PREFERENCES FOR COMBINATIONS OF COLORS USED IN THE DESIGN OF COMPUTER DISPLAYS submitted by Stephanie Diane Dolsky in partial fulfilment of the requirements for the degree of Master of Education in Adult and Higher Education.

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DEDICATION

Many waters cannot quench love, neither can the floods drown it.

Song of Solomon
VIII. 7

To my husband, Robert, who redefined the meaning of the terms tolerance, sacrifice and unconditional love.

ABSTRACT

The computer is an instructional tool widely utilized in all areas of teaching and learning. Computer display technology has advanced to the point where color has become a viable design variable. Unfortunately, research has failed to keep pace with technology, and therefore little is known about how to best apply color to the design of computer displays.

The purpose of this study was to investigate adult preferences for combinations of four colors presented on a computer display using a grey background. The sample consisted of 112 volunteer subjects with normal color discrimination 20 years of age and older. Color discrimination was assessed using the Farnsworth Panel D-15 Test. Color preference data were collected using an on-line color preference survey. Subjects rated the appeal of all possible combinations of four colors from a base of eight, including red, orange, yellow, green, blue, purple, magenta and black. A five-point rating scale was used to indicate the degree of preference: Very Much, Much, Somewhat, Little, Very Little. Analysis of variance (ANOVA) was used to evaluate the interaction of color preference and age group, gender and previous computer experience.

Mean scores were calculated for each of the 70 combinations. According to the data, the ten most preferred combinations were blue, red, purple, black; purple, magenta, black, yellow; purple, blue, black, magenta; orange, black, red, purple; red, yellow, purple, black; red, magenta, blue, black; yellow, black, blue, red; yellow, purple, blue, red; and red, black, magenta, purple. The ten least preferred combinations were orange, magenta, green, red; black, green, yellow, blue; yellow, magenta, green, red; black, green, purple, orange; magenta, black, green, orange; yellow, magenta, green, purple; purple, black, green, yellow; magenta, yellow, green, blue; purple, green, blue, orange; and yellow, green, orange, red.

Grand mean scores were tabulated for the 10 most preferred and the 10 least preferred combinations. The difference in grand means between the two groups was proven to be statistically significant using a two-tailed t-test.

ANOVA revealed only seven of a possible 70 instances where the differences between the mean scores for four age groups reached statistical significance. This same test showed that the mean scores for gender were statistically significant in only four instances. On the basis of these findings, the researcher therefore concluded these differences were of no importance overall.

This study provides evidence that adults have distinct preferences for combinations of color presented on a computer display. The results have importance implications for the application of color to computer display design and underscore the need for further research in the area.

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CHAPTER ONE

THE PROBLEM

Introduction

The last decade has witnessed an explosion in the use of the computer as an instructional tool. Hence, computer-based instruction is now used in all aspects of teaching and learning and predictions suggest the use of this technology will continue to increase. Recent advances in display technology have led to the use of color as a standard design variable. Like all design variables, color has its limitations, many of which are based on the physiology of color vision (Durrett & Trezona, 1982). The rigorous application of guidelines based on sound empirical research are necessary to fully realize the instructional benefits of color. Although general display design guidelines flood the literature, those pertaining to color are based almost exclusively on experiential data and therefore lack the consistency and comprehensiveness necessary to be useful. Few experimental studies have been conducted within the specific context of computer displays, hence the widespread existence of methodological shortcomings such as the failure to control for brightness and saturation (Silverstein, 1987) and the lack of attention to the method by which color is applied.

To date, there has been no attempt to systematically investigate the application of color based on practical considerations of brightness, saturation, contrast, background and number of colors. The time is ripe for empirical investigation into the application of color to the design of color computer displays within this context.

The lack of empirical investigation into the application of color to the design of computer displays may be explained by the recency of color in computers and the once prevalent viewpoint that research should focus on the factors which promote learning rather than the delivery medium itself (Hativa & Teper, 1988). It needs to be recognized, however, that computer displays and print materials have different properties, most notably computer displays are self luminating and print materials are not. This distinction alone warrants color research specific to computer displays. Research is required if empirically-based color guidelines are to be established.

Statement of the Problem

The purpose of this study was to address the following problem: What are adult preferences for combinations of four colors presented on a computer display using a grey background and intended for use within the instructional computing context?

Sub-Problems

The following sub-problems guided this investigation:

1. How do adult preferences for combinations of four colors vary with age?
2. How do adult preferences for combinations of four colors vary with gender?
3. How do adult preferences for combinations of four colors vary with computer experience?

Scope

The scope of this study is outlined below.

1. The study investigated adult color preferences as they relate to the presentation of information.
2. The study included all possible combinations of four colors from a base of eight: red, orange, yellow, green, blue, purple, magenta and black.
3. With the exception of black, the foregoing colors were of the same brightness and saturation.
4. A relatively low level of saturation was used.
5. The study explored display design from the standpoint of color only.

6. The study utilized one method of assessing color blindness, the Farnsworth Panel D-15 Test.

Limitations

The following limitations will influence the extent to which the results of this study can be generalized to the population of adults.

1. The method by which the sample was obtained introduced bias to the sample, thereby limiting the extent to which the results may be generalized to the overall population. For example, the respondents who participated represented the higher levels of socioeconomic status and education.
2. This study was limited by the specific color selections and brightness and saturation levels that were used. Each of these were arbitrarily determined as described in Chapter three.

Definition of Terms

Terms relevant to this study are defined below.

Adult - Any individual 20 years of age or older.

Hue - Another term for color.

Chroma - "The purity or saturation of a color and is perceived as the degree of departure from gray" (Wigert-Johnston, 1987, p. 142).

Value - Another term for brightness.

Saturation - The product of hue and brightness; it is reduced by the addition of white light (Durrett & Trezona, 1982).

Brightness - Refers to the intensity of light (Durrett & Trezona, 1982).

Contrast - The perceived difference between foreground and background.

Luminance - The amount of light discharged by a display (Murch, 1987).

Display - The face of a monitor used with most terminals and microcomputers.

Human factors - "The discipline...[dealing] with factors which affect human performance in the context of human-machine interaction" (Kearsley & Hillelsohn, 1982, p. 74).

Ergonomics - Another term for human factors.

Authorware Professional - An authoring system developed for MacIntosh and IBM computers.

Authoring system - A computer program used to develop computer-based applications. Whereas a programming language requires the use of commands, an authoring system requires the use of icons in the development of software (Alessi & Trollip, 1985).

Display design - The task of specifying the nature, structure and positioning of information on a display (Galitz, 1981).

Computer-based instruction (CBI) - "The entire field of using interactive computers to enhance instruction, including both CAI and CMI" (Heines, 1984, p. 147).

Computer-assisted instruction (CAI) - "The use of a computer system as a tutor. The computer presents instruction to students using text and graphics to illustrate important points and allows students to interact with the computer to practice the skills being taught" (Heines, 1984, p. 147).

Computer-managed instruction (CMI) - "Any system in which a computer is used to perform overall instructional management. It usually includes a testing and evaluation function, a planning function, and a record-keeping function. All CAI has elements of CMI built in, but CMI usually refers to a more complete, stand-alone system" (Burke, 1982, p. 187).

Alphanumeric characters - Includes all letters, numbers and special characters.

Acuity - "The capacity to discriminate the fine details of objects in the field of view" (Riggs, 1965, p. 321).

Color discrimination - The capacity to differentiate colors along the visible spectrum.

Normal color discrimination - For this study, an assessment of normal vision with no error as determined by the Farnsworth Panel D-15 Test of color blindness.

On-line color preference survey - A survey administered by a computer such that questions are presented on the display and responses are entered using a combination of keyboard and mouse.

Preference - For this study, the rating assigned to a color display using an on-line survey (Very Much, Much, Somewhat, Little and Very Little).

Assumptions

The following list of assumptions formed the basis for this study.

1. It was assumed that all subjects were functionally literate.
2. It was assumed that all subjects completed the on-line survey to the best of their abilities.

Significance of the Study

With the increasing prevalence of color displays, the use of color in computer-based instruction is inevitable. "The development of instructional design principles specifically tailored for [instructional computing] is needed" (Kearsley & Hillelsohn, 1982, p. 82). Investigation into adult preferences for combinations of four colors presented on a computer display using a grey background is consistent with this research need. This study will extend the boundaries of knowledge in the area through the development of an innovative methodology for computer-based color research and the advancement of empirically-based recommendations.

Summary

The general problem addressed in this chapter was: what are adult preferences for combinations of four colors presented on a computer display using a grey background and intended for use within the instructional computing context? The problem was delineated in terms of limitations, scope and assumptions. Definitions of terms were provided.

CHAPTER TWO

LITERATURE REVIEW

Color Vision

In this age of technology, we have become accustomed to the prevalence of color. It is used in television, video games, and of course, computer displays. How are the sensations of color produced? Color is processed in the retina of the eye. Consisting of rods and cones, it is the latter which are responsible for the perception of color (Durrett & Trezona, 1982). Not all persons are born with normal color vision. According to the literature, six to eight percent of all males (Burns, 1982; Galitz, 1981) and .4% of all females have a color discrimination deficiency (Galitz, 1981). In addition, "color vision varies to some extent as a function of the age of the observer. Rapid improvement has been reported for color discrimination up to approximately 25 years of age, followed by a gradual decline which becomes more pronounced around age 65" (Burnham as cited in Silverstein, 1987, p. 38). In a study by Cooper, Ward, Gowland and McIntosh (1991), they reported:

> An age gradient of selective loss of discrimination and saturation beginning at age 50 was demonstrated with rapid change noted after age 60. Similar findings were seen for hue but were not evident for brightness.

For reasons of effectiveness, software developers must fully consider the color vision capabilities of the user group when designing color computer displays.

Color and Display Design

Display designers of the nineties are faced with the challenging task of selecting colors from electronic palettes rich in potential. Since computers have the capacity to generate many colors, designers must decide not only on the colors to be used, but also on the intensity of those colors (Wigert-Johnston, 1987). Within the display design context, the misuse of color is widespread (Durrett & Trezona, 1982; Faiola & DeBloois, 1988). An awareness of the limitations and requirements of this new design variable may help to curtail the extent of this problem. England (1984) advanced the idea that "the effective use of colour depends on relating the colour's function to practical considerations of hue, brightness, luminosity, saturation, contrast, amount and number of colours used" (p. 320). A review of the literature in the areas of instructional design, graphic arts, ergonomics and human factors, color vision, and computer-based instruction were consistent in their attention to the following factors: foreground color, background, contrast, combinations of colors, number of colors, saturation and the use of common color denotations. As it is based on the most recent literature, the latter list of factors is thought to be representative of current thinking in the area. Each factor will be discussed under separate heading in this section of the review.

Color

The topic of color is well represented in the current literature. The focus of attention is a group of colors consisting of blue, green, cyan, white, yellow, red, black, purple, orange and magenta. The literature reveals a wide range of perspectives concerning the functional value of these colors within the specific context of color display design. These perspectives derive from practical considerations such as legibility, acuity, perceptibility, discriminability and identifiability. This section of the review addresses color as used as foreground.

The Controversial Color. The viability of blue in the design of color displays appears uncertain given the diversity of perspectives which exist in the literature. Support for the use of this color derives from both experiential and empirical data. Hansel and Stafford (as cited in Narborough-Hall, 1985) recommend this color for outlines and background alphanumerics. That blue is one of the colors recommended for use in the Ceefax, Oracle, and Prestel (Hauesing as cited in Reynolds, 1979) development tools is worth noting.

Pettersson (1985) reports that blue was rated as the most popular color in studies of perceived effort in reading text on a high resolution color display. Hauesing (as cited in Reynolds, 1979) similarly found that subjects were able to identify six color categories projected on a television monitor with 90% accuracy; blue being one of the color categories.

The color blue is reported to have many shortcomings. Among them, it is described as the least legible (Reynolds, 1979); the least bright and the most perceptually difficult (Durrett and Trezona as cited in Alessi & Trollip, 1985; Galitz, 1981). Experimental data support this perspective. According to Meister and Sullivan (as cited in Silverstein, 1987), a study which investigated the relative legibility of seven colors using reading rates as an indicator found that blue produced a noticeable performance decrement.

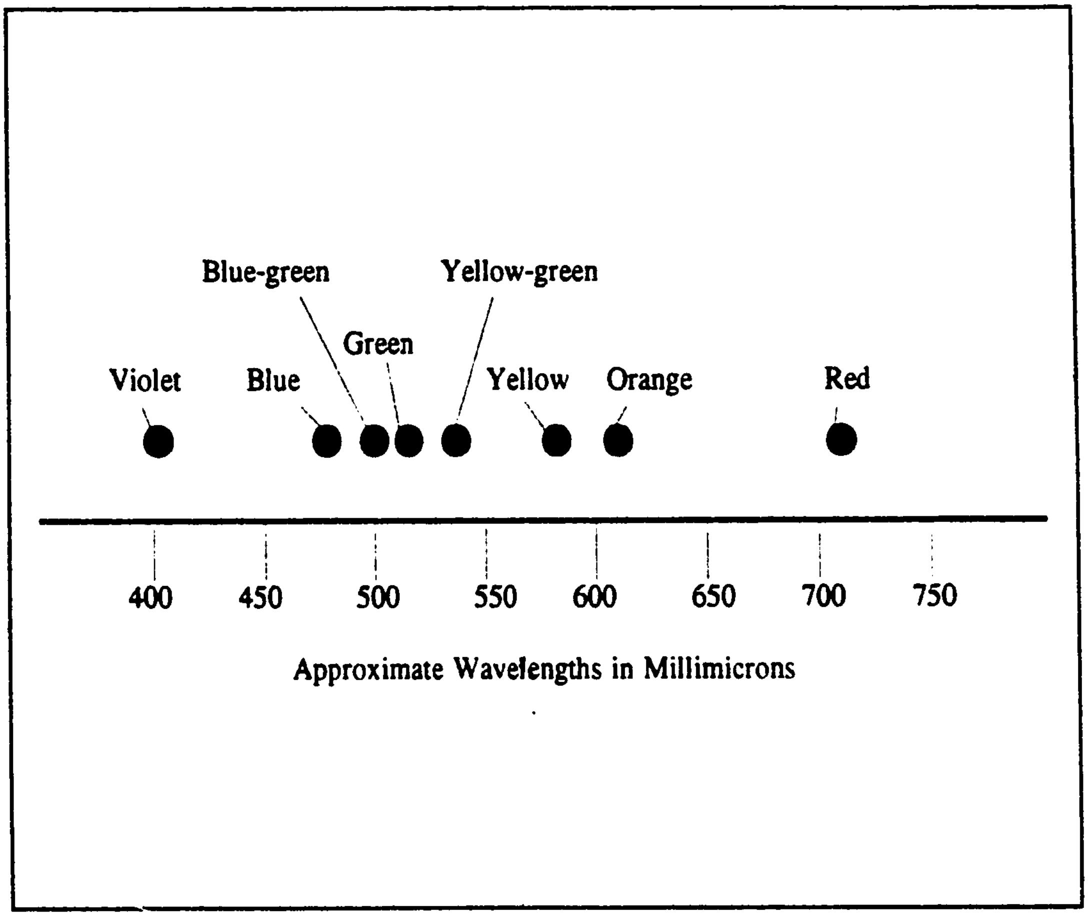
The differential sensitivity of the human eye to various wavelengths (Durrett & Trezona, 1982; Reynolds, 1979) provides a physiological explanation for the poor acuity of the color blue. This phenomenon is explained by Smith (1987):

> ...if the eyes are adapted to a typically lighted environment, maximum sensitivity is in the green or yellowish green regions of the visible spectrum...[These are longer wavelengths colors]. For a dark-adapted eye (working in a very dark office), the eyes are actually more sensitive to colors at the lower end of the visible spectrum, in the blue-green range [These are the shorter wavelength colors] (p. 109).

The yellow filter effect provides further physiological support for the poor acuity of blue. The yellow filter effect occurs after age forty (Schulz & Ewen, 1988) when the lens of the eye becomes more yellow (Holcomb & D'Angelo, 1990). This reduces the amount of light entering the eye (Holcomb & D'Angelo, 1991, p. 2), filtering out the shorter wavelengths. See Figure 1 for a graphic representation of the visible spectrum for the standard colors (Galitz, 1981).

Figure 1

The Visible Spectrum (Adapted from Galitz, 1991)



Cristarella and Pokorny, Smith, Verriest and Pinckers (as cited in Acheson Cooper, 1985, p. 254) suggest that the capacity to discriminate shorter wavelengths of light decreases with age. This is consistent with the literature addressing the yellow filter effect. Also consistent is Saxton's (as cited in Holcomb & D'Angelo, 1991) assertion that older individuals having color discrimination deficiencies are more capable of distinguishing reds and yellows than blues, greens and purples (the shorter wavelength colors). Except for the addition of orange to the list of more distinguishable colors, Schulz and Ewen (1988) concur with Saxton.

In summary, support for the value of blue is based on statements that it is popular. recommended for specific applications, and used in the design of several development tools. Furthermore, research suggests this color is readily identifiable. On the other hand, blue is described as poorly legible. Support for this latter perspective derives from empirical and physiological data.

There is a great deal of evidence to support the avoidance of small, blue wavelengths. Nevertheless, one must not ignore the suggestion that the dark-adapted eye is more sensitive to colors at the blue-green than the yellow-green end of the spectrum. Blue characters may very well prove to be advantageous under conditions of poor lighting. Further research is required to ascertain the practical value of the color blue within the context of computer display design and thereby resolve the controversy which surrounds this color.

Colors Most Recommended. A group of colors whose use is strongly advocated in the literature is addressed in this section of the review: green, cyan, white, and yellow. From the standpoint of perception, Kinney and Culhane (as cited in Narborough-Hall, 1985) cite green. cyan and white among the list of most usable colors. Each is used in the development of air traffic control applications (Breen, Miller-Jacobs & Miller-Jacobs, 1987) as well as in the Ceefax. Oracle and Prestel (Hartley, 1985) development tools.

Numerous advantages have been associated with the colors which comprise this group. Reynolds (1979) includes green, cyan, white and yellow in her list of most legible colors for computer displays, adding that "green is likely to be one of the most legible colors because it is produced by a single electron gun and the image is therefore sharp, it has adequate luminance. and it is one of the colours to which the eye is most sensitive and for which acuity is greatest" (p. 8). England (1984) points out that "green and white retain their legibility when considered with wavelength variations, [while] yellow and cyan lose some legibility..." (p. 319). Reynolds

(1979) states that white and green light provide the best acuity. This may be explained by Smith's (1987) assertion that the light-adapted eye is most sensitive to colors which cluster around the green area of the visible spectrum. Galitz (1981) reports that "green provides good general visibility over a broad range of intermediate luminances" (p. 140). The results of a study described by Meister and Sullivan (as cited in Silverstein, 1987) support the legibility of the color white. This study investigated the relative legibility of colors using reading rates as an indicator and found that white produced one of the highest rates. In addition to being legible, green and cyan are described as identifiable (Haeusing as cited in Reynolds, 1979) and green, alone, is depicted as perceptible (Durrett and Trezona as cited in Alessi & Trollip, 1985).

Although yellow, the last color in this group, is not characterized as usable and is excluded from the list of colors used in air traffic control applications, it is however, described as identifiable (Haeusing as cited in Reynolds, 1979), perceptible (Durrett & Trezona as cited in Alessi & Trollip, 1985) and legible (Reynolds, 1979). The color legibility study reported by Meister & Sullivan (as cited in Silverstein, 1987) found that yellow produced a high reading rate. That the eyes are most sensitive to yellow wavelengths (Smith, 1987; Acheson Cooper, 1985) points to the legibility of yellow. Contrary to England's (1984) claim that yellow loses some legibility when wavelength variations are considered, Galitz (1981) maintains that "yellow provides good general visibility over a broad range of luminances" (p. 140). In contrast to all other colors in this group, Connolly, Spanier and Champion; and Aschenbach, Kopala, and Douglass (as cited in Narborough-Hall, 1985) describe yellow as poorly discriminable. This viewpoint constitutes a clear departure from the mainstream of thought and should be treated with circumspection.

