

# Visualization Ability, Proofreading, and Color Configurations of a Computer Screen—Interactions and Implications

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*This study expanded on the significant research in the areas of instructional design, screen design, visual literacy, color and proofreading. The study was a 2 x 4 repeated measures design that divided the 90 subjects according to visualization ability and used four screen color configurations. It examined the effect of color configuration of a video display terminal on the operator's ability to detect typographical errors in keyboarded copy. The subjects were asked to proofread four documents containing embedded errors. Results indicated that no statistically significant relationship existed between visualization ability and color configuration. However, there was a relationship between proofreading ability and visualization ability. The study also indicated that both high and low visuals proofread more accurately with dark text on a light background.*

## Introduction

As the use of computers has become increasingly common in society, the number of people working with computer monitors has risen dramatically. The computer user, possibly the weakest link in the computer's productivity, has been frequently overlooked by manufacturers and software developers. If this link is to be improved, then designers and manufacturers must devote more attention to improving the interface between user and machine.

One important aspect of this interaction between user and computer is the area of screen layout and design. One question primary to good design is that of the color configuration of the screen text itself. Color has been identified as being an important design consideration (Dwyer, 1972), but variations in the configuration have received less conclusive research attention.

Further, a second question primary to good design is that of the relationship between visualization ability and user success in interacting with the computer interface. Visualization ability is an integral part of visual literacy, which is the way the user communicates using visual images. Proofreading, the perceptual process of detecting

errors, may be affected by the way a user sees visual images or words. A user's ability to proofread screen text may be impaired by computer monitor resolution quality, color, and contrast configurations.

### *Color in Computer Monitors*

Some research has confirmed the connection between color and the interface's visible structure. Taylor and Murch (1986) reviewed principles for effective color coding on video monitors. They found that not all colors were equally legible. Dark spectrum extreme colors, like red or blue, make good background colors. Desaturated hues and bright center spectrum colors, like green and yellow, make text that is more legible.

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Research on the effectiveness of color in improving the usability of a display has been inconclusive. Studies by Kopala (1981) and Sidorsky (1982) have shown that color has improved performance; studies by Christ (1975) and Carter (1982) have shown color improves visual search. On the other hand, Tullis (1981) has shown that color does not improve performance, and Christ and Teicher (1973) have shown that color may impair performance. In 1985 in another study, McTyre and Frommer demonstrated that poor character background color combinations led to poorer performance.

Moreover, Joyner (1989) concluded that users' ability to detect errors in keyboarded text was not affected by the computer monitor's color configuration. On the other hand, Szul (1995) found that color combinations did affect users' ability to detect errors.

The user's ability to view images projected by a computer screen is dependent upon the contrast and stability of the screen (Joyner, 1992). Edstrom (1987) and Schnure (1986) both found that using high resolution and no-flicker monitors could alleviate vision problems associated with the use of a computer screen. Gruning (1985) favored a positive contrast—light text on a dark background—on a computer screen because it created fewer flickers; however, a negative contrast resulted in greater legibility.

Clearly, the often contradictory findings of these studies emphasize the need for more systematic investigation of the factor of screen text color configuration, particularly with regard to the characteristics of the particular user and user's experience with a computer screen.

### *Visualization*

Sein, Olfman, Bostrom, and Davis (1993) citing Ekstrom, French, and Harman defined *visualization ability* as “the ability to manipulate or transform the image of spatial patterns into other arrangements” (p. 600). Visualization ability is one competency of visual literacy, the ability to understand and communicate using visual images (Casey & Wolf, 1989).

These authors summarized research on the relationship between subjects' visualization ability

and computer interfaces and found that visualization ability was a strong predictor of user learning success. Further, they recommended that “since visualization ability is an important factor, more research needs to be carried out on methods to improve an individual's visualization ability” (p. 616).

Did being “literate in the medium's rules of interaction” relate to a subject's visualization ability? Hillman, Willis, & Gunawardena (1994) stated that a user interpreted the interface's visual structure and such understanding influenced the successful learner-interface interaction. If this mental model were formed by the user's interpretation of the interface's “visual structure,” would there be a relationship between color, which is part of the visible structure, and the user's visualization ability?

### *The Process of Proofreading*

Proofreading is the process of editing and correcting a document. West (1983) concluded that proofreading errors occurred because proofreaders did not see the errors rather than because they did not know the correct spelling of words or correct grammar rules. Consequently, the visual perception of words when proofreading affected the error detection process. Smith (1986) defined the visual perception process as condensing sensory visual stimuli into specific segregated units, which did not involve merely a mechanical recording of the stimuli. He reviewed business education research and psychological research to describe visual perception and its relationship to location errors. There were two major themes reported within this study: (1) specific language arts or spelling instruction had no effect on increasing an individual's ability to detect and correct errors; and (2) the way a proofreader perceived words may have affected the ability to detect errors. Galitz (1989) also concurred that proofreading errors were a perceptual expectancy error; humans saw not how a word was spelled but how they expected to see it spelled.

Furthermore, Gropper (1988) defined text display two ways: (1) the deployment of words on a page, and (2) the look of the page that

deployments produce (p. 15). Like Fleming and Levie (1993), Gropper concluded that text not only had meaning in itself but also in the appearance of text on the page. A learner saw a table on a page, and that look predisposed the learner to have certain learning strategies ready when beginning to process the information contained in the table.

Wong (1975) found it was important to help students use visual clues, i.e., marks of punctuation, parts of speech, articles, final s and es on nouns, as signals to indicate the possible presence of problems. It was also important to help them use their monitoring skills so that the problems could be eliminated.

## Purpose

This study sought to expand on the significant research of experts in the areas of visual literacy, color, and proofreading. Findings from two previous studies (Szul, 1995; Woodland, 1995) also provided impetus for this study. The current study examined the effect of the color configuration of a computer monitor on the user's ability to detect typographical errors in screen copy.

This study addressed two questions: (1) Is there a relationship between visualization ability and color configuration of the computer monitor in terms of user's proofreading ability? (2) Is there a difference in the proofreading abilities of users who have higher visualization ability than those who have lower visualization ability?

## Research Procedures

### *Variables*

The variables of visualization ability, proofreading, and screen color configurations were selected because previous research (Schnure, 1986; Joyner, 1989; Szul, 1995; Woodland, 1995) was inconclusive regarding the interaction of proofreading and screen color

configurations. Furthermore, visualization ability was selected as a variable to test the interaction among that ability, proofreading, and color configurations. Previous research (Sein, Olfman, Bostrom, & Davis, 1993; Hillman, Willis, & Gunawardena, 1994) has identified these variables as ones that contributed to a user's ability to interface effectively