To summarize, there is widespread support for the use of green, white, cyan and yellow. Using descriptors such as legible, perceptible and visible; the literature depicts these colors as visually sound. It is interesting to note that empirical evidence supports the use of these descriptors. Further research is required to determine the nature and extent of adult preferences for colors which comprise this group.

<u>Colors Requiring Further Attention.</u> The final group of colors in this section is characterized by a striking lack of attention in the literature: red, black, purple, orange and magenta. The color red is used in the development of air traffic control applications (Breen, Miller-Jacobs & Miller-Jacobs, 1987) as well as in the Ceefax, Oracle and Prestel development tools (Hartley, 1985). Haeusing (as cited in Reynolds, 1979) promotes red as identifiable and Meister and Sullivan (as cited in Silverstein, 1987) advance red as legible based on their knowledge of a study on the relative legibility of seven colors which found red to produce one of the highest reading rates. That red is identified as one of the more discriminable colors for older persons with distorted color perception further supports the legibility of red. Galitz (1981) states that red is highly perceptible under conditions of high ambient illumination and Murch and Huber (as cited in Narborough-Hall, 1985) report that many authors support the use of this color provided that contrast requirements are satisfied.

There are those who refute the legibility of the color red. Reynolds (1979) describes red as one of the least legible colors and Durrett and Trezona (as cited in Alessi & Trollip, 1985) identify it as one of the most perceptually demanding. Graham (as cited in Reynolds, 1979) reports that red is three times less legible than white which is said to have high acuity. Consistent with previous comments, England (1984) describes red as the most poorly discriminable color. Galitz (1981) suggests that the color red is difficult to perceive under conditions of low symbol luminance. The light adapted eye is most sensitive to colors at the yellow-green end of the color spectrum. Reynolds (1970) suggests that red is 6% as legible as green, the color which is said to provide the best acuity. The foregoing figure underscores the ineffectiveness of the color red.

Common to black, purple, orange and magenta is their use in the development of air traffic control applications (Breen, Miller-Jacobs & Miller-Jacobs, 1987). The colors black and purple are free from negative comment; orange however is described as poorly discriminable (Connolly, Spanier & Champion; Aschenbach, Kopala & Douglass as cited in Narborough-Hall. 1985) and magenta is described as one of the least legible colors (Reynolds, 1979). Contrary to the suggestion that orange provides poor discriminability, Schulz and Ewen (1988) include orange in their list of more discernable colors for individuals with distorted color perception.

That little is known about the use of red, black, purple, orange and magenta points to the need to extend the boundaries of knowledge in this area by way of further research.

<u>Summary.</u> Based on the varying perspectives reflected in the literature, the value of the color blue in the design of color displays appears questionable. Further information is required before this color can be recommended. The colors red, black, purple, orange and magenta have received little attention in the literature. The best colors for the design of color displays appear to be green, cyan, white, and yellow. With the exception of yellow, each is free from negative comment. The suggestion that yellow is poorly discriminable deviates from the mainstream of thought.

There is a physiological explanation for the acuity differences in the colors in the visible spectrum. Differential wavelength sensitivity suggests that the light adapted eye is most sensitive to the green or yellowish-green areas and the dark-adapted eye is most sensitive to the blue-green end (Smith, 1987). This framework supports the legibility of the color green.

The difficulty experienced by older individuals with color discrimination deficiencies in distinguishing between blues, greens, and purples as compared to reds and yellows (Saxton as cited in Holcomb & D'Angelo, 1991) points to an age-related shift in the discernability of color;

a shift which favours the longest wavelength colors. This shift is explained by the yellow filter effect, physiological changes which reduce the amount of light entering the eye, thereby filtering out the shorter wavelengths of light.

It is interesting to note that the literature uses the terms perceptible, visible, discernable, discriminable and acuity to describe the legibility of various colors. In the absence of operational definitions, it is impossible to determine the extent to which these terms are synonymous. This creates obvious problems with respect to generalization.

<u>**Background and Contrast**</u>

More than a decade ago, Reynolds (1979) predicted the genesis of technological advancements permitting the display of characters of any color on a background of any color. In this same article, she addressed the relationship between contrast and background:

> colours of relatively high and low luminance presented side by side appear respectively lighter and darker than if viewed alone, while adjacent colours of high and low saturation appear respectively more or less saturated than if viewed alone. The use of background colour will, however, result in considerable losses in luminance contrast between image and background and this will almost certainly have a marked effect on legibility (p. 8).

Based on the relativity of color, contrast is defined as the observed difference between foreground and background (Acheson Cooper, 1985). Contrast is an important factor in the perception of color. An increase in contrast leads to increased perceptual abilities making it easier to distinguish elements on a display (Durrett & Trezona, 1982). In other words, darker colors are less perceptible than lighter colors when both are presented against a dark background (Durrett & Trezona). The opposite is also true; when contrast is reduced the ability to ascertain details is also reduced. (Durrett & Trezona, 1982). In summary, visual acuity is optimal in situations where the differentiation between foreground and background is great (Pett, 1989).

Authors such as Pett (1989), Pettersson (1985) and England (1984) address the importance of contrast within the context of character-background combinations. Narborough-Hall (1985) states that adequate contrast with the background is essential to the color coding of alphanumeric data. Contrast ratios in the range of 6 to 1 to 10 to 1 are recommended. The National Institute for Occupational Safety and Health likewise recommends the use of characters "...6 to 10 times brighter than the background" (Making Yourself Comfortable..., 1982, p. 178). While adequate contrast is important, Wigert-Johnston (1987) cautions against the excessive use of contrast, which according to Madge, Meyer and Sweezie (1986) can reduce educational effectiveness.

The decision as to which background is most appropriate for the design of color displays is confounded by contrast, which is inherent to all foreground-background combinations. The mutual inclusivity of foreground and background makes contrast issues inevitable.

Not all recommendations concerning background derive from contrast issues. Faiola and DeBloois (1988) suggest that background colors high in value and chroma be avoided because the optical response to high value and chroma reduces text legibility.

Background Most Recommended. The literature suggests that a neutral background is optimal for the design of color displays. Faiola and DeBloois (1988) explain that such a background serves to enhance other colors on the display. Pett (1989) adds that the color of an object can be emphasized using a gray background specifically. Narborough-Hall (1985) states that "it is better to have a greyish background which remains neutral in colour under the ambient illumination provided in the room and which looks like a surface on which the characters are placed" (p. 52). Narborough-Hall recommends the selection of background be based on three factors: foreground character colors, lighting and the brightness of other display elements. Note that the comments made by Faiola and DeBloois, Narborough-Hall and Madge, Meyer and Sweezie are specific to color computer displays. Madge, Meyer & Sweezie (1986) promote the consistent use of a neutral background.

In summary, several authors recommend the use of a neutral background such as grey in the design of color displays. It is argued that neutrality enhances other colors on the display and is suitable under conditions of ambient light.

Background Colors Requiring Further Attention. The current literature lacks consistency in its assessment of the effectiveness of light versus dark backgrounds. Recommending the use of a light background, Farrell and Booth and Pitt and Winter (as cited in Silverstein, 1987) state that color characters displayed on a light background are perceived as being more saturated than the same characters offset against a dark background. Silverstein (1987) adds that "the increased chromatic sensitivity resulting from surround lightness generally facilitates color discrimination" (p. 36). Smith (1987) reports that computer users prefer a white background. He suggests this is because of the bias that occurs from being accustomed to seeing print on a white background.

Narborough-Hall (1985) advises against the use of very light backgrounds as they may be incapable of producing the levels of brightness necessary to satisfy contrast requirements. Smith (1987) suggests that light screens may contribute more to the problem of glare than do dark screens. He further suggests that when dark images are presented on a light background, the perception of flicker is greater than when light images are displayed on a dark background. Another disadvantage, according to Smith (1987), is that characters presented on a light background appear smaller than when displayed in reverse order. He explains "this occurs because of the 'blooming effect' of white or colors that are significantly lighter than dark colors" (Smith, 1987, p. 108).

Arguments regarding the effectiveness of a dark background derive from contrast issues. Pettersson (1985) rates black as the best background color, stating it provides good contrast with most colors. Not all authors agree. Narborough-Hall (1985) maintains that

> coloured tabular information should not be used against a background which is black and has no apparent visual texture as this produces an excessive contrast between the background and characters so that the latter may have a tendency to appear to float in space and appear at different visual distances (p. 52).

Smith (1987) contradicts the argument that black provides a high contrast background. He maintains that the combination of light characters on a dark background creates reflections and glare spots, resulting in reduced contrast. Glare, according to Smith (1987), has a desaturating effect on color CRT images analogous to the outcome of adding white light to color. Pett (1989) is of the view that good contrast facilitates acuity and advises against the use of dark lettering on red or blue backgrounds.

In summary, the current literature suggests that light backgrounds have both advantages and disadvantages. Contrast issues underlie the divergent options regarding the use of a dark surround. That authors cannot agree on the nature of the contrast provided by dark background colors makes it difficult to assess. The effectiveness of light and dark backgrounds associated with the display of color computer images is uncertain. Further research would assist in resolving these variances.

Foreground-Background Combinations. A limited number of references address the issue of foreground-background color combinations. Foster and Bruce (as cited in Hartley, 1985) more specifically advise "...that when selecting colour on colour combinations, dark colours (red and blue) should be paired with light ones (white, yellow, cyan) and that neither two light nor two medium colors (green and magenta) should be used together" (p. 137). Contrast issues may form the basis for this recommendation.

Using four software packages (a database, a word processor, a spreadsheet, and an integrated package), Holcomb and D'Angelo (1991) investigated the relative effectiveness of four foreground-background combinations: the default screen; grey text on vivid blue; green text on red; white on vivid blue; and yellow on black. Preliminary findings suggested that adults over the age of 40 most preferred white text on a vivid blue background. Yellow on black was the second preference. Pettersson (1985) asserts that the reverse combination (black text on a white or yellow background) is best. To enhance the legibility of text, Faiola and DeBloois (1988) suggest designers focus more on value than hue. They specifically recommend "...text on background colors which creates contrast; white on black, white on dark gray, white on dark blue, dark blue on light gray or white, black on light gray or dark gray" (p. 17). The results of the Holcomb and D'Angelo study are consistent with this recommendation. Additional research must be undertaken to alleviate the dearth of knowledge concerning optimal foreground-background combinations displayed on color displays.

<u>Summary.</u> The literature focuses almost exclusively on backgrounds which are neutral, dark or light. Principal issues include contrast, glare, color discrimination, enhancement of other colors on the display and acuity. The relationship between contrast and background is such that the greater the contrast between characters and background, the more legible the display. Contrast ratios of 6 to 1 to 10 to 1 are recommended. Contrast constitutes the sole justification for comments surrounding the dark background; it did not, however, enter into discussions pertaining to neutral or light backgrounds. It appears that contrast is an issue which is secondary to background.

Free from negative comment, the neutral background appears to have the greatest potential for the design of color displays. In contrast, mixed perspectives characterize discussions concerning the use of light and dark backgrounds. Issues concerning their effectiveness cannot be resolved without benefit of further research. Little has been written on foreground-background color combinations; a topic which is both highly relevant and deserved of further investigation to identify those which are optimal for users of color displays.

Foreground Color Combinations

This section of the review addresses the relative effectiveness of combinations of colors juxtaposed on a single display. Despite the prevalence of specific recommendations, there is an absence of general commentary on the subject. The focus of attention is combinations comprised of red-blue, yellow-blue, red-green, blue-orange, violet-yellow, orange-yellow, blue-violet; red-green-blue; and red-green-blue-white.

The Combination Most Criticized. The literature unanimously recommends the avoidance of the combination of red and blue. Also unanimous is the reference to visual factors in the accompanying rationale. Pariseau (as cited in Madge, Meyer, & Sweezie (1986) reports that red and blue should not be used together if learners are required to focus on these colours simultaneously. He argues that the human eye lacks the physical capacity to focus on them at the same time because the colors are located at opposing ends of the visible spectrum. Durrett and Trezona (1982) point out that vibrations are an undesirable by-product of the red-blue combination. Reynolds (as cited in England, 1984) reiterates that "...if red and blue are used near each other, then the eye will jump from one to another to focus them separately" (p. 319). Alessi and Trollip (1985) concur with the anti red-blue perspective.

In summary, the literature indicates that red and blue should not be used together on the same screen. Support for this perspective is unanimous and is based on the inability of the eye to focus on these colors at the same time.

Color Combinations Receiving Mixed Reviews. The combinations of yellow-blue and red-green are controversial. Recommendations based on visual factors and the incompatibility of specific color pairs conflict with those deriving from the use of color to convey relationships between elements on the display. The concept of opponent-color combinations is central to the discussion of visual factors. Durrett and Trezona (1982) explain that

> the current theory of color perception is based on an opponent-process mechanism. Three opponent receptions--blue/yellow, green/red and white/black--produce color sensation by increasing and decreasing neural firing rates. The theory emphasizes adaptation, contrast, color appearances, and afterimages to explain color vision (p. 14).

Where the goal is to impart textual or graphic material, these authors recommend the unqualified avoidance of opponent-color combinations. According to Durrett and Trezona (1982), "yellow on a blue field...produce[s] the sensation of 'shadows' on the display and afterimages with color reversal" (p. 14). Alessi and Trollip (1985) are likewise opposed to the use of yellow and blue. In contrast, Galitz (1981) promotes the use of this combination as a means of emphasizing and conveying separation of display elements.

Similar arguments surround the use of red and green. Durrett and Trezona (1982) cite the same problem with red on green as with yellow on blue--shadows and afterimages with color reversal. Faiola and DeBloois (1985) recommend color combinations which are compatible. They state that complementary pairs such as red and green are incompatible and for this reason, recommend that their use should be based on due consideration, taking into account the design requirements. Alessi and Trollip (1985) oppose the use of red and green on the same screen for unspecified reasons. Galitz (1981) recommends this combination be used for the purpose of emphasizing and conveying separation of display elements.

In summary, the combinations of yellow-blue and red-green have received mixed reviews in the literature. Support for the use of these combinations is based on their value in conveying relationships between screen elements, whereas opposition to their use is based on their negative visual impact and the contention that these pairs are incompatible, and should therefore be avoided. To ascertain which color combinations are most effective within the context of color display design will require intensive study.

Color Combinations Receiving Limited Attention. The literature specifically advocates the use or avoidance of specific color combinations. These statements are single-referenced, indicating a general lack of support. Faiola and DeBloois (1988) maintain that complementary colors such as blue-orange and violet-yellow are incompatible and should therefore be used discerningly. Galitz (1981) promotes the use of orange-yellow and blue-violet as a means of conveying similarity among display elements. Galitz (1981) also advocates the use of color triads, including red, green, blue; and red, green, blue and white to emphasize and convey separation among display elements.

Summary. The literature consistently describes red-blue as a poor combination of colors. These colors, in fact, constitute the most severely criticized combination of those represented in the literature. The inability of the eye to focus on these colors simultaneously accounts for this negative assessment. Controversy surrounds the use of the combinations of yellow-blue and red-green. Support for their use is based on the value of using color to communicate relationships between display elements, whereas opposition is based on their negative visual impact as well as their incompatibility. The effectiveness of combinations recommended for emphasizing and conveying separation of display elements (i.e., yellow-blue and red-green) may derive from the fact that they challenge the visual system by creating the illusion of shadows and afterimages. The human eye may actually be drawn to color pairs which are perceptually difficult.

Compatible colors are recommended for use. Complementary pairs such as blue-orange, red-green and violet-yellow fail to satisfy this criterion. Commentary on the merits of multiple-color combinations is noticeably lacking in the literature. This is difficult to understand given that color display design typically involves the use of multiple colors. Further research is required to identify the color combinations which are most likely to be effective within the context of color display design and to broaden the focus of current attention to include multiple-color combinations.

Number of Colors

Much has been written on the optimal number of colors for use on a single display. The literature includes a combination of general statements and specific recommendations, the latter taking the form of ranges and absolutes. With respect to ranges, two presentations are evident; the first characterized by upper and lower limits (i.e., three to seven), and the second by upper limits only (i.e., up to four).

General Comments. In light of the detrimental effects of overuse, the number of colors is important to the design of computer displays. According to Fitz (1990), "having too many colors on the screen can be visually distracting, especially when it's matter of using color for color's sake" (p. 18). Wigert-Johnston (1987) asserts that the excessive use of color can create clutter and confusion, and Durrett and Trezona (1982) maintain that overuse detracts from color's attention-gaining potential. Consistent with previous authors, Galitz (1981) suggests that too many colors can lead to confusion on the part of the user, and "...will negate color's value as an attention-getting mechanism" (p. 141). Durrett and Stimmel (1982) maintain that "if color is used in excessive amounts, it does not serve to direct attention and no improvement in learning is observed" (p. 10). Rather, the learning experience in negatively impacted. In summary, Smith (1987) states that the imprudent application of color can result in frustration, stress and degraded performance.

Galitz (1981) points out that overuse can be avoided by selecting colors based on their practicality to the user. The issue for this author is task relevance. Other authors also link the number of colors to the task at hand. Narborough-Hall (1985) states that a large number of colors may be beneficial where relative judgements are required and under conditions where the use of color is supplemented by other coding dimensions. Haeusing and Krebs, Wolf and

Sandvig (as cited in Silverstein, 1987) agree, stating that the number of discriminable colors is greater for situations requiring comparative judgements as opposed to relative judgements. Krebs, Wolf and Sandvig; and Silverstein and Merrifield (as cited in Silverstein, 1987) report that color discrimination tasks become more demanding as the number of colors increases, and Galitz (1981) relates that the following will increase with the number of colors: "...the time required to respond to a specific color, the probability of confusion among colors, and the demands on hardware for reliably reproducing each other" (p. 139). Investigating the effects of the number of colors, Cahill and Carter (1976) found that search times increased as more colors were added to an uncoded display. This lends support to the notion of increased difficulty with increased numbers of colors. Breen, Miller-Jacobs and Miller-Jacobs (1987) suggest that the decision concerning the number of colors is application dependent and that "a multitude of colors may be valuable in an imagery system, while in text and graphic applications too many colors, can result in an overwhelming and potentially confusing presentation" (p. 184). Galitz (1981) similarly points out that "...graphic displays can employ more colors than alphanumeric displays" (p. 141).

To summarize, the literature suggests that the excessive use of color on a display can be detrimental to learning and that consideration should be given to both task and application in deciding the number of colors to be used. The comments embodied in the previous paragraphs provide insights into the factors which are relevant to the number of colors that can effectively be displayed on a display at one time.

Number of Colors Most Recommended. According to Narborough-Hall (1985), most authors recommend the use of "...no more than six colours, and optimally three to four as there are few applications where larger numbers of colours may be advantageous" (p. 51). The literature generally supports this contention, however, a maximum of seven is more commonly recommended than a maximum of six.

Fitz (1990) advances the position that text should never be displayed in more than three colors on a single screen. Silverstein and Merrifield (as cited in Silverstein, 1987) suggest using three to four colors in cases where absolute color judgements must be made. Several authors advise a limit of four colors per screen (Madge, Meyer, & Sweezie, 1986). Durrett and Trezona (1982) describe this limit as appropriate within the context of novel displays, whereas Faiola and DeBloois (1988) describe it as appropriate when a screen is comprised of only text and a limited number of graphic elements (i.e., bars, buttons, or menus).

Hauesing; Kinney; Krebs, Wolf and Sandvig; Silverstein and Merrifield; and Teichner (as cited in Silverstein, 1987) report that "recommendations on the number of usable colors for display coding purposes have been found to be in the range of three to seven colors" (p. 36). Smith (1987) states that "for most applications, between four and seven is the maximum number of colors on a screen at one time" (p. 109). She points out that some applications may necessitate the use of more colors, such as "a line graph with more than seven variables, a split screen with different (unrelated) types of data plotted in the different sectors, a representation of geographic areas (e.g., the states in the U.S), [and] realistic simulations or pictorial representations" (p. 109). The human factors literature supports the four to seven color maximum (Wigert-Johnston, 1987) as identified by Smith (1987). To accommodate the limits of short-term memory, Durrett and Trezona (1982) recommend a more narrow range of five to seven colors. Hauesing; Silverstein and Merrifield (as cited in Silverstein, 1987) recommend a maximum of "...six or seven colors for applications where comparative discrimination is the primary performance requirement" (p. 38).

For the most part, the above-noted recommendations take the form of ranges expressed as a maximum number of colors to be used on a display at one time. The numbers three, four and seven predominate the literature, and thus constitute a logical focal point for future research into the optimal number of colors.

<u>Recommendations Requiring Further Attention.</u> Faiola and DeBloois (1988) recommend a limit of six colors per screen, this being the number of colors the human eye can monitor at one time. Galitz (1981) suggests the eye can differentiate a maximum of eight colors at one time and therefore recommends this limit where color discrimination is the primary performance requirement.

In summary, limited consideration has been given to the human capacity to process multiple colors on a single display. It stands to reason that this factor is germane to the assessment of the number of colors and should therefore be the subject of rigorous investigation.

<u>Summary.</u> The literature indicates that the excessive use of color in the design of computer displays can be detrimental to learning. The imprudent application of color can result in clutter, confusion, frustration, stress, degraded performance, and impaired attention-gaining potential. The relevance of task and application to the assessment of number of colors is well documented in the literature, and is exemplified in the many recommendations which are task and application specific. The complexity of the display is also significant. The literature supports specific limits in the number of colors. These are summarized in Table 1.

Table 1

Limits in Number of Colors

Number of Colors	Rationale
4	• Absolute color judgements. • Simple screens. • Novel screens.
7	• Memory limitations.

Recommendations concerning the number of colors are based on a complex set of factors, calling into question the feasibility of determining a single optimal number of colors for use on computer displays. Narborough-Hall (1985) may well be correct in his assertion that "there is no single recommended number of colours within one display" (p. 51). The channelling of energies into the development of a bi-faceted set of guidelines may be more realistic. In light of Table 1, researchers would be well advised to investigate the appropriateness of three to four colors for simple displays, and six to seven colors for complicated displays.

<u>**Saturation**</u>

Although numerous authors identify the concept of saturation or chroma as integral to an understanding of color (Narborough-Hall, 1985; Durrett & Trezona, 1982; Acheson Cooper, 1985; Wigert-Johnston, 1987) and its use (Faiola & DeBloois, 1988; England, 1984), few address its relevance within the specific context of computer display design.

<u>General Comments.</u> Narborough-Hall (1985) advances the position that the use of highly saturated colors provides little in the way of benefits and may actually prove to be detrimental through the introduction of bias. The chief concern is chromatic aberration, a phenomenon in which there is "...the tendency for coloured information to appear to float in space and for information in different colours to appear at different visual distances" (Narborough-Hall, p. 50). Narborough-Hall (1985) explains that

> minor residual bias may occur after prolonged session using a display so that, with a strongly saturated green for example, controllers may see red or pink for a period of up to 15 minutes after going off watch. Saturated blues and reds in particular...have a tendency to appear to float in space at different visual distances. Highly saturated greens and yellows are more likely to be acceptable but may induce excessive contrast. Pale yellows, light blues, relatively unsaturated greens, pinks, magentas and cyans may not only be readily distinguishable from each other and meet contrast requirements but are often more satisfactory when used in conjunction with white (p. 5[illegible]).

Faiola and DeBloois (1988) also oppose the use of highly saturated colors, stating that "the optical response to high value or chroma hinders the legibility of the text" (p. 17). Pett (1989) advises against the use of highly saturated colors in materials intended for adult use.

Despite negative commentary, some authors contend that high degrees of saturation are practical. Durrett and Trezona (1982) maintain that the most readable colors are those which are highly saturated. Pett (1989) cites greater attention-getting potential for extreme differences in saturation than for hue and therefore recommends the use of highly saturated colors when the objective is to emphasize differences. According to this author, the greater attention-getting potential of saturation may stem from the fact that more saturate colors may appear brighter than those which are less saturated (p. 14). Faiola and DeBloois (1988) recommend the use of more chromatic colors under conditions requiring a quick response. The practical value of high saturation is also intimated in recent research, which according to Madge, Meyer and Sweezie (1986) promotes the use of different intensities of the same color rather than a variety of colors. These authors recommend the use of "...different intensities of the same colour for each of the following: headings, sub headings, text, borders, backgrounds, [and] instructions" (p. 373).

Summary. The relevance of saturation to the design of color displays is presently unclear. The negative implications of chromatic aberration and the allegedly poor optical response to high degrees of saturation account for the opposition to the use of highly saturated colors. At the same time, highly saturated colors are described as valuable in terms of their potential for accentuating differences and facilitating rapid responses. Current research supports the use of different intensities of the same color, and thereby strengthens the credibility of arguments emphasizing the practical value of high saturation. Continued research will be necessary to determine the relevance of saturation to the design of color displays. Researchers must examine the effects of various degrees of saturation on adult user groups.

Common Color Denotations and Color-Response Associations

Common color denotations (i.e., green for go and red for stop) and color-response associations (i.e., the calming effect of blue) constitute similar, yet distinct concepts relevant to the design of computer displays. Common color denotations bring about behavioral responses, whereas color-response associations bring about physiological changes. Each has the far-reaching potential for the design of color displays. Recommendations calling for the use of common color denotations are well represented in the literature. That these recommendations are based on supposition, rather than empirical evidence is worth noting. The application of color-response associations is well established within the field of psychology, but its application to display design remains unexplored.

Common Color Denotations. The literature strongly promotes the use of common color denotations in the design of color displays (Durrett & Trezona, 1981; Faiola & DeBloois, 1988). Galitz (1981) specifically advises the use of color associations that reflect the common experience. Alessi and Trollip (1985) concur, stating that color usage should be congruous with common usages prevalent in society. Along a similar vein, Wigert-Johnston (1987) recommends color coding which is relevant to the intended meaning. Galitz (1981) explains that "color meanings consistent with traditional color expectancies...[are] easier to use [because] they are well ingrained in human behavior and difficult to unlearn" (p. 137).

Commenting on utility, Wigert-Johnston (1987) points out that the use of common color denotations results in time savings, as well as a decreased probability of error (Wigert-Johnston, 1987). Durrett and Trezona (1982) support the performance maximizing potential of common color denotations while intimating that the use of color "...in ways contrary to accepted meanings interferes with information processing and can result in incorrect conclusions" (p. 16). They explain that information processing will be facilitated in cases of color application consistent with standard denotations.

In summary, the literature strongly supports the use of common color denotations that are consistent with conventional usages in society. The application of common color denotations results in learner-oriented benefits including time savings, and a reduced probability of error. Using color in ways consistent with accepted meanings facilitates information processing, opposite interferes with information processing.

<u>The Most Common Color Denotations.</u> The most common color denotations include the use of red to mean danger (Faiola & DeBloois, 1988; Durrett & Trezona, 1982; Galitz. 1981), stop (Faiola & DeBloois, 1988; Durrett & Trezona, 1982; Galitz, 1981) caution (Faiola & DeBloois, 1988); warning (Faiola & DeBloois, 1988) and down (Durrett & Trezona, 1982); green to indicate go (Faiola & DeBloois, 1988; Durrett & Trezona, 1982; Galitz, 1981), go to next screen (Faiola & DeBloois, 1988), proceed (Faiola & DeBloois, 1988), all clear (Faiola & DeBloois, 1988), up (Durrett & Trezona, 1982), OK (Faiola & DeBloois, 1988; Durrett & Trezona, 1982), and normal (Galitz, 1981); yellow to mean yield, pause, and wait (Faiola & DeBloois, 1988); and amber to indicate caution (Galitz, 1981).

In summary, the literature recommends the use of common denotations consistent with conventional usages in society, such as red for stop, green for go and yellow for caution. The most common denotations are predictable--therein lies their value in communicating the desired behavioral responses.

<u>Color-Response Associations.</u> The literature from the field of psychology considers color in terms of the physiological responses evoked. The application of color-response associations to the design of multi-color displays opens up a wide range of possibilities.

Consider the following associations:

> "Red raises blood pressure, quickens the pulse and increases the rate of breathing" (Francis, p. C2).

"Blue slows down the body activity, lowering the blood pressure, dropping the respiratory rate. It speeds up the perception of time and improves concentration" (Francis, p. C2).

"Orange--the eat-and-run color because it not only stimulates people's appetites, it also makes them impatient and restless. Orange in a work environment gets people working but it also irritates them" (Francis, p. C2).

"Green--Soothing and restful on the eyes and the nerves" (Francis, p. C2).

"White--Too much in an interior environment can be harsh. It tends to rush people and leave them feeling cold" (Francis, p. C2).

The potential of color-response associations within the computer display design context can be exemplified using the colors red and blue. The stimulating effect of the color red, for example, may find useful application in the air traffic control industry, where controllers must respond expeditiously to situations characterized by inherent danger. Physiologically, red appears to be the most appropriate code for danger. The sedative effect of blue with its potential for improving concentration may make it invaluable in terms of designing displays intended for examination purposes or a workplace environment where attention to detail for extended periods is required.

In summary, the subject of color-response associations pervades the psychological literature. The concept of using color to evoke constructive physiological responses in computer users cannot be ignored in light of the far reaching possibilities which exist.

<u>Summary.</u> The literature strongly supports the use of common color denotations consistent with the social conventions. The application of common color denotations facilitates information processing, resulting in learner-oriented benefits such as time savings, reduced probability of error and maximized performance; however, the use of color in ways contrary to accepted meanings interferes with information processing. Recommendations concerning the use of common color denotations are based exclusively on supposition, calling credibility into question. A concentrated effort is needed to produce quantitative validation pertaining to color

denotations and advance valid recommendations concerning their use.

The concept of capitalizing on the physiological effects of color has been unexplored by those concerned with the application of color to the design of color displays and the possibilities afforded by response associations. The utility of exploiting the physiological effects of color as a display design variable cannot be established without benefit of further study.

Graphics and Display Design

Technology has advanced to the point where low-cost computers can now generate highly sophisticated graphic illustrations (Soulier, 1988) which can be readily incorporated into computer-based instruction. This development is relatively recent and has significant instructional implications (Soulier, 1988) for computer display design. Unfortunately, empirical inquiry has failed to keep pace with technology. This is evidenced by the lack of research into the potential of computer-based graphics. This impact will become more pronounced as technology continues its rapid advance.

In this section of the review, the use of graphics in display design is addressed. Instructional functions, a classification system, instructional effectiveness, design guidelines and principles will be discussed.

Instructional Functions

Graphic illustrations can serve many functions for the display designer (Soulier, 1988). According to Soulier (1988),

> one of the most significant is to attract and hold a learner's attention. [He explains that] an interesting illustration not only attracts attention to itself but also to the text portion of the page [and that] learners generally are more likely to read text that is associated with an illustration than they are to read unrelated text (p. 202).

Hartley (1985) agrees that graphics which are inherently interesting may serve to direct attention to text, which is not inherently interesting. Fleming and Levie (as cited in Alessi & Trollip,

1985) support the attention-gaining potential of graphics, and points out that graphics have greater attention-gaining potential than text. Alesandrini (1985) acknowledges that graphics attract attention, and calls attention to their motivational value.

Soulier (1988) suggests that graphics facilitate the synthesis and organization of information and notes that concepts presented in visual form allow information to be processed simultaneously, while concepts presented in textual form must be processed one word at a time. Hartley (1985) points out that graphics can be used to illustrate sequential processes. Soulier (1988) advances the viewpoint that graphics enhance understanding, and are instrumental in avoiding the excessive use of jargon.

Alessi and Trollip (1985) identify three primary uses of graphics in computer-based instruction: "...as the primary information in a presentation, as an analogy or mnemonic [and] as a cue" (p. 78).

<u>Classification System</u>

Alesandrini (1985) promotes a classification system for graphics based on the meaning they impart. The system is comprised of three categories, including representational (i.e., line drawings), analogical (i.e., showing similarity) and abstract (i.e., schematic diagrams) graphics. Although research supports the instructional value of each type of graphic, courseware typically includes the representational variety (Alesandrini, 1985).

Representational graphics can depict material directly and indirectly (Alesandrini, 1985). Graphics in this category are also called realistic because they are similar to the objects or subjects they represent (Alesandrini, 1985). The degree of realism depicted by these graphics is highly variable. For this reason, Alesandrini (1985) advances the term representational as less confusing than the term realistic.

Alesandrini (1985) describes analogical graphics as advantageous based on "...the assumption that new information will be better learned and remembered if it can be related to prior knowledge" (p. 6). Graphics in this category have been effectively used to promote problem solving (Alesandrini, 1985) and empirical evidence supports the role of analogical graphics in facilitating learning (Alesandrini, 1985).

Abstract graphics provide an abstract or conceptual representation of the objects they portray and are useful establishing a structured format for verbal text and facilitating learning (Alesandrini, 1985).

The aforementioned categories of graphics (representational, analogical, and abstract) form the basis for the Instructional Graphics Checklist, an instrument developed by Alesandrini (1985). A tool for the educator, the Checklist is intended to provide general guidelines for assessing the merit of a CAI lesson in terms of its use of graphics. The instrument is comprised of three sections which address use, relevance, and types of graphics. Alesandrini (1985) describes the Checklist as informal given that the relative importance of each item has yet to be established.

Instructional Effectiveness

The instructional effectiveness of graphics is presently unclear. Although there is evidence to suggest that relevant pictures have the potential to reinforce learning (Alesandrini, 1985), there is also evidence to suggest that the improper use of pictorial information can be detrimental (Dwyer as cited by Alessi & Trollip, 1985). Research supports the detrimental effects of irrelevant, inaccurate and unnecessary graphics (Alesandrini, 1985). In an article on screen design for computer assisted instruction, Madge, Meyer and Sweezie (1986) point out that "unnecessary graphics can impede the learning process by slowing the pace of the course and distracting the student" (p. 374). The distracting potential of graphics is inferred in a study described by Fisher (1983):

> ...a [CAI] program with extensive graphics, sound, and animation [was compared] with another program featuring text only. [Fisher (1983) reports] when low-achieving students seemed to learn more from the plain version, the researchers concluded that graphics may have served only to distract the students, and draw them away from the real lesson at hand (pp. 82 & 84).

Design Guidelines

The literature provides numerous guidelines pertaining to the use of graphics in display design, and includes contributions from Caldwell (1982), Alesandrini (1985); Alessi and Trollip (1985); Madge, Meyer and Sweezie (1986); Soulier (1988); and Fitz (1990). What follows is a compilation of the design guidelines which govern the use of graphics.

Instructional graphics should:

1. Be relevant and congruent with the subject matter.
2. Be used to enhance, reinforce and clarify conceptual material.
3. Be used to direct attention to the important aspects of a lesson.
4. Be used to present content, and also, to provide feedback.
5. Include a cross-section of representational, analogical and abstract graphics.

Designers should refrain from using:

1. Unnecessary graphics.
2. An excessive number of graphics throughout an application.
3. An excessive number of graphics on a single display.
4. Graphics on each and every display.

Design Principles

Design principles (more prescriptive than guidelines) pertaining to the use of graphics are provided by Soulier (1988), Alessi and Trollip (1985), Fitz (1990), and to a lesser degree Madge, Meyer and Sweezie (1986). What follows is a compilation of the recommendations from these sources:

1. Avoid excessive detail and realism. Simple line drawings are generally recommended over realistic and complex pictures.
2. If complex pictures must be used, they should be developed on-screen by revealing and overlaying components part one at a time. This describes a technique called progressive disclosure.
3. Position graphics above or next to related text. Graphics and corresponding text should be as proximal as possible and should not be split over two displays.
4. Use icons to denote consistent features of the lesson.
5. Use simple graphics, such as borders, to *anchor* the display.
6. Use common symbols and symbol representations (i.e., a stop sign could be used to pause the lesson).
7. Generate graphics rapidly unless overlays are to be used.

Summary

Graphics serve many instructional functions such as attracting attention, synthesizing and organizing information, facilitating understanding, and helping to avoid the excessive use of technical terms. A different conceptualization is embraced by Alessi and Trollip (1985) who assert that the three fundamental uses of graphics are as primary information, as an analogy or mnemonic and as a cue.

Alesandrini (1985) promotes a classification system for graphics comprised of three categories: representational, analogical, and abstract. Representational graphics are most common to computer-based instruction. The above-noted categories are integral to the Instructional Graphics Checklist, an informal assessment instrument developed by Alesandrini (1985). The Checklist touches on the use, relevance and types of graphics.

The literature suggests that the instructional effectiveness of graphics is contingent on their use, and that irrelevant, inaccurate and unnecessary graphics are at best ineffective. Distraction is one of the detrimental effects of the imprudent use of graphics.

The use of graphics in display design is the subject of a great deal of attention. Relevant guidelines and principles are interspersed throughout the literature. It is worth noting that few are based on empirical research, which raises the question of validity.

Text and Display Design

Print is the oldest form of text, while the electronic version is amongst the newest. Comprising 80 to 90 percent of CBI displays (Soulier, 1988), text is an important design variable. Nevertheless "...most CBI designers spend little time making design decisions that involve the text portion of the screen. This is because they assume that they have very little choice as to what the text is to look like or where and how it is to be placed on the screen" (Soulier, 1988, p. 190).

Despite the recency of electronic text and the lack of attention to the presentation of text in display design, the literature includes a wide range of recommendations. Hartley (1985) maintains there is a general tendency to assume the generalizability of design principles for printed text to the design of electronic text. He suggests that some principles are generalizable (e.g., the importance of pre-planning, spatial consistency, the use of simple language, justification, and the avoidance of word breaks), while others are not. Hartley (1985) explains that important distinctions between electronic text and printed text (e.g., the availability of space for electronic text and different horizontal and vertical configurations and the dimensions of width and depth) make it impossible to completely generalize design principles for print to electronic text.

Contrary to Hartley (1985), Faiola and DeBloois (1988) assert that "the traditional principles of type should remain constant in application" (p. 13). These authors maintain that although display units now come in a variety of shapes and sizes, differences in space and proportion still exist between print and electronic text.

This section will review the application of text to display design from the standpoint of justification, line length, spacing, typefaces and fonts, upper and lower case characters, and organization and form.

Justification

Text margins are either justified or ragged. Justified margins are flush, as seen in this document; whereas ragged margins are uneven, as seen in a typed document. An integral aspect of display design, justification is the subject of much attention. Authors (Reilly & Roach, 1986; Madge, Meyer & Sweezie, 1986; Heines, 1984) unanimously support the use of left justified text. The basis for this support includes factors such as the speed of information processing, the effective response of the eye, and the advantages of using familiar patterns such as lists.

Left and right justified text is a format common to print (Heines, 1984) and is produced by inserting "...extra space between words in lines of type so that both the left and right margins are even, smooth" (Covington & Downing, 1989, p. 170).

The professional appearance of typeset text derives from the use of proportionally spaced fonts, kerning, and the capacity to insert small spaces between adjacent letters to create line expansions (Heines, 1984). Desktop publishing packages and more sophisticated word processing packages include the foregoing features. These features are absent from existing authoring packages and without them, left and right justification is achieved by inserting whole spaces. As Heines points out, "...the effect of this technique is not generally pleasing, and the large variations in spacing seriously impair readability" (Heines, 1985, p. 88). For this reason, double justified text is not recommended within the CBI context.

Line Length

According to Heines (1984), line length is the second most important factor affecting readability. The literature supports the use of shorter line lengths (Meyer & Sweezie, 1986; Galitz, 1981; Heines, 1984). This may be explained on the basis that "long lines require excessive eye movement and make it difficult for readers to move their eyes smoothly from the end of one line to the beginning of the next" (Heines, 1984, p. 87). Herein lies the reason for the predominance of the multiple column format in newspapers.

Galitz (1981) promotes a maximum of 50 to 55 characters per line, while Heines (1984) recommends an eight to ten word limit. The latter recommendation takes into account the fact that

> ...reading text from a computer screen is more difficult than reading it from a piece of paper. The resolution is lower, the angle of view is less comfortable, and the luminous nature of the screen can put more strain on the eye (p. 87).

Spacing

Guidelines concerning the effective use of spacing in the presentation of text in CBI are noticeably lacking in the literature. Caldwell (1980) recommends the use of double spacing to enhance the visual effect. According to Faiola and DeBloois (1988), research consistently suggests the need for care when using double spacing. Further research is required to establish valid and reliable guidelines specific to the use of spacing within the context of display design.

Typefaces and Fonts

The proper selection of typeface and font can enhance the aesthetic and instructional value of textual presentations. "Typeface refers to the design of letters of an alphabet, whereas font refers to a complete set of letters within an alphabet, upper and lower case, and always of a single size" (Faiola & DeBloois, 1988, p. 13). Covington and Downing (1989) explain that "italics, boldface, and different sizes count as a single font" (p. 13). Faiola and DeBloois (1988) state that only specific typefaces and fonts provide a clean, yet appealing textual image (Faiola & DeBloois, 1988) and note that typographical decisions for display design are limited by the selection of typefaces and fonts included in authoring software. It is therefore imperative that display designers be prepared to use available selections to their best advantage.

Typefaces. Soulier (1988) recommends the serif typeface over the sans serif typeface. Serif letters are characterized as having feet, also known as serifs. This document employs a serif typeface. As the name suggests, sans serif (sans meaning without) letters are more square in shape. Soulier (1988) suggests the very nature of the serif lettering style makes it more interesting. He further suggests that the serif typeface produces a more readable textual display. Covington and Downing (1989) promote the use of a proportionally spaced, roman typeface with serifs. The term proportionally spaced means that the width of the character determines the amount of space allotted that character on a line. Because "w" is wider than "l," "w" would be allotted more space proportional to its needs. In the case of a non-proportionally spaced typeface, each character is allotted the same amount of space regardless of width. This document employs a proportionally spaced typeface. Covington and Downing (1989) advance the roman types as most readable, adding that it is commonly used in books. They point out that unusual typefaces such as Old English can be extremely difficult to read.

Fonts. Faiola and DeBloois (1988) advise a limit on the number of typefaces and fonts used on a single display. They specifically recommend the selection of two fonts, along with the designation of sizes which should correspond to function. Covington and Downing (1989) support the two font maximum, submitting that "multiple font documents are almost always ugly" (p. 315).

Hartley (1985) suggests that continuous italicized text is more difficult to read than other standard fonts. For this reason, the use of italics should be reserved for emphasizing single words on a display.

<u>**Upper and Lower Case Characters**</u>

There is widespread support for the use of lower case characters (Heines, 1984; Alessi & Trollip, 1985; Hartley, 1985; Madge, Meyer, & Sweezie, 1986; Soulier, 1988). This supports derives from the higher levels of readability associated with lower case as opposed to upper case characters (Heines, 1984; Faiola & DeBloois, 1988). Faiola and DeBloois (1988) explain that

> the variation of shapes makes the screen more legible, primarily because words are perceived by shape and outline and not letter by letter. As a result, researchers have found that lower case text provides optimum levels of legibility to the reader for titles, subtitles and bodies of text (p. 15).

In contrast, Hartley (1985) suggests that upper case characters offer less distinctive information, which may, in turn, increase the time required for word recognition. This is not to suggest that the use of lower case characters should be avoided with the display design context. Hartley (1985) and Galitz (1984) condone the use of upper case characters for major headings, while Galitz (1984) also supports their use for labels and visual search tasks.

<u>**Organization and Form**</u>

Several authors comment on the organization and form of electronic text (Galitz, 1981; Alessi & Trollip, 1985; Hartley, 1985; Reilly & Roach, 1986; Faiola & DeBloois, 1988; Soulier, 1988). Relevant issues include amount of text, organizing text, consistency of organization, chunking of information, determining location in on-line materials, and the use of conventions. These will be discussed in the paragraphs that follow.

<u>**Amount of Text.**</u> The amount of text on a display is well within the control of the designer (Soulier, 1988). Nevertheless, excessive amounts of text is common (Hartley, 1985). This is problematic from two perspectives. First, learners are limited in their capacity to retain textual material; and secondly, a causal relationship has been established between large

amounts of text and reading fatigue (Soulier, 1988). Soulier (1988) explains that

> ...a learner's eyes seem to seek a place to rest when looking at large quantities of video text material. Sometimes that resting place is a margin, sometimes it's an illustration and sometime's it's an empty area in the middle of the screen. When the eye and mind can't find a resting point within a frame, the eye goes elsewhere, and the mind wanders away from the computer lesson (p. 191).

Research suggests blank space should comprise 50 percent of any given display (Soulier, 1988). Soulier (1988) recommends the use of a hardcopy when large amounts of text are necessary.

Organizing Text. Research points to the need for a recognizable order for displayed materials (Reilly & Roach, 1986). Within the north american culture, reading requires that the eye move from left to right and top to bottom (Reilly & Roach, 1986; Alessi & Trollip, 1985). According to Alessi and Trollip (1985), the addition of information to a display should adhere to this convention.

Order can also be achieved through the use of outlines, titles, summaries, indexes and glossaries (Hartley, 1985). "Research suggests that readers prefer text which has such lists or numbered sequences spaced out and separated, rather than run-on in continuous text" (Hartley, 1985, p. 51). In addition, space has been used to differentiate the various functional areas of a display such as title, information, and help; and to group related concepts (Soulier, 1988).

The topic of organizing text would not be complete without a discussion of general aesthetic considerations. Soulier (1988) recommends that text be centered on a display. This precludes the standard use of margins and the common practice of clustering text at the top of the display. Soulier (1988) similarly recommends no part of the screen be under-used. "The first line of a paragraph is called a widow if it appears by itself as the last line of a page" (Covington & Downing, 1989, p. 327) and "the last line of a paragraph is called an orphan if it appears by itself as the first line of a page" (Covington & Downing, 1989, p. 222). The use of blank lines between paragraphs is promoted by Galitz (1981) and Soulier (1988).

Summary

Justification, line length, spacing, typefaces and fonts, upper and lower case characters, and organization and form are important aspects in the application of text to display design. Despite the recency of electronic text, numerous design guidelines exist. There is a general tendency to generalize design principles for printed text to electronic text. It must be recognized that the distinctions between the media are significant enough that special consideration and attention is required designing displays which text.

CHAPTER THREE

DESIGN AND METHODOLOGY

Introduction

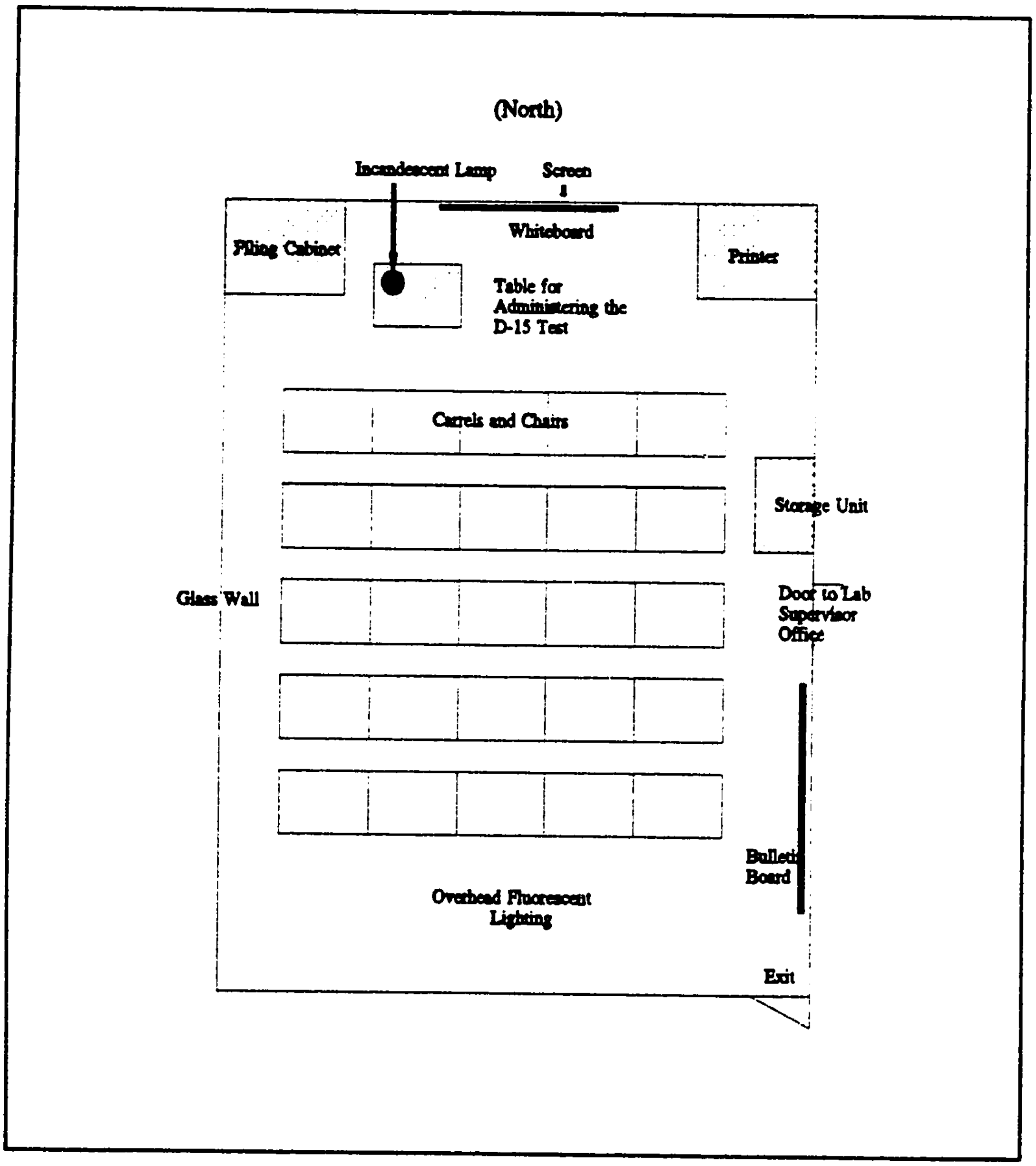
In this study, adult preferences for combinations of four colors presented on a color display using a grey background are investigated. The setting, subjects, instrumentation and methodology, including data collection and analysis procedures are described in the following chapter.

Setting

Data collection took place in the Macintosh computer laboratory owned and operated by the Instructional Technology Centre (ITC), Faculty of Education at the University of Alberta in Edmonton, Alberta. The laboratory was equipped with 25 Macintosh IIci machines positioned in individual carrels; carrels were aligned in five rows, with five carrels per row. A filing cabinet was situated in the northwest corner of the laboratory (See Figure 2). To the right, a small table furnished with an incandescent lamp and a chair was used in the administration of the Farnsworth Panel D-15 Test of color blindness. A laser printer was located in the northeast corner of the laboratory. A whiteboard and pull-down screen were anchored to the north wall. Positioned along the east wall, next to the entrance of the laboratory supervisor's office was a storage unit. A bulletin board hung on the southeast wall. A glass wall separated the Macintosh laboratory from the Apple laboratory located to the west. Access was gained to the facility through an exit located in the southeast corner. Illumination was provided by overhead fluorescent lighting; there were no windows in the walls or door to admit external natural or artificial light.

Figure 2

Diagram of Instructional Technology Centre Macintosh Computer Laboratory



Subjects

The sample consisted of 112 volunteer subjects with normal color discrimination 20 years of age and older. Six additional subjects participated in the data collection phase of the study but were omitted from the analysis based on their performance on the Farnsworth Panel D-15 Test of color blindness. A diagnosis of normal vision with no error was necessary for inclusion in this study.

Because it was anticipated that a large sample would be required, the researcher opted to use a modified snowball sampling technique (Henry, 1990). The snowball sampling began by the researcher contacting numerous professors, colleagues, friends and acquaintances. The snowball continued when the contact persons successfully recruited additional subjects. Later in the data collection process, the researcher presented the study to one graduate and two undergraduate classes offered by the Department of Adult, Career and Technology Education in the Faculty of Education and one computer class from the Spring Session for Seniors Program offered by the Faculty of Extension at the University of Alberta in an effort to solicit participation. In addition, the researcher approached a number of students working in both the Apple laboratory and the Macintosh laboratory. Each individual or group was verbally introduced to the study, then provided with multiple copies of a letter of invitation (See Appendix A); one for the contact person and the rest for other potential subjects.

Three different letters of invitation were used. The first identified designated laboratory times and included the researcher's home telephone number. The second letter included the laboratory times only and was used well into the data collection process. As the researcher was available during the specified periods, the telephone number was considered unnecessary. Late in the data collection process, turnout during the designated laboratory times was poor. For this reason, a third version of the letter was drafted, requesting potential subjects to contact the researcher by telephone to book an appointment for the experimental session.

Instrumentation

The Farnsworth Panel D-15 Test

The Farnsworth Panel D-15 Test is a standard optometric test designed to diagnose color blindness and to determine the extent of the problem in affected individuals. This instrument was recommended for use by Dr. Gordon Hensel (personal communication, 1992), a practising optometrist. For the purpose of this study, the D-15 was researcher-administered and researcher-interpreted. The Farnsworth D-15 Panel Test consists of a carrying case, 16 color caps and score sheets. 15 caps are randomly positioned on a table illuminated using a combination of fluorescent and incandescent bulbs, providing the full spectrum of light necessary for the conduct of this test. "A sixteenth color cap, fixed at the left end of the case, is used as a reference" (The Farnsworth Panel, p. 1). The subject is asked to arrange the caps, placing them into the carrying case. Under normal circumstances, the following occurs. The numbers on the underside of the caps are recorded on the score sheet once the task is completed. If an error is detected, the results are then plotted on the bottom of the score sheet. The test is then re-administered, and if an error is detected, the results are once again plotted on the score sheet. Based on the configuration, one of seven diagnoses is made: normal vision with no error, normal vision with minor errors, normal vision with one error, blindness to red, blindness to green, blindness to blue, and blindness to red, green and blue.

The standard score sheet was not used in this study; instead, the date and the subject's name were recorded in the Subject Log (Appendix B), using the next available identification number. The sample was defined to include only those individuals diagnosed with normal vision with no error. If an error was detected at the point of the re-test, a notation was in the Normal Color Discrimination column of the Subject Log to ensure that electronic record was deleted from the database prior to analysis.

Validity and reliability statistics were unavailable for the Farnsworth Panel D-15 Test. The researcher sought this information from several sources, including the D-15 procedures guide, Medline, ophthalmic distributors and the Department of Ophthalmology at the University of Alberta Hospital.

<u>On-Line Color Preference Survey</u>

<u>Development.</u> The on-line color preference survey was designed by the researcher and developed by Brett McConkey using Authorware Professional, an authoring system for Macintosh and IBM computers. The survey consisted of two parts; Part 1 which collected demographic and computer experience data, and Part 2 which collected color preference data. The color preference component of the survey was specifically designed to investigate all possible combinations of four colors from a base of eight, including red, orange, yellow, green, blue, purple, magenta and black. Using the following formula, it was determined a total of 70 displays would be required:

$$\frac{8!}{4! \times (8-4)!} \text{, where}$$

8! is the number of colors used in the formation of the combinations, (8-4)! is the number of colors comprising each combination and 4! eliminates duplicate combinations resulting from variations in sequence. In this study, all possible combinations of a four-color combination were treated as one in the same (i.e., blue, black, green, red were considered the same as red, green, blue, black). A complete list of color combinations is included in Appendix C.

Table 2 identifies the style features that were incorporated into each of the 70 displays of the on-line color preference survey:

Table 2

Style Features For On-Line Color Preference Survey

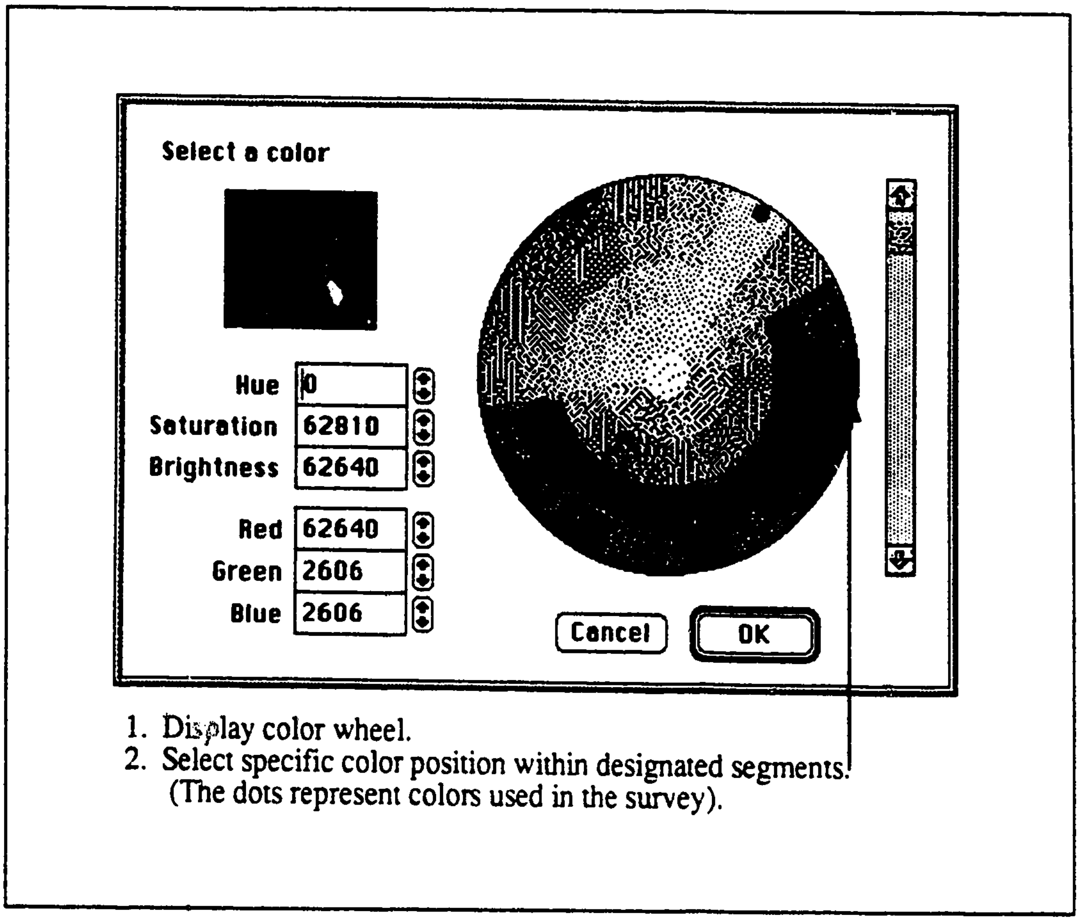
Feature	**Description**
Typeface	Roman.
Case	Mixed case characters for all text, including titles and subtitles.
Number of Fonts	Three.
Subject Matter	One Canadian trivia question.
Graphics	One which is relevant to textual portion of the display; that is, the Canadian trivia question.
Directions	Simple directions for responding to questions presented on the display.

The display layout provided for adequate white space.

<u>Color Specifications.</u> The colors red, orange, yellow, green, blue, purple, magenta and black were selected for this study. They were addressed in the literature and were, therefore, included in the study. The process for determining the numeric value for each of these colors is delineated below. To begin, the color wheel was displayed on a Macintosh IIci computer. (It is located under the control panel on the general controls screen and is accessed by double clicking on one of the colored boxes displayed on-screen). The colors red, orange, yellow, green, blue, purple and magenta were each matched to the one of 18 segments comprising the wheel. Next, the exact position within the designated segments was determined. The researcher opted for colors located in the centre of the segments on the outer edge of the wheel. See Figure 3 for a schematic of the position of the eight colors on the color wheel and Appendix D.

Figure 3

Position of Colors on Color Wheel



A mathematical approach was used to translate position on the color wheel into numeric values. The highest value for hue in the Macintosh environment was determined to be 65538; the number of segments in the color wheel was known to be 18. The distance from the centre of one segment to the centre of the next was calculated as 3641, represented as 65538 ÷ 18. The researcher arbitrarily then assigned a value of 0 to the sector designated as the color red. The distance from red to orange was one segment. The numeric value for orange was represented as the numeric value for red plus the distance from one sector to another; *0 + (3641 x 1)*. As another example, the distance from red to yellow was 3 segments represented as *0 + (3641 x 3)*.

Table 3 provides a breakdown of the numeric values by color.

Table 3

Numeric Values by Color

Hue	Numeric Value
Red	0
Orange	0 + (3641 x 1) = 3641
Yellow	0 + (3641 x 3) = 10923
Green	0 + (3641 x 6) = 21846
Blue	0 + (3641 x 12) = 43692
Purple	0 + (3641 x 14) = 50974
Magenta	0 + (3641 x 16) = 58256

The literature points out that previous studies failed to control for brightness and saturation (Silverstein, 1987), making it impossible to determine whether subjects responded to color cues brightness or saturation cues. Learning from the mistakes of the past, this study controlled for brightness and saturation by assigning numeric values and holding them constant across the eight colors. For the purpose of this study, brightness was set at 62640 and saturation was set at 62810. These values were entered via the control panel on the general controls screen on the Macintosh IIci computer.

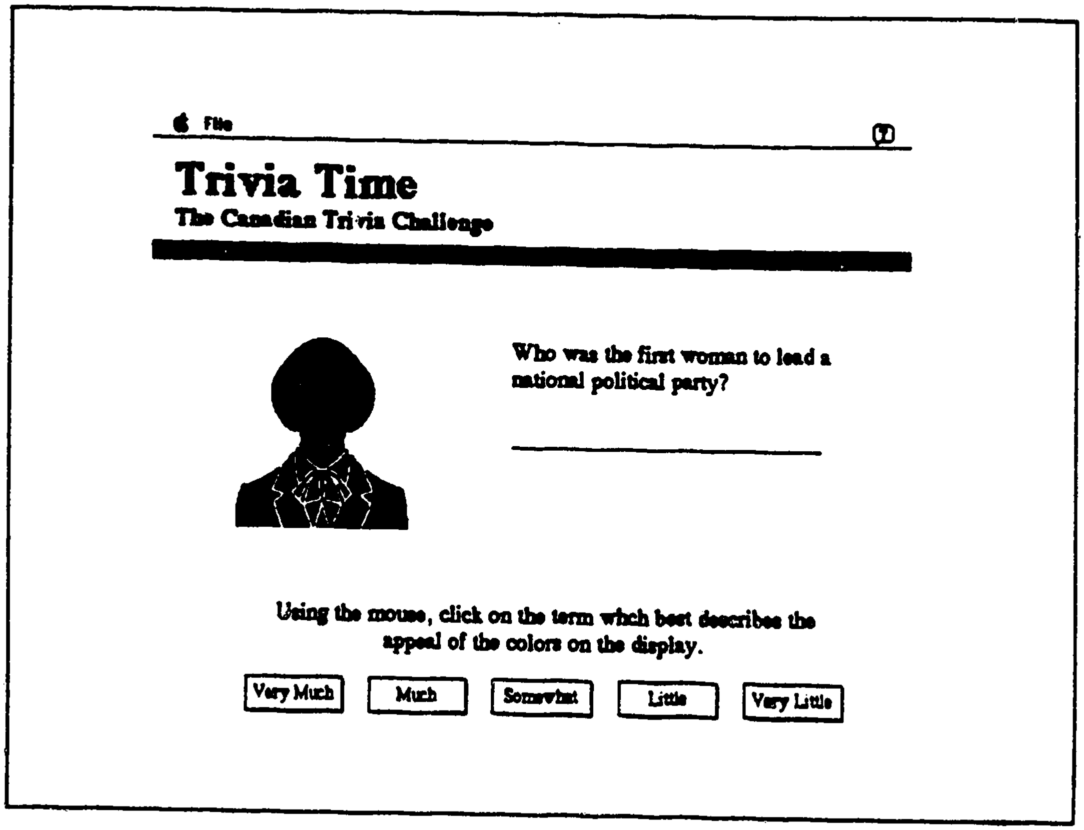
Each of the 70 displays consisted of four color-coded elements: title bar (Trivia Time: The Canadian Trivia Challenge); Canadian trivia question, answer and feedback; graphic and rating scale.[1] As part of the colorization process, the list of color combinations was randomized as was the assignment of individual colors to the display elements. However, each color

[1] The graphics displayed in the on-line survey represent a sampling from the PicturePak clip art libraries from Marketing Graphics Incorporated (MGI) P.O. Box 6589, Richmond, VA 23230. (804) 353-0443 (c) 1988, 1989, 1990. A letter authorizing the researcher to use these graphics in the conduct of this study is included in Appendix F.

combination, once established by this process, remained the same for each respondent. As a result, the rating for each combination was limited by the context within which the four colors were presented. See Figure 4 for a sample display format.

Figure 4

Sample Display Format



__Procedures.__ The survey software files were installed on the file server for the network located in the Macintosh computer laboratory. Two levels of security were established through the use of passwords. One provided access to the survey software (Level 1); another to the screen from which survey was executed (Level 2). In advance of each experimental session, the researcher accessed the survey software using the designated password. Following the subjects' arrival at the lab, the researcher provided access to the run screen.

An animated title page marked the beginning of the on-line color preference survey. (See

Appendix F). Part 1 of the survey followed. At this point, subjects were instructed to complete a series of statements pertaining to background and computer experience by filling in the blank or keying the number corresponding to the appropriate response. Statements 1 and 2 required that subjects enter the respondent identification number and year of birth. Note that a no-response option was provided for each statement, enabling subjects to bypass sensitive statements. See Appendix G for a reproduction of Part 1 (Background Information).

Part 1 of the on-line survey was followed by the purpose of the study (Appendix H) and instructions for completing Part 2 (Appendix I). To ensure the process was clearly understood, a simulation of the response process was provided. Subjects were advised on-screen that the instructions were available in print form if required, but this option was not exercised. By depressing the return key, subjects were able to advance to Part 2, the color preference survey itself. The 70 displays were presented in random order. After studying each display carefully, subjects responded to the Canadian Trivia question by keying an answer and depressing the return key or depressing the return key to display the correct answer. In the event of an incorrect response, the computer provided the correct answer. Once the trivia question was dealt with, subjects rated the appeal of the combination of colors on the display using a five-point Likert scale (Very Much [1], Much [2], Somewhat [3], Little [4], Very Little [5]). In making this assessment, subjects were instructed to imagine the combination of colors on each and every screen of a computer-based course. He or she was asked the extent to which the combination was pleasing to the eye and would it have an instrumental or detrimental effect on learning? Using the mouse subjects clicked on the term in the scale which best described the appeal of the colors on the display, causing the next display to be presented. An untimed exercise, this process was repeated until all 70 displays were rated. Since this exercise did not exceed one hour for any of the subjects, it was felt a fatigue factor would not be introduced. See Appendix J for a list of

Canadian trivia questions and answers.

Pilot Testing. The on-line survey was piloted by two people prior to data collection. They evaluated the survey in terms of clarity of instructions, ease of completion and aesthetics. Since their feedback was positive, no revisions were required.

Methodology

Data Collection

Upon arriving at the Macintosh Computer Lab, each subject was seated at a work station. At this time, the consent form (Appendix K) was completed and a respondent identification number was assigned. The date and the subject's name were recorded in a subject log (Appendix B) to facilitate data maintenance in the event of a database error. The experimental procedures were briefly explained and the use of the return, backspace and delete keys and the mouse was described to those unfamiliar with computer technology. Following this, the researcher entered the Level 2 password, enabling the subject to commence the survey. Once the survey was completed, the Farnsworth Panel D-15 Test was administered. Once the subject left the facility, the researcher recorded the outcome of the D-15 on the subject log. Figure 5 summarizes the experimental procedures.

Figure 5

Experimental Procedures

Subject Entry

Time

- Subject seated at work station.
- Consent form completed.
- Respondent identification number assigned.
- Date and subject's name recorded in subject log.
- Experimental procedures explained.
- On-line survey completed.
- Farnsworth Panel D-15 Test administered.
- Outcome of D-15 recorded in subject log.

Subject Exit

Data Analysis

Subject Data. Background information, including demographic, educational, visual and computer experience data was collected in Part 1 of the on-line color preference survey which was completed by all subjects. These data were summarized and presented in tabular form.

Color Preference Data. Color preference data was collected in Part 2 of the on-line color preference survey. Subjects rated the appeal of 70 combinations of four colors deriving from the colors red, yellow, green, blue, purple, magenta and black using a five-point Likert scale (Very Much, Much, Somewhat, Little, Very Little). Mean scores and standard deviations were calculated for each of the combinations and the associated data were summarized and presented in tabular form. Subsequently, grand mean scores were calculated for the 10 most popular combinations and the 10 least popular combinations. These were then subjected to a two-tailed t-test to determine whether the difference in the grand means between the two groups were statistically significant. The results of this analysis were summarized and presented in tabular form.

Color Preference and Age. Mean color preference scores and standard deviations were calculated for each color combination for four age groups (20 - 29, 30 - 39, 40 - 49 and 50 +). The significance of the interaction between color preference and age was evaluated using analysis of variance (ANOVA). The foregoing data and the results of the analysis were summarized in tabular form.

Color Preference and Gender. Mean color preference scores and standard deviations were calculated for each color combination for both genders. ANOVA was used to test for the significance of a relationship between color preference and gender. The data and resulting analysis were summarized in tabular form.

Color Preference and Computer Experience. As the number of non-computer users was less than that required to produce meaningful statistics (five), the relationship between color preference and computer experience was not explored.

Summary

One hundred and twelve volunteer subjects with normal color discrimination 20 years of age and older participated in this study. The data for this study were collected using an on-line color preference survey consisting of two parts; background information was collected in Part 1 and color preference data was collected in Part 2. Mean scores and standard deviations were calculated for each of the combinations, then grand mean scores were calculated for the 10 most preferred combinations and the 10 least preferred combinations. A two-tailed t-test was used to determine whether the difference in the means between the two groups were statistically significant. ANOVA was used to test for a possible relationship between color preference and age and gender. It was not possible to explore the relationship between color preference and computer experience. The resulting data, analyses and findings are presented in the following chapter.

CHAPTER FOUR

DATA ANALYSIS AND RESULTS

Introduction

An analysis of findings of the study is presented in this chapter. The sample is described in terms of demographics, education, and visual characteristics and computer experience. The preferences for combinations of four colours presented on a multi-color display using a grey background were examined. The mean scores and standard deviations were calculated for each of the 70 combinations and the grand mean scores for the 10 most preferred and 10 least preferred combinations were tabulated. To determine whether the difference in the grand mean scores between the two groups was statistically significant, a two-tailed t-test was conducted. The interaction of color preference and age group, gender and previous computer experience was evaluated using ANOVA. The results of these statistical analyses are presented here.

Subject Data

Relevant information was gathered using Part 1 (Background Information) of the on-line color preference survey. Demographic, educational, visual and computer experience data are presented in Table 4.

Demographic Data

The subjects ranged in age from 22 to 75. As seen in Table 4, 19.8% of the subjects in this study were 20-29 years of age; 32.4% were 30-39 years; 26.1% were 40-49 and 21.6% were 50 years of age or older. Male subjects comprised 38.4% of the sample and female subjects 50.9%. Gender information was unavailable for the remaining 10.7% of the sample. For the most part, the sample tended to be either married (47.3%) or single (27.7%).

Table 4

Subject Data (N=112)

Characteristics	Results n	%	
Demographic			
20 - 29 years	22	19.8%	
30 - 39 years	36	32.4%	
40 - 49 years	29	26.1%	
50+ years	24	21.6%	
Males	43	38.4%	
Females	57	50.9%	
No response	12	10.7%	
Single	31	27.7%	
Married	53	47.3%	
Separated	7	6.3%	
Divorced	11	9.8%	
Common-law	5	4.5%	
No response	5	4.5%	
Educational			
Years of training beyond high school			
None	5	4.5%	
One	19	17.0%	
Two	16	14.3%	
Three	11	9.8%	
Four	11	9.8%	
More than four	42	37.5%	
No response	8	7.1%	
Currently a student			
Yes	38	33.9%	
Graduate school (13)			11.6%
Undergraduate program (14)			12.5%
Extension program (5)			4.5%
College (2)			1.8%
Technical school (1)			.90%
Other (1)			.90%
No	69	61.6%	
No response	5	4.5%	
Visual (Glasses or Contact Lenses)			
Yes	79	70.5%	
No	28	25.0%	
No response	5	4.5%	

Table 4 (continued)

Characteristics	Results	
	n	%
Previous Computer Experience		
Yes	105	93.8%
No	5	4.5%
No response	2	1.8%

Education

This sample was well educated with 88.4% having completed post-secondary preparation. A significant number of subjects (37.5%) had completed more than fours years of training beyond high school. The data show that 33.9% of the subjects had a student status at the point of data collection, 36.8% of which were enrolled in an undergraduate program and 34.2% of which were in graduate school.

Visual Characteristics

As expected the majority of subjects in this sample wore glasses or contact lenses (70.5%). All subjects had normal color discrimination as determined by the Farnsworth Panel D-15 test. Six additional subjects participated in the data collection phase of the study but were omitted from the analysis based on their performance on the Farnsworth Panel D-15 Test of color blindness; a diagnosis of normal vision with no error was necessary for inclusion in this study.

Computer Experience

Most of the sample (93.8%) possessed previous computer experience at the point of data collection. As seen in Table 4, 77.1% of this group used a microcomputer on a regular basis and 91.4% felt comfortable with the technology. The non-computer users constituted 4.5% of the subjects in this sample. Despite their inexperience, 60.0% were interested in learning how to utilize the technology and 60.0% of subjects believed they had the capacity to learn. Computer experience data were unavailable for 1.8% of the sample.

Color Preference Data

The purpose of this study was to investigate adult preferences for all possible combinations of four colors from a base of eight presented on a multi-color display using a grey background. As described in chapter three, the required data were collected using an on-line color preference survey. Subjects rated the appeal of 70 combinations deriving from the colors red, yellow, green, blue, purple, magenta and black using a five-point Likert scale (Very Much [1], Much [2], Somewhat [3], Little [4], Very Little [5]). Color preferences were assessed on the basis of mean scores. For the purpose of comparison, the means were ranked in ascending order. The smaller the mean score, the stronger the preference and vice versa.

The overall mean scores and standard deviations for the ten most preferred and ten least preferred color combinations are presented in Tables 5 and 6. Complete data for all 70 four-color combinations are reported in Appendix L. Here the colors within each combination are presented in alphabetical order. The subjects in this study most preferred the combination of blue, red, purple and black as indicated by a mean of 2.02. A mean of 4.17 was observed for the least preferred combination of yellow, green, orange and red.

Table 5

Means and Standard Deviations of the 10 Most Preferred Color Combinations

Color Combination	Mean	SD
Blue, red, purple, black	2.02	.89
Purple, magenta, black, yellow	2.09	.82
Purple, blue, black, magenta	2.23	.93
Orange, black, red, purple	2.33	.99
Red, yellow, purple, black	2.34	.92
Red, magenta, blue, black	2.36	.90
Yellow, black, blue, red	2.40	.97
Yellow, purple, blue, red	2.42	.91
Magenta, purple, blue, red	2.47	.98
Red, black, magenta, purple	2.47	.91

An analysis of Table 5 reveals that several colors were very popular. As seen in Table 5, the colors red, purple and black appeared eight times out of 10, while blue appeared six times and magenta five times. It is interesting to note that the color green is absent from this list. The combination of red, purple and black was found to exist in four of these combinations, while red, purple and blue were found in three. The combination of red with either purple or blue was present in five of the color combinations with the best overall mean scores.

Of the top five combinations, six included the combination of red, purple and black, while the remaining four included magenta, purple and black. Note that the controversial combination of red and blue is absent from this list (Durrett & Trezona, 1982; Alessi & Trollip, 1985).

Table 6 summarizes the mean scores and standard deviations for those combinations which were least preferred. Virtually every combination in Table 6 is characterized by the presence of green and yellow (which is in six of the 10 combinations) or green and orange (which is in four); and the least preferred combination of colors includes green, yellow *and* orange. All eight colors are included in the combinations represented in Table 6.

Table 6

Means and Standard Deviations of the 10 Least Preferred Color Combinations

Color Combination	Mean	SD
Orange, magenta, green, red	3.87	1.03
Black, green, yellow, blue	3.92	1.02
Yellow, magenta, green, red	3.92	.96
Black, green, purple, orange	3.94	.88
Magenta, black, green, orange	3.94	.89
Yellow, magenta, green, purple	3.97	1.02
Purple, black, green, yellow	4.02	.90
Magenta, yellow, green, blue	4.05	.88
Purple, green, blue, orange	4.13	.72
Yellow, green, orange, red	4.17	.80

The grand mean scores for the 10 most preferred and 10 least preferred combinations and the results of the two-tailed t-test are presented in Table 7.

Table 7

Comparison of Grand Means of the 10 Most Popular and 10 Least Popular Color Combinations

Grand Mean of the 10 Most Preferred Combinations = 2.35 SD = .57		
Grand Mean of the 10 Least Preferred Combinations = 3.99 SD = .64		
t = -23.24	DF = 111	2-Tail Prob. = .00

As seen in Table 7, the grand mean score for the 10 most preferred combinations was 2.35 and the grand mean score for the 10 least preferred combinations was 3.99. A two-tailed t-test produced a t value of -23.24 with a two-tail probability of .00. This was statistically significant at the .05 level.

Color Preference and Age

The interaction of color preference and age group was evaluated using ANOVA at the .05 level of probability. The results of these analysis reveal only seven (of a possible 70) instances where the differences between the mean scores for the four age groups reached statistical significance. In other words, 63 combinations showed no statistically significant differences, leading the researcher to conclude there was very little practical relevance. These data are discussed below.

The mean scores and standard deviations for the combination of blue, green, purple, and magenta for each of the four groups are summarized in Table 8. The data revealed this color combination to be least popular with the 40 - 49 age group (4.13), followed by the 30 - 39 age group (3.63), and the 50+ age group (3.62). The combination of blue, green, purple and magenta was most popular with subjects 20 - 29 years of age (3.27). As seen in Table 8, the mean scores increased with age group, until 50+ at which point a decrease in mean score is observed. The F score of 2.71 yields a significance of .03, confirming significant differences (.05 level).

Table 8

Analysis of Variance - Age Group and Blue, Green, Purple and Magenta

Age Group			Mean		SD
20 - 29			3.27		1.20
30 - 39			3.63		1.01
40 - 49			4.13		.83
50+			3.62		1.09
Source of Variation	**SS**	**D.F.**	**Mean Square**	**F**	**Sig of F**
Between	11.53	4	2.88	2.71	.03
Within	113.74	107	1.06		

Table 9 presents a summary of the means and standard deviations for the combination of green, magenta, orange and purple for each of the four age groups. Inspection of the means indicate that only slight differences exist between the groups. Further inspection reveals that this combination is least preferred by the 30 - 39 age group (3.75), followed by the 40 - 49 (3.62), the 20 -29 (3.31) and the 50 + groups respectively. The F score is 2.89 giving a significance of .02.

Table 9

Analysis of Variance - Age Group and Green, Magenta, Orange and Purple

Age Group			Mean		SD
20 - 29			3.[illegible]1		.89
30 - 39			3.7[illegible]		.90
40 - 49			3.6[illegible]		.86
50+			3.[illegible]		.97
Source of Variation	**SS**	**D.F.**	**Mean Square**	**F**	**Sig of F**
Between	9.56	4	2.39	2.89	.02
Within	88.35	107	.82		

A summary of the means and standard deviations for the combination of yellow, magenta, green and purple for each of four age groups is presented in Table 10. An inspection of the means indicates substantial differences between the groups. As seen in Table 10, the highest mean score (4.34) belongs to the 40 - 49 years-olds. This group liked the combination of yellow, magenta, green and purple less than the others. The 30 - 39 year-olds liked this combination more than the 40 - 49 year-olds (4.05); however with mean in the range of 4.05 and 4.34, neither group liked the combination much. The 20 - 29 age group rated these colors more favourably than did the previous groups (3.68). The combination of yellow, magenta, green and purple was most popular with the 50+ group (3.62). Table 10 shows the mean scores increasing with age group, until 50+ at which point a decrease in mean score is observed. The results of the ANOVA revealed an F score of 2.52 with a significance of .04. Thus, there are significant differences (.05).

Table 10

Analysis of Variance - Age Group and Yellow, Magenta, Green and Purple

Age Group			**Mean**		**SD**
20 - 29			3.68		1.12
30 - 39			4.05		.82
40 - 49			4.34		.89
50+			3.62		1.20
Source of Variation	**SS**	**D.F.**	**Mean Square**	**F**	**Sig of F**
Between	10.08	4	2.52	2.52	.04
Within	106.83	107	.99		

Table 11 presents a summary of the means and standard deviations for the combination of orange, magenta, green and red for each of the four groups. Inspection of the means reveal that the 40 - 49 year-olds as having the highest score (4.10); therefore the lowest rating. The 30 - 39 year-olds similarly disliked this combination as indicated by a mean score of 4.02. The mean decreased slightly for the 20 - 29 age group (3.81). A mean of 3.37 is indicative of a much more favourable judgement on the part of subjects 50 years of age and older. The results revealed an F score of 2.38, which was significant at the .05 level.

Table 11

Analysis of Variance - Age Group and Orange, Magenta, Green and Red

Age Group			**Mean**		**SD**
20 - 29			3.81		.90
30 - 39			4.02		.94
40 - 49			4.10		1.11
50+			3.37		1.05
Source of Variation	**SS**	**D.F.**	**Mean Square**	**F**	**Sig of F**
Between	9.69	4	2.42	2.38	.05
Within	108.55	107	1.01		

Summaries of the means and standard deviations for the combination of green, black, yellow and orange for each of the age groups are summarized in Table 12. With a mean of 3.90, the youngest age group disliked this combination more than any other group. The 40 - 49 and 30 - 39 age groups show mean scores of 3.65 and 3.38, respectively. As seen in Table 12, the combination of green, black, yellow and orange is most popular with the subjects 50 years of age and older. The results of an ANOVA on the mean scores for the combination of green, black, yellow and orange yielded an F score of 2.49 which is significant at the .05 level.

Table 12

Analysis of Variance - Age Group and Green, Black, Yellow and Orange

Age Group	Mean	SD
20 - 29	3.90	.86
30 - 39	3.38	.99
40 - 49	3.65	.76
50+	3.25	.98

Source of Variation	SS	D.F.	Mean Square	F	Sig of F
Between	8.35	4	2.08	2.49	.04
Within	89.42	107	.83		

Table 13 summarizes the means and standard deviations of the mean scores for the combination of black, green, blue and yellow for each of the four age groups. Inspection of the means reveal that the preference for this combination of colors was approximately equal for the oldest three age groups. The 30 - 39 age group had a mean of 4.02; the 40 - 49 a mean score of 4.00 and the 50+ group a mean score of 4.12. With a mean of 3.34, the combination of black, green, blue and yellow was most popular with the youngest group of subjects. The F score was 2.40 with a significance of .05, which confirms significant differences in mean scores for the combination of black, green, blue and yellow for the four groups.

Table 13

Analysis of Variance - Age Group and Black, Green, Blue and Yellow

Age Group	Mean	SD
20 - 29	3.36	1.04
30 - 39	4.02	1.08
40 - 49	4.00	.88
50+	4.12	.94

Source of Variation	SS	D.F.	Mean Square	F	Sig of F
Between	9.58	4	2.39	2.40	.05
Within	106.68	107	.99		

Summaries of the means and standard deviations for the combination of blue, red, purple and black for each of the age groups are summarized in Table 14. Inspection of the means indicates this combination was most preferred by subjects 40 - 49 years of age (1.68), followed by those in the 30 - 39 (2.00) and 20 - 29 (2.04) age groups. Subjects comprising the oldest age group least preferred the combination of blue, red, purple and black. The mean score for this group was 2.45. The results of ANOVA indicate significant differences (.05 level) in the mean scores for the combination of blue, red, purple and black between the four age groups.

Table 14

Analysis of Variance - Age Group and Blue, Red, Purple, and Black

Age Group			**Mean**		**SD**
20 - 29			2.04		.95
30 - 39			2.00		.86
40 - 49			1.68		.66
50+			2.45		1.02
Source of Variation	**SS**	**D.F.**	**Mean Square**	**F**	**Sig of F**
Between	7.79	4	1.95	2.57	.04
Within	81.11	107	.75		

<u>Color Preference and Gender</u>

The interaction of color preference and gender was evaluated using an ANOVA at the .05 level of probability. The results of this analysis reveal only four out of the 70 instances where the difference in mean scores reaches statistical significance. In other words, 66 combinations showed no significant differences. These figures, once again, led the researcher to conclude there was very little practical relevance. These data are discussed below.

The means and standard deviations for the combination of yellow, magenta, green and purple for gender are summarized in Table 15. An inspection of the means reveal that the males (4.18) disliked the above-noted combination more than the females (3.70). The subjects who failed to report gender had a mean of 4.50, a rating which translated somewhere between *Little* (4.00) and *Very Little* (5.00). ANOVA revealed a probability level of .01 thus indicating there are significant differences in the mean scores for the combination of yellow, magenta, green and purple for gender.

Table 15

Analysis of Variance - Gender and Yellow, Magenta, Green and Purple

Gender			**Mean**		**SD**
Male			4.18		.85
Female			3.70		1.13
No Response			4.50		.67
Source of Variation	**SS**	**D.F.**	**Mean Square**	**F**	**Sig of F**
Between	9.47	2	4.73	4.80	.01
Within	107.44	109	.98		

Summaries of the means and standard deviations for the combination of orange, purple, yellow and blue are presented in Table 16. An inspection of the means reveal that the degree of preference was approximately equal for males (3.13) and females (3.36). The no response group, however, rated the combination of yellow, magenta, green and purple more positively (2.75) than the other two groups. ANOVA revealed an F score of 2.89, yielding a significance of .05. This confirms significant differences in mean scores for the combination of orange, purple, yellow and blue for the three groups.

Table 16

Analysis of Variance - Gender and Orange, Purple, Yellow and Blue

Gender			Mean		SD
Male			3.13		.88
Female			3.36		.85
No Response			2.75		.62
Source of Variation	**SS**	**D.F.**	**Mean Square**	**F**	**Sig of F**
Between	4.18	2	2.09	2.89	.05
Within	78.67	109	.72		

The mean scores and standard deviations for the combination of purple, orange, red and blue for gender are summarized in Table 17. An inspection of the means reveal comparable ratings across the three groups: 2.62 for the males, 2.89 for the females and 2.25 for the no response group. The mean scores suggest that the latter group judged this combination of colors most favourably. ANOVA revealed significant differences at the .05 level in mean scores for the combination of purple, orange, red and blue between the three groups.

Table 17

Analysis of Variance - Gender and Purple, Orange, Red and Blue

Gender			Mean		SD
Male			2.62		.95
Female			2.89		.90
No Response			2.25		.75
Source of Variation	**SS**	**D.F.**	**Mean Square**	**F**	**Sig of F**
Between	4.75	2	2.37	2.89	.05
Within	89.66	109	.82		

Summaries of the mean scores and standard deviations for the combination of magenta, purple, green and black for gender are presented in Table 18. An inspection of the means reveal the males had the highest mean score for the above-noted combination (4.00), followed by the females (3.47) and the no response group (3.83). Clearly, the combination of magenta, purple, green and black was most popular with the female segment of the sample. ANOVA yielded an F score of 2.92, giving a significance of .05. This confirms significant differences at the .05 level.

Table 18

Analysis of Variance - Gender and Magenta, Purple, Green and Black

Gender			Mean		SD
Male			4.00		.92
Female			3.47		1.19
No Response			3.83		1.11
Source of Variation	**SS**	**D.F.**	**Mean Square**	**F**	**Sig of F**
Between	6.97	2	3.49	2.92	.05
Within	129.87	109	1.19		

<u>Color Preference and Computer Experience</u>

As the number of non-computer users was less than that required to produce meaningful statistics (five), the relationship between color preference and computer experience was not explored.

Summary

In summary, the results of this study reveal that this sample was comprised of adults of various ages with adequate representation from both genders. Most subjects in this study reported previous computer experience.

The total sample most preferred the combination of blue, red, purple and black. The findings indicate that the 10 most preferred combinations of colors included red, purple, black, blue and magenta to the exclusion of green and a reduced occurrence of yellow and orange. The inclusion of either red, purple and black or red, purple and blue was characteristic of this set of combinations. Each of the 10 least preferred combinations included the combination of green and yellow or green and orange, with the lowest ranking combination encompassing green, yellow *and* orange, along with red. The difference in the grand mean scores for the 10 most preferred and the 10 least preferred combinations was proven to be statistically significant using a two-tailed t test. This is an important finding which lends credence to the difference between the grand means between the two groups.

Investigation into the relationship between color preference and age revealed seven significant results for only seven of 70 combinations. Given this small proportion, it is reasonable to conclude that, overall, there was very little practical relevance. Exploration into the interaction of color preference and gender showed that only four combinations reached statistical significance. Again, it is reasonable (if not necessary) to conclude there was little practical significance. The statistical analysis pertaining to the relationship between color preference and computer experience was precluded due to insufficient numbers, and therefore the nature of the relationship between the above-noted variables remains unknown.

CHAPTER FIVE

SUMMARY, DISCUSSION, IMPLICATIONS AND RECOMMENDATIONS

This chapter provides a summary of the study and a discussion of the findings presented in Chapter 4. The researcher considers implications for the design of color displays intended for use within the instructional computing context and advances recommendations for further research.

Summary

The purpose of this research was to examine adult preferences for combinations of four colors presented on a color display using a grey background. An on-line color preference survey was developed for the purpose of collecting demographic and color preference data. The design of the survey was based on the literature from the broader areas of instructional design, graphic arts, ergonomics and human factors, color vision and computer-based instruction. The literature was consistent in the attention paid to the following practical considerations which were addressed in the design specifications and hence controlled for in this study: foreground color, background, contrast, brightness, saturation, combinations of colors, number of colors and the use of common color denotations. This study included all possible combinations of four from a base of eight colors, including red, orange, yellow, green, blue, purple, magenta and black. This resulted in a total of 70 combinations, each of which were presented on a single display in the on-line survey. The displays consisted of four basic elements: title bar; Canadian trivia question, answer and feedback; a graphic and a rating scale. Random assignment was used to match the color combinations to the Canadian trivia questions. This same process was used to match the colors in each combination to the four elements on the display. It is important to note that the Canadian trivia questions were presented in random order, such that each subject was presented with a computer generated sequence of questions. The color preference component of the survey required that participants rate the appeal of the combination of colors on the display using a five-point Likert scale: Very Much, Much, Somewhat, Little and Very Little. The demographic component of survey was included to describe the demographic, educational, visual and computer experience characteristics of the sample.

The on-line survey was administered to 118 adults, however, six were excluded from the analysis based on the results of the Farnsworth Panel D-15 test of color blindness. Only those adults with a diagnosis of normal color vision with no error were included. Mean scores and standard deviations were calculated for each of the 70 combinations. Subsequently, grand mean scores were tabulated for the 10 most preferred and the 10 least preferred combinations. These were then subjected to a two-tailed t-test to determine whether the difference in the grand means between the two groups were statistically significant. The relationship between color preference and age, gender and computer experience was explored using ANOVA.

Discussion

The following discussion addresses the demographic characteristics, color preference data and the relationship between color preference and age, gender and computer experience. Caution must be exercised when drawing conclusions from the findings of this study. The extent to which these findings can be generalized to the population of adults is limited by the specific selection of colors and the levels of brightness and saturation used in this investigation. Furthermore, it was impossible to determine the basis upon which a rating was assigned. Was it the presence of three legible colors that led a subject to rate a combination favourably? Was it the presence of a single poorly legible color that caused a subject to rate a combination unfavourably? Or was it the contrast created by the interaction of the combination of colors with the grey background?

Demographic Characteristics

The sample of volunteers consisted of 112 adults ranging in age from 22 to 75. Male subjects comprised 38.4% of the sample and female subjects 50.9%. The majority of subjects were married (47.3%). With almost half of the subjects having more than four years of training beyond high school, the sample is well educated. Many of the subjects were students at the time of data collection (38%), 34.2% of which were in graduate school and 36.8% of which were enrolled in an undergraduate program. The majority of the subjects reported wearing glasses or contact lenses, which is consistent with the literature on age-related physiological changes.

Color Preference

Color preference data were collected using a researcher-developed on-line color preference survey. The Macintosh version of Authorware Professional was utilized for the development; the product of which was used to present the 70 displays and collect the data. This sample preferred combinations consisting of red. purple, black, blue and magenta; the colors which may have given the appearance of greater vividness. The most popular combination was blue, red, purple and black, followed by purple, magenta, black and yellow; purple, blue, black and magenta; orange, black, red and purple; red, yellow, purple, and black; red, magenta, blue and black; yellow, black, blue and red; yellow, purple, blue and red; magenta, purple, blue and red; and red, black, magenta and purple. Interestingly, the color green was not included in the 10 most preferred combinations of colors.

The least preferred combinations were characterized by green and yellow and green and orange; colors which may have been perceived as the least vibrant of the eight colors included in the study. The least popular of the 70 combinations was yellow, green, orange and red. Note this combination included the colors which may have given the appearance of lesser vividness. (green, yellow and orange). The next least popular combination was purple, green, blue and orange; followed by magenta, yellow, green, and blue; purple, black, green and yellow; yellow, magenta, green and purple; magenta, black, green, and orange; black, green, purple and orange; yellow, magenta, green and red; black, green, yellow and blue; and orange, magenta red and green. The difference between the grand mean scores for the 10 most preferred and the 10 least preferred combinations was proven to be statistically significant.

The researcher found no studies in the literature which investigated adult preferences for multiple-color combinations presented on a computer display. Focusing on the effect of single colors, Start (1989) explored the best colors for audiovisual materials. The most relevant study was conducted by Holcomb and D'Angelo (1991) who investigated the relationship between color preference and combinations of two colors presented on a color display for computer users over the age of forty. Galitz (1981), the only author to address the use of four-color combinations, recommended that red, green, blue and white be used to emphasize and convey separation among display elements. Unfortunately, this combination was excluded from this study as the researcher felt that white would not provide adequate contrast against the grey background.

Without benefit of previous studies, the researcher can only speculate as to the basis for the results of this study. The findings of this study suggest the colors which gave the possible appearance of greater vividness were most popular with the subjects. Combinations comprised of red, purple, black, blue and magenta outperformed combinations comprising green, yellow and orange. Of one thing the researcher is certain--brightness and saturation did not affect the results of this study as those variables were carefully controlled. The researcher theorized that the findings are a direct result of the contrast created by the various combinations against the grey background. It may well be that the colors which gave the possible appearance of greater vividness (red, purple, black, blue and magenta) provided better contrast against the grey background than did the colors which gave the possible appearance of lesser vividness (green, yellow and orange). Note the latter group of colors predominated the lowest ranking combinations; appearing to affect a less legible display. This line of thinking is consistent with Faiola and DeBloois (1988) who recommend that designers focus more on value (brightness) than hue to enhance the legibility of text. The viewpoint that adequate contrast contributes to legibility is supported by Durrett and Trezona (1982).

Pettersson (1985) reported that the color blue was ranked most popular in studies of perceived effort in reading text on a high resolution color display. It is interesting to note that in this study the color blue appeared in the 10 most preferred combinations with considerable frequency.

Smith (1987) explained the differential sensitivity of the eye to different wavelengths of light:

> ...if the eyes are adapted to a typically lighted environment, maximum sensitivity is in the green or yellowish green regions of the visible spectrum. For a dark-adapted eye (working in a very dark office), they eyes are actually more sensitive to colors at the lower end of the visible spectrum, in the blue-green range (p. 109).

This study was conducted in the Instructional Technology Macintosh laboratory, a facility with adequate illumination provided by overhead fluorescent lighting. This, in the researcher's view, satisfies the criterion of a typically lighted room as described above. The study notes that subjects least preferred combinations which included green and yellow and most preferred those comprised of the more vivid colors such as blue. This finding is inconsistent with the concept of differential wavelength sensitivity.

The literature suggests that the color blue becomes less legible with age. The yellow filter effect occurs when the amount of light entering the eye is reduced and the shorter wavelengths of light are filtered out. This study observed that the shorter wavelength colors were well represented in the 10 most preferred combinations. Purple was included in eight of these combinations and blue was included in six, indicating that these colors may be more discriminable than previously reported.

Saxton (as cited in Holcomb & D'Angelo, 1991) states that older individuals having color discrimination deficiencies are more capable of distinguishing reds and yellows than blue, greens and purples. Schulz and Ewen (1988) concur with Saxton except for the inclusion of orange in the list of more discriminable colors. That red was included in eight of the 10 most preferred combinations appears to support the viewpoint of Saxton and Schulz and Ewen (1988). The inclusion of purple in eight of the most preferred combinations and the prevalence of the combinations of red, purple and black (four) and red, purple and blue (three) seemingly contradict the assertion that purple is poorly legible. Perhaps the foregoing authors were referring to a lighter shade of purple than was used in this study. It is argued that the absence of the color green from the 10 most popular combinations indicates a lack of popularity with this sample. The absence of green may also support the notion that color green is poorly legible.

The literature strongly supports the use of green, cyan, white and yellow. Hauesing (as cited in Reynolds, 1979); Durrett and Trezona (as cited in Alessi & Trollip, 1985) and Reynolds (1979) respectively describe the color yellow as identifiable, perceptible and legible. It is important to note that this perspective is advanced within the specific context of computer display design. Interestingly, yellow was included in only four of the 10 most preferred combinations where it was always combined with the more vivid colors including red, blue, purple, black and magenta. In other words, the presence of the more vivid colors may have had more to do with the high ratings for these combinations than did the mere presence of the color yellow. Yellow was included in five of the 10 least preferred combinations. This study provides evidence which neither supports or refutes the legibility of yellow.

The results of this study appear to refute Reynolds (1979) claim that green and white light provide the best acuity. That the least popular combinations included the color green is in keeping with Saxton (as cited in Holcomb & D'Angelo, 1991) and Schulz and Ewen (1988) who assert that green is difficult to perceive as a result of the yellow filter effect. Smith (1987) suggests that the light-adapted eye is most sensitive to colors which cluster around the green end of the visible spectrum. Perhaps this so-called sensitivity is uncomfortable to the eye, thereby affecting the legibility of green and the extent to which it is preferred.

The popularity of the color red is indicated by the inclusion of red in eight of the 10 most preferred combinations. This finding appears to be consistent with statements that the color red is identifiable (Hauesing as cited in Reynolds, 1979), legible (Meister & Sullivan as cited in Silverstein, 1987) and readily discriminable for older persons with distorted color discrimination (Saxton as cited in Holcomb & D'Angelo, 1991; Schulz & Ewen, 1988). Murch and Huber (as cited in Narborough-Hall, 1985) report that many authors support the use of red provided that contrast requirements are satisfied. In this study, the color red was placed against a grey background with a relatively low level of saturation; thereby creating a situation of good contrast.

Several authors recommend that red and blue not be used together on the same display (Pariseau as cited in Madge, Meyer & Sweezie, 1986; Durrett & Trezona, 1982; Reynolds as cited in England, 1984; Alessi & Trollip, 1985). It is interesting to note that in this study five of the 10 most popular combinations included red and blue, while the lowest ranking combinations excluded it. Hence, the subjects in this study did not appear to react negatively to the pairing of red and blue.

Alessi & Trollip (1985) advise against the use of yellow and blue; and red and green together on the same screen citing the latter combination as incompatible. In this study, it was observed that yellow and blue was included in two of the 10 most preferred combinations as well as in two of the 10 least preferred combinations. Interestingly, the combination of red and green did not appear in the most popular combinations and was included in only two of the least preferred combinations. These findings are not definitive enough to affirm or negate the recommendations pertaining to the use of yellow and blue, and red and green.

Color Preference and Age

An analysis of variance revealed a significant relationship between color preference and age for seven of 70 color combinations. The affected combinations are listed below: blue, green, purple and magenta; yellow, magenta, green and purple; orange, magenta, green and red; green, magenta, orange and purple; green, black, yellow and orange; black, green, blue and yellow; and blue, red, purple and black.

The pattern of means for the first three combinations revealed an increase from the 20 - 29 age group to the 30 - 39 age group, through to the 40 - 49 age group. The means then decreased for those 50 years of age and older. In other words, the 40 - 49 years-olds had the highest mean scores (the lowest degree of preference). Furthermore, the 50+ age group had the smallest means for the combinations yellow, magenta, green and purple; and orange, magenta, red and green (the greatest degree of preference). Including the color green, it is interesting to note that each of these combinations were also included among the lowest ranking combinations. The literature reports a decreasing capacity to discriminate shorter wavelengths of light (i.e., violet, blue, blue-green and green) with increasing age (Cristarella; Pokorny, Smith, Verriest & Pinckers as cited in Acheson Cooper, 1985; Holcomb & D'Angelo, 1991). One must question why the 50+ group most preferred combinations consisting of colors which are said to be poorly legible for older adults. One possible explanation may be that the most dramatic changes in color perception are alleged to occur around age 40, when the yellow filter effect comes into play. The nature of change, itself, may be the basis for the harshest ratings for the above combinations. Individuals 50 years of age and older, on the other hand, may have adapted to a situation of reduced color discrimination. Consequently, the so-called poorly legible colors may be less perceptually difficult for these older adults. Clearly, the foregoing pattern of means is, in part, inconsistent with the current literature.

The results of ANOVA indicate significant differences (.05 level) in the mean scores for the combination of blue, red, purple and black between the four age groups. Upon inspection, the summary of the means revealed no obvious pattern. The mean scores indicate that this combination was most preferred by the 40 - 49 age group (1.68) and is least preferred by subjects 50 years of age and older (2.45). It is interesting to note that the combination blue, red, purple and black was rated most popular by the total sample.

This combination consists of the colors which give the possible appearance of greater vividness colors including blue and purple, which according to Schulz and Ewen (1988), are less discriminable than red, yellow and orange.

The popularity of this combination with the 40 - 49 year-olds and the lack of popularity with the 50 plus group may be explained by the dynamic of change. As previously discussed, the 40 - 49 year-olds are characterized as undergoing physiological changes which directly negatively impact on their color discrimination capabilities. It seems only reasonable that the more vivid colors would lend themselves to being more visible during the forties which mark the decline color vision system. That the combination blue, red, purple and black is least popular with those fifty years of age and older defies explanation on the part of the researcher.

The results of ANOVA indicate significant differences (.05 level) in the mean scores for the combination of green, magenta, orange and purple between the four age groups. Upon inspection, no obvious pattern is suggested by the mean scores. This combination was least liked by the 30 - 29 age group (3.75) and most liked by those fifty years of age and older (3.00). The research cannot offer any reasonable explanation for the above-noted findings.

Upon inspection, the mean scores for the combination green, black, yellow and orange fail to reveal an obvious pattern. This study observed that the 20 - 29 year-olds least preferred this combination (3.90) while the 50+ group most preferred it (3.25). Comprising green and yellow, colors identified as less discriminable for older adults, it is difficult to formulate a reasonable explanation for the popularity of this combination with the 50+ age group.

Upon inspection, the pattern of means for the combination of black, green, blue and yellow indicates that this combination is most preferred by the 20 - 29 age group (3.36). With means clustering around 4.00, the remaining age groups are approximately equal in their dislike of black, green, blue and yellow. The researcher cannot even speculate as to the basis for these findings.

Color Preference and Gender

The interaction between color preference and gender was evaluated using ANOVA. This analysis revealed only four instances where the differences in mean scores reached statistical significance: yellow, magenta, green and purple; magenta, purple, green and black; orange, purple, yellow and blue; and purple, orange, red and blue.

The results of this study indicate that the females preferred the combinations of yellow, magenta, green and purple; and magenta, purple, green and black more than did the males. It is noteworthy that both combinations comprise the colors magenta, purple and green. The problem is to rationalize the reason for these differences. One possible explanation relates to previous experience, and fashion may be one of them. The term fashion, as used here, extends beyond wardrobe to include items such as automobiles, home furnishings and the decorative arts. The researcher suggests the concept of gender socialization may adequately explain the foregoing difference in color preference as reported in this study.

The last two combinations to be discussed are orange, purple, yellow and blue; and purple, orange, red and blue. Common to these combinations are the colors purple, orange and blue. Inspection of the means scores revealed that males and females were approximately equal in terms of their preference for orange, purple, yellow and blue; (3.13 and 3.36, respectively) and purple, orange, red and blue (2.62 and 2.89, respectively). How might this be explained? The lack of research into the relationship between preference for combinations of four colors and gender make it difficult to even speculate as to the basis for these findings.

Color Preference and Computer Experience

The number of non-computer users in this sample was small (five), making it impossible to statistically evaluate the relationship between color preference and computer experience.

Implications for the Design of Color Displays

This study investigated adult preferences for combinations of four colors presented on a color display using a grey background and intended for use within the instructional computing context. Although the scope was limited by the selection of colors and the specific brightness and saturation levels used, this study yielded findings which were both interesting and useful. The primary objective of any display design effort is to communicate effectively and efficiently. This can only be accomplished by a thorough understanding of the conceptual nature and usage of color. The availability low-cost color computer technology has firmly established color as a standard design variable--one which must be carefully considered as part of the design process. The following section will discuss the implications for color display design based on the findings of this study.

The findings of this study revealed few significant differences, permitting the researcher to ultimately conclude there were no significant differences in color preference for adults of various of ages and both genders. This, in itself, suggests it is unnecessary to account for color to the extent one might think. By implication, the application of color to the design of computer displays cannot be left up to the personal preference of display designers; the preferences of the user group must be considered. The design of educational and other computer software should include a feature which enables users to select the colors of preference; in other words, change the default settings. Alternatively, designers should use the combinations most preferred by the sample in this study, avoiding those which were least preferred. As a guideline, designers should strenuously avoid combinations which are poorly discriminable and provide poor contrast. The display design process should include a review of the color specifications by the user group. Ideally, the software development project and display design process would conclude signoff by the user group, ensuring their color preferences were addressed.

Recommendations for Further Research

Research pertaining to color and computers is in its infancy. This study provides evidence that previous findings concerning the effects of color in print materials do not directly apply to the design of color displays. Clearly, further investigation into adult preferences for combinations of four colors presented on a color display using a grey background is required. The following recommendations derive from the findings of this study, which could serve as a pilot for color display design research.

This study investigated adult preferences for combinations of four colors presented on a grey background intended for use within the instructional computing context. All possible combination of four colors from a base of eight were studied, including red, orange, yellow, green, blue, purple, magenta and black. Brightness and saturation levels were carefully controlled. Studies incorporating the best shade of these colors in terms of contrast against a grey background should be conducted. The researcher therefore recommends that control over brightness and saturation be abandoned in favour of using colors which provide the best contrast.

The researcher further recommends similar studies be conducted using colors other than those used here. Random assignment was used to match the colors in each combination with the four display elements (title bar, Canadian trivia question, answer and feedback, graphic and rating scale). The extent to which the assignment of color to the specific display elements affects adult preferences for combinations of four colors on a grey background should be explored. Certain colors may actually perform better when applied to graphics rather than text. Extensive research is required if the boundaries of knowledge in the area of color display design are to be extended.

As a further recommendation, this study should be replicated using a larger sample of adults of various ages. Since this study excluded individuals diagnosed as having a color discrimination deficiency, further research needs to be done with color blind subjects. Color display design must take into account the special needs of the visually impaired to ensure the effectiveness of displays for the full range of participants in adult education.

While color preference is important to display design, effectiveness is also important (perhaps more so) and should therefore be the subject of future study. The final recommendation for further research pertains to the issue of contrast which has received little attention in the literature and is deserving of rigorous investigation; it may be that color per se is only as important as the contrast they provide when placed upon a specific background.

Conclusion

The present study found that combinations consisting of the potentially more vivid colors red, purple, black, blue and magenta were more popular than those consisting of the less vivid colors such as green, yellow and orange. These differences were proven to be statistically significant. Although there were significant relationships between color preference and age and color preference and gender, they were so few in number that the researcher ultimately concluded that these differences were of little practical relevance. From a practical point of view, the results of this study provide evidence that adults have a definite reaction to combinations of four colors presented on a computer display using a grey background. There is a need for researchers to determine which combinations produce positive reactions within specific adult groups, then incorporate them into computer display design. From a research point of view, the results of this study clearly lead to further study in the area of color and computers.

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The Farnsworth Panel D-15 Test

APPENDIX A

Letters of Invitation

STUDY ON ADULT PREFERENCES FOR COLORS PRESENTED ON A MULTI-COLOR DISPLAY

The last decade has witnessed an explosion in the use of the computer as an instructional tool. Recent advances in display technology have led to the use of color as a standard design variable. The rigorous application of color guidelines based on sound empirical research are necessary to take full advantage of the instructional benefits of color. Although general display design guidelines flood the literature, those pertaining to color are grossly under-represented. And those which do exist lack the consistency and comprehensiveness necessary to be useful. The time is ripe for investigation into the application of color to the design of multi-color displays used for computer-based instruction.

Hence the inception of this study, the purpose of which is to assess adult preferences for combinations of four colors presented on a multi-color display using a grey background and intended for use in computer-based instruction. I would like to take this opportunity to invite you to participate in this study. Your involvement as a subject is important and necessary for the advancement of research in the area of color display design.

The study will require that you complete a simple color blindness test along with a computer-based color preference survey. The survey consists of 70 multi-color displays presented one after the other. Each display is made up of color-coded four elements: a title, a Canadian trivia question, a graphic and a rating scale. You will be asked to:

1. Study each display carefully, paying special attention to the *combination of colors* used.
2. Respond to the Canadian trivia question by keying an answer and pressing the Return key. If you prefer not to specify an answer, simply press the Return key. The computer will provide feedback on your response.
3. Rate the appeal of the *combination of colors* on the display.

You will repeat this process until all 70 displays have been rated. The experiment will take approximately one hour of your time. It will be conducted on the University of Alberta campus in the ITC Macintosh computer lab located in room 155 Education South during the following time blocks:

Tuesdays	5:00 pm - 8:00 pm
Wednesdays	5:00 pm - 9:00 pm
Saturdays	2:00 pm - 4:00 pm

As a voluntary participant, you will have the right to *opt out* of the study at any time and your identity will be kept *strictly confidential* by the researcher. I am asking each participant to recruit up to 5 additional subjects, if possible.

If you are interested in participating in this study or have any questions or concerns, please feel free to contact me ITC lab or telephone me at XXX-XXXX. I look forward to talking with you. Thank you for your interest.

Sincerely, Stephanie Dolsky (Graduate Student)

STUDY ON ADULT PREFERENCES FOR COLORS PRESENTED ON A MULTI-COLOR DISPLAY

The last decade has witnessed an explosion in the use of the computer as an instructional tool. Recent advances in display technology have led to the use of color as a standard design variable. The rigorous application of color guidelines based on sound empirical research are necessary to take full advantage of the instructional benefits of color. Although general display design guidelines flood the literature, those pertaining to color are grossly under-represented. And those which do exist lack the consistency and comprehensiveness necessary to be useful. The time is ripe for investigation into the application of color to the design of multi-color displays used for computer-based instruction.

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If you are interested in participating in this study or have any questions or concerns, please feel free to contact me ITC lab or leave a message in my mailbox located on the 6th floor of Education South. Thank you for your interest.

Sincerely, Stephanie Dolsky (Graduate Student)

STUDY ON ADULT PREFERENCES FOR COLORS PRESENTED ON A MULTI-COLOR DISPLAY

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As a voluntary participant, you will have the right to *opt out* of the study at any time and your identity will be kept *strictly confidential* by the researcher. I am asking each participant to recruit up to 5 additional subjects, if possible.

If you are interested in participating in this study, please book an appointment to meet me at the lab by calling XXX-XXXX. I look forward to meeting with you. Thank you for your interest.

Sincerely,

Stephanie Dolsky (Graduate Student)

APPENDIX B

Sample of Subject Log

SUBJECT LOG

ID Number	Date	Name	Normal Color Discrimination?
101			
102			
103			
104			
105			
106			
107			
108			
109			
110			

APPENDIX C

List of Color Combinations

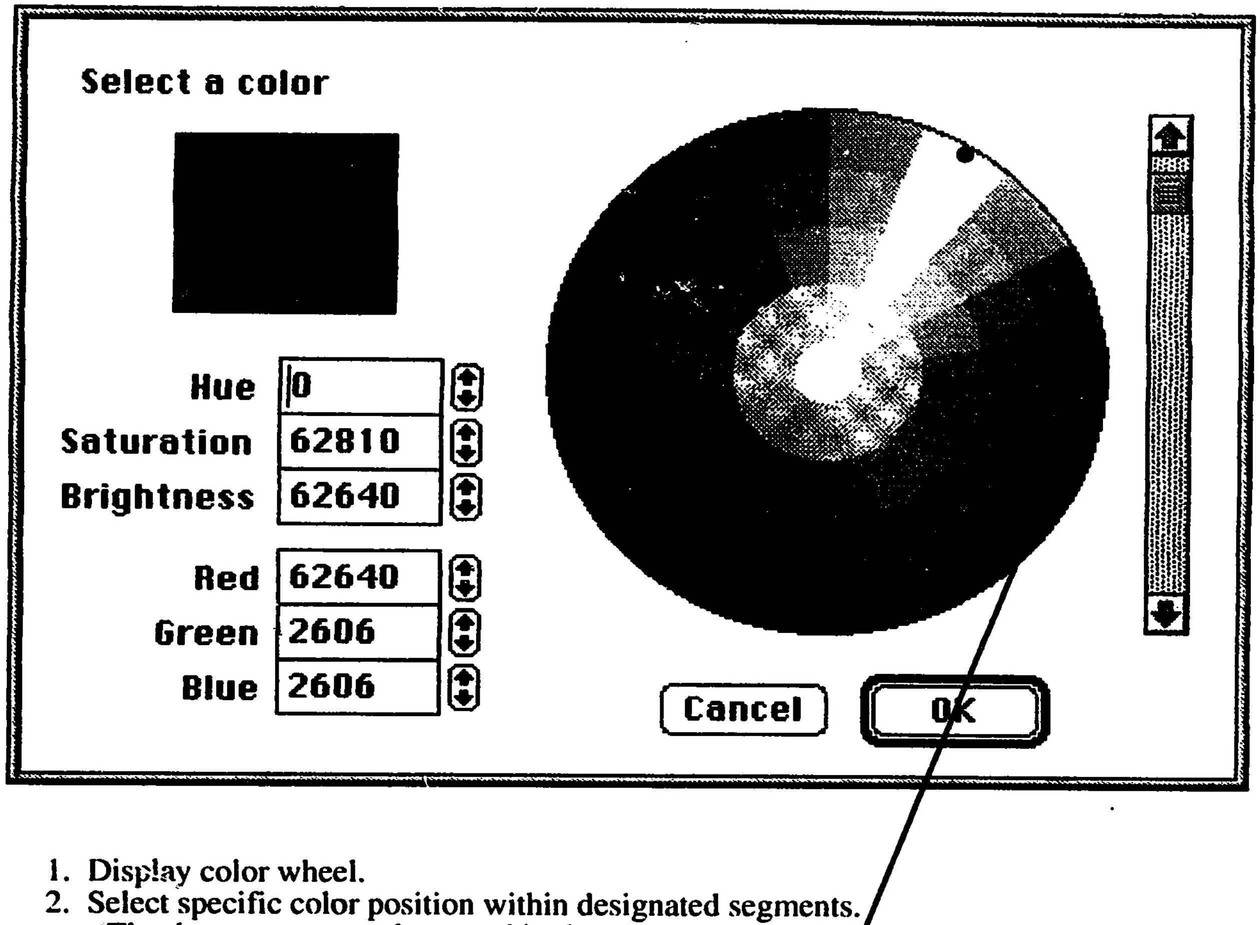
LIST OF COLOR COMBINATIONS

1. Blue, green, magenta, yellow
2. Blue, green, magenta, red
3. Blue, green, magenta, black
4. Blue, green, magenta, purple
5. Blue, green, magenta, orange
6. Blue, green, yellow, red
7. Blue, green, yellow, black
8. Blue, green, yellow, purple
9. Blue, green, yellow, orange
10. Blue, green, red, black
11. Blue, green, red, purple
12. Blue, green, red, orange
13. Blue, green, black, purple
14. Blue, green, black, orange
15. Blue, green, purple, orange
16. Blue, magenta, yellow, red
17. Blue, magenta, yellow, black
18. Blue, magenta, yellow, purple
19. Blue, magenta, yellow, orange
20. Blue, magenta, red, black
21. Blue, magenta, red, purple
22. Blue, magenta, red, orange
23. Blue, magenta, black, purple
24. Blue, magenta, black, orange
25. Blue, magenta, purple, orange
26. Blue, yellow, red, black
27. Blue, yellow, red, purple
28. Blue, yellow, red, orange
29. Blue, yellow, black, purple
30. Blue, yellow, black, orange
31. Blue, yellow, purple, orange
32. Blue, red, black, purple
33. Blue, red, black, orange
34. Blue, red, purple, orange
35. Blue, black, purple, orange
36. Green, magenta, yellow, red
37. Green, magenta, yellow, black
38. Green, magenta, yellow, purple
39. Green, magenta, yellow, orange
40. Green, magenta, red, black
41. Green, magenta, red, purple
42. Green, magenta, red, orange
43. Green, magenta, black, purple
44. Green, magenta, black, orange
45. Green, magenta, purple, orange
46. Green, yellow, red, black

47. Green, yellow, red, purple
48. Green, yellow, red, orange
49. Green, yellow, black, purple
50. Green, yellow, black, orange
51. Green, yellow, purple, orange
52. Green, red, black, purple
53. Green, red, black, orange
54. Green, red, purple, orange
55. Green, black, purple, orange
56. Magenta, yellow, red, black
57. Magenta, yellow, red, purple
58. Magenta, yellow, red, orange
59. Magenta, yellow, black, purple
60. Magenta, yellow, black, orange
61. Magenta, yellow, purple, orange
62. Magenta, red, black, purple
63. Magenta, red, black, orange
64. Magenta, red, purple, orange
65. Magenta, black, purple, orange
66. Yellow, red, black, purple
67. Yellow, red, black, orange
68. Yellow, red, purple, orange
69. Yellow, black, purple, orange
70. Red, black, purple, orange

APPENDIX D

Colorized Version of Color Location on Color Wheel



1. Display color wheel.
2. Select specific color position within designated segments. (The dots represent colors used in the survey).

APPENDIX E

Letter of Permission

MGI
Marketing
Graphics
Incorporated

October 10, 1990

Ms. Stephanie Dolsky
#1506 - 10883 Saskatchewan Drive
Edmonton, Alberta
Canada T6E 4S6

Dear Ms Dolksy:

Thank you for your interest in using MGI's product in your upcoming thesis.

Generally, MGI requires a written statement acknowledging the understanding of the copyright agreement and an indication of what the uses will be used for, which you have already provided. You may use the following copyright reference in a footnote of your thesis:

> "Clip art images displayed here represent a sampling from the PicturePak clip art libraries from Marketing Graphics Incorporated (MGI), P.O. Box 6589, Richmond, VA 23230. (804)353-0443 (c) 1988, 1989, 1990"

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Sincerely,

Louise A. Beller
Marketing Manager

The Publishers of
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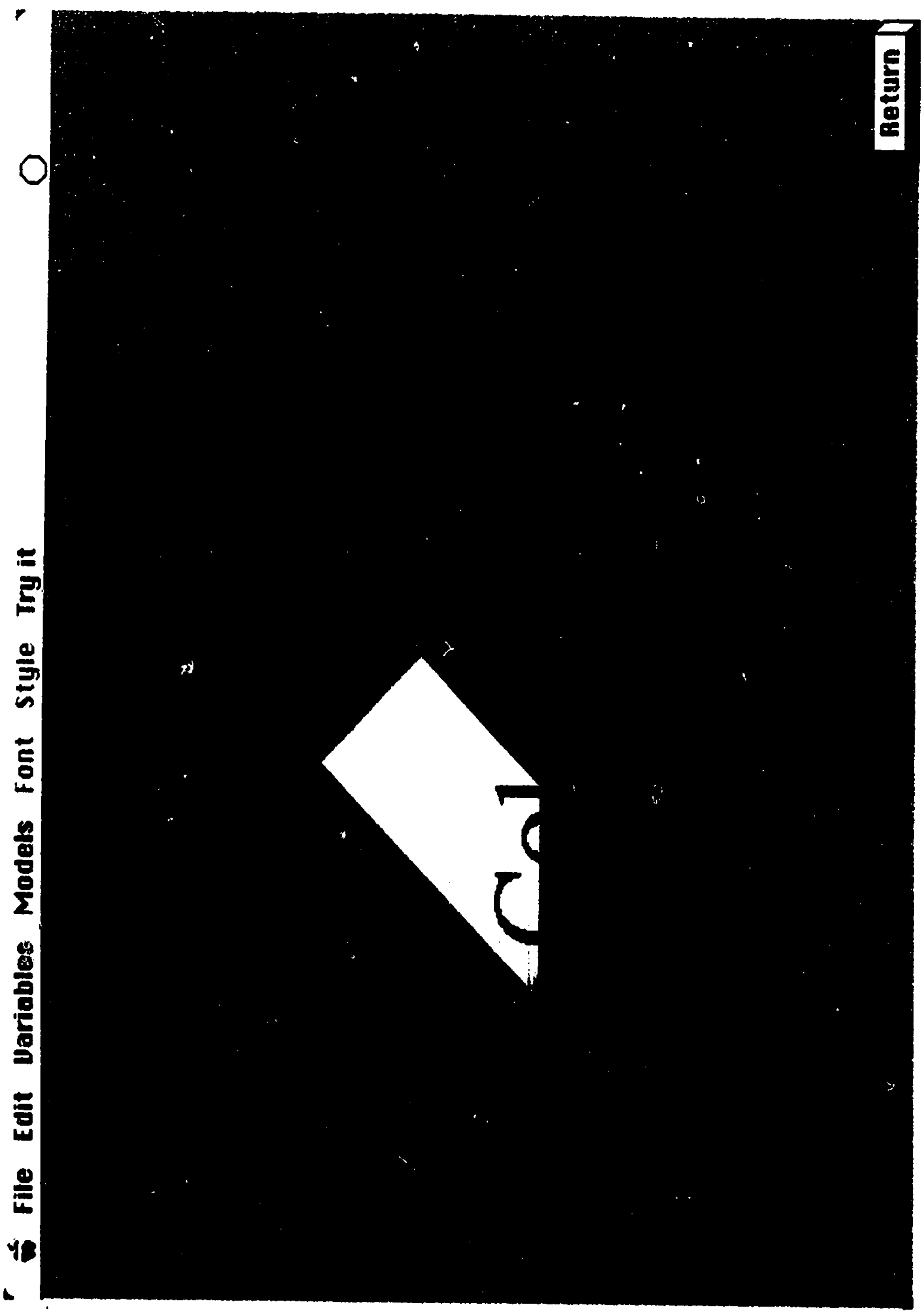
Suite 210
Glen Allen, Virginia 23060-3379
(804) 747-6991

APPENDIX F

Title Page for On-Line Color Preference Survey


File Edit Variables Models Font Style Try it
Return

APPENDIX G

Part 1 (Background Information) of On-Line Color Preference Survey

ON-LINE SURVEY

The purpose of this section of the on-line survey is to gather background information on the subjects in this study.

Your participation is greatly appreciated and is considered important. The gathered information will be used in a statistical study and will be kept strictly confidential. Your anonymity is guaranteed and your involvement is voluntary. Thank you for your cooperation.

PART 1: BACKGROUND INFORMATION

Complete the following statements by filling in the blank and pressing the Return key or keying the number which corresponds to the appropriate response.

A. Demographic Data

1. Your respondent identification number is: __ __ __

2. Your year of birth is: 19__ __

3. Your gender is:
   1. Male
   2. Female
   3. No response

4. The highest school grade you completed was:
   1. 10
   2. 11
   3. 12
   4. 13
   5. No response

5. The number of years of training beyond high school you completed is:
   1. None
   2. One
   3. Two
   4. Three
   5. Four
   6. More than four
   7. No response

6. Your marital status is:
   1. Single
   2. Married
   3. Separated
   4. Divorced
   5. Common-law
   6. No response

7. Do you wear glasses or contact lenses?
   1. Yes
   2. No
   3. No response

8. Have you been diagnosed as having any type of color blindness?

1. Yes
2. No
3. No response

9. Are you presently a student?

1. Yes
2. No
3. No response

10. If you answered "yes" to the previous question, please indicate the institution you attend.

1. University (Graduate program)
2. University (Undergraduate program)
3. University (Extension program)
4. College
5. Technical
6. High school
7. Other

B. Computer Experience

11. Have you ever used a computer?

1. Yes
2. No
3. No response

If you answered "yes" to question 11, please respond to questions 12 and 14.

If you answered "no" to question 13, please respond to questions 13 and 15.

12. Do you use a microcomputer regularly?

1. Yes
2. No
3. No response

14. Do you feel comfortable using the computer?

1. Yes
2. No
3. No response

13. Are you interested in learning how to use the computer?

1. Yes
2. No
3. No response

15. Do you believe you have the capacity to learn how to use the computer?

1. Yes
2. No
3. No response

APPENDIX H

Purpose of the Study

PURPOSE OF THE STUDY

The last decade has witnessed an explosion in the use of the computer as an instructional tool. Recent advances in display technology have led to the use of color as a standard design variable. The rigorous application of color guidelines based on sound empirical research are necessary to take full advantage of the instructional benefits of color. Although general display design guidelines flood the literature, those pertaining to color are grossly under-represented. And those which do exist lack the consistency and comprehensiveness necessary to be useful. The time is ripe for investigation into the application of color to the design of multi-color displays used for computer-based instruction.

Hence the inception of this study, the purpose of which is to assess adult preferences for combinations of four colors presented on a multi-color display using a grey background and intended for use in computer-based instruction.

APPENDIX I

Instructions for Completing Part 2 of On-Line Color Preference Survey

COMPLETING THE COLOR PREFERENCE SURVEY

You will be presented with 70 multi-color displays, one after the other. Each display will consist of four color-coded elements:

1. Title (purple)
2. Canadian trivia question, answer, and feedback (magenta)
3. Graphic (green)
4. Rating scale (yellow)

Trivia Time
The Canadian Trivia Challenge

Who was the Canadian Co-star of "The Sound of Music?"

Graphic (here)

_ _ _ _ _ _ _ _ _ _

(ljhlkjlkjhkljhkjlkjkjh)

|___| |___| |___| |___| |___|

Very Much   Much   Somewhat   Little   Not At All

1. Study each display carefully, paying special attention to the combination of colors used.

2. Respond to the Canadian Trivia question by keying an answer and pressing the Return or Enter key. If you prefer not to specify an answer, simply press the Return or Enter key.

   The computer will give feedback on your response.

3. Rate the appeal of the colors on the display.

   In making this assessment, imagine this combination on each and every screen of a computer-based course. Are they pleasing to the eye? What effect would these four colors have on learning? Would they be instrumental? Detrimental?
   Using the mouse, click on the term which best describes the appeal of the colors on the display (Very Much, Much, Somewhat, Little, Very Little).

   Once this is done, the next display will be presented.

4. Repeat this process until all 70 displays have been rated.

APPENDIX J

Canadian Trivia Questions and Answers

CANADIAN TRIVIA QUESTIONS

1. Which Canadian Prime Minister won the Nobel Peace Prize?
   Lester B. Pearson.

2. Who was the first Canadian Prime Minister to be born in the 20th century?
   Pierre Elliot Trudeau.

3. Who was the longest serving Prime Minister?
   Mackenzie King.

4. Which Prime Minister was referred to as "Uncle?"
   Louis St. Laurent--"Uncle Louis."

5. Who was the last surviving Father of Confederation?
   Joey Smallwood, Newfoundland.

6. Who was the shortest serving Prime Minister?
   Joe Clark.

7. What is the name of the first female Governor General?
   Jeanne Sauve.

8. What is the name of Canada's first Canadian-born Governor General?
   Vincent Massey.

9. What is the name of Canada's first Native Lieutenant Governor?
   Ralph Steinhauer, Alberta.

10. What is the name of a Member of Parliament later hanged for treason?
    Louis Riel.

11. What is the highest award in hockey?
    Stanley Cup.

12. The Stanley Cup was name after the holder of what office?
    Lord Stanley, Governor General.

13. The highest award in Canadian Football.
    Grey Cup.

14. The Grey Cup was named after the holder of what office?
    Earl Grey, Governor General.

15. What is the highest award in Canadian Baseball?
    Pearson Cup.

16. The Pearson Cup was name after the holder of what office?
Lester Pearson, Prime Minister.

17. What is the meaning of Canada's motto "A Mari Usque Ad Mari?"
"From sea to sea."

18. What animals appear in the Canadian Coat of Arms?
Beaver, lion, unicorn.

19. What animals appear in Alberta's Coat of Arms?
Beaver, lion, pronghorn antelope.

20. Which city holds the most weather records?
St. John's, Newfoundland.

21. What are the names of the two generals who fought and died on opposing sides at the Plains of Abraham?
Wolfe and Montcalm.

22. What is the year of Alberta's entry into Confederation as a Province?
1905.

23. What animal appears on the Canadian nickel?
Beaver.

24. What animal appears on the Canadian quarter?
Caribou.

25. What animal appears on a Canadian $2 bill?
Robin.

26. What animal appears on a Canadian $5 bill?
Kingfisher.

27. What animal appears on a Canadian $10 bill?
Osprey.

28. What animal appears on a Canadian $1 coin?
Loon.

29. What plant appears on a Canadian penny?
Maple Leaf.

30. What means of transportation is show on a Canadian dime?
Boat.

31. What is the name of boat which appears on a Canadian dime?
Bluenose.

32. Who was the first Canadian inducted into the Baseball Hall of Fame?
Ferguson Jenkins.

33. What is the name of the Canadian holding the most hockey records?
Wayne Gretsky.

34. Which Canadian Football team has the fewest Grey Cups?
Calgary Stampeders.

35. What is the location of the world's largest mall?
Edmonton.

36. What is the location of the world's largest Easter Egg?
Vegreville.

37. What is the location of the world's largest perogie?
Glendon.

38. What is the name of the world's largest national park?
Wood Buffalo--Alberta.

39. What basketball team holds a world record for most wins?
Edmonton Grads.

40. Who was the first woman magistrate in the British Empire?
Emily Murphy.

41. Who was the first woman to lead a national political party?
Audrey McLaughlin, NDP.

42. Who was the first woman Premier?
Shirley Johnson, British Columbia.

43. Who was the first Canadian woman astronaut?
Roberta Bondar.

44. Who were Canada's 2 "PETS?"
Pierre Elliot Trudeau and Our "pet," Juliette.

45. Who is Canada's "America's Sweetheart?"
Mary Pickford.

46. Who was the Canadian Native Oscar nominee (Best Supporting Actress)?
Tantoo Cardinal.

47. Who was the Canadian Native Oscar nominee (Best Supporting Actor)?
Graham Greene/Chief Dan George.

48. Canadian Native Oscar winner (Best Song: "Up Where We Belong")?
Buffy St. Marie.

49. Canadians vacationing in Arizona and Florida are named after what Canadian song?
"Snowbirds."

50. Who is Canada's Snowbird?
Anne Murray.

51. "The Snowbirds" are ____?
Canadian Air Force Aerobatics Team.

52. Who is the Canadian inventor of the telephone?
Alexander Graham Bell.

53. Who discovered insulin?
Banting and Best.

54. What province was named after a Princess?
Alberta (Princess Alberta Louise).

55. What provincial capital was named after the generic Latin word for Queen?
Regina.

56. What province was named after the Indian word for "Great Spirit?"
Manitoba ("Manitou").

57. Who is Superman's Canadian girlfriend?
Margot Kidder ("Lois Lane").

58. Who is Papa Ben Cartwright?
Lorne Green.

59. Which member of the Royal Family celebrated a 21st birthday in Edmonton?
Princess Diana.

60. Which member of the Royal Family attended school in Ontario?
Prince Andrew.

61. What is the longest running Canadian television show?
Front Page Challenge.

62. What is the "royal" event of the Canadian Triple Crown?
Queen's Plato.

63. Who was Edmonton's first female mayor?
Jan Reimer.

64. Who was Alberta's first female Lieutenant Governor?
Helen Hunley.

65. What is the forestry capital of Canada?
Edmonton.

66. Who was the first female to win the World Equestrian Championship?
Gail Greenough (Edmonton).

67. Who is St. Albert's captain of the New York Rangers?
Mark Messier.

68. A small, clever, reddish, bushy-tailed predator whose name is the last name of Canadian born television and movie star?
Michael J. Fox.

69. Who is Alberta's Canadian Male Country Music Award Winner?
George Fox.

70. What is the number of Great Lakes entirely located within Canada?
None.

APPENDIX K

Consent Form

CONSENT FORM

I ______________ (Name of Subject) agree to participate in the study on adults' preferences for combinations of four colors presented on a multi-color display using a grey background and intended for use within the instructional computing context and consent to the following:

1. To provide the researcher, Stephanie Dolsky, with information required for the study.

2. To authorize the release of this information for purposes related to the study.

   I understand that my identity shall remain confidential and shall be present only in the master records of the researcher.

   I understand that my participation in this study is voluntary and that I may withdraw my participation at any time during the course of the study upon written notice being delivered to the researcher.

Dated this ____ day of _____ (Month), A.D 1993, in the City of Edmonton in the Province of Alberta.

__________________ (Signature of Subject)

__________________ (Printed name of Subject)

__________________ (Signature of Witness/Researcher)
Stephanie Dolsky

APPENDIX L

Mean Scores and Standard Deviations for all 70 Color Combinations

Mean Scores and Standard Deviations for all 70 Color Combinations

Color Combination	Mean	SD
Black, blue, purple, red	2.02	.89
Black, magenta, purple, yellow	2.09	.82
Black, blue, magenta, purple	2.23	.93
Black, orange, purple, red	2.33	.99
Black, purple, red, yellow	2.34	.92
Black, blue, magenta, red	2.36	.90
Black, blue, red, yellow	2.40	.97
Blue, purple, red, yellow	2.42	.91
Blue, magenta, purple, red	2.47	.98
Black, magenta, purple, red	2.47	.98
Blue, magenta, purple, yellow	2.50	.91
Magenta, purple, red, yellow	2.50	.89
Blue, magenta, orange, red	2.53	.98
Black, blue, magenta, yellow	2.58	.92
Black, blue, purple, yellow	2.59	.90
Blue, green, orange, red	2.66	.94
Black, orange, purple, yellow	2.66	.94
Black, blue, orange, red	2.67	.89
Black, blue, orange, purple	2.67	.90
Blue, orange, purple, red	2.72	.92
Blue, magenta, red, yellow	2.75	.91
Black, magenta, red, yellow	2.79	.87
Magenta, orange, purple, red	2.81	.94
Black, blue, green, purple	2.83	.99
Magenta, orange, red, yellow	2.89	.99
Blue, magenta, orange, purple	2.89	.84

Color Preference Data for Total Sample (continued)

Color Combination	Mean	Standard Deviation
Orange, purple, red, yellow	2.89	.92
Black, magenta, orange, yellow	2.89	.86
Black, magenta, orange, red	2.91	.98
Magenta, orange, purple, yellow	2.91	.95
Black, magenta, orange, purple	2.97	.83
Blue, magenta, orange, yellow	3.01	.83
Black, blue, magenta, orange	3.02	.86
Blue, orange, red, yellow	3.03	1.00
Blue, green, magenta, red	3.05	.97
Black, green, red, yellow	3.09	1.03
Black, green, magenta, yellow	3.12	.92
Black, orange, red, yellow	3.18	.95
Black, green, orange, red	3.20	.99
Blue, orange, purple, yellow	3.21	.86
Black, blue, orange, yellow	3.26	.90
Blue, green, red, yellow	3.33	.93
Green, purple, red, yellow	3.38	.97
Blue, green, magenta, orange	3.39	.90
Purple, black, blue, green	3.42	.98
Green, magenta, orange, purple	3.47	.93
Blue, green, purple, yellow	3.54	.95
Black, green, orange, yellow	3.54	.93
Green, magenta, orange, yellow	3.56	.89
Green, orange, purple, red	3.58	.93
Black, green, magenta, red	3.58	1.01
Blue, green, orange, purple	3.58	.92

Color Preference Data for Total Sample (continued)

Color Combination	Mean	Standard Deviation
Green. magenta, purple, red	3.63	1.0
Black, blue, green, magenta	3.62	1.14
Blue, green, orange, yellow	3.62	.98
Black, blue, green, red	3.67	1.03
Blue, green, magenta, purple	3.70	1.06
Black, green, magenta, purple	3.71	1.11
Black, green, purple, red	3.71	1.11
Green, orange, purple, yellow	3.80	.89
Green, magenta, orange, red	3.87	1.03
Black, blue, green, yellow	3.92	1.02
Green, magenta, red, yellow	3.92	.96
Black, green, orange, purple	3.94	.88
Black, green, magenta, orange	3.94	.89
Green, magenta, purple, yellow	3.97	1.02
Black, green, purple, yellow	4.02	.90
Blue, green, magenta, yellow	4.05	.88
Blue, green. orange, purple	4.13	.72
Green, orange, red, yellow	4.17	.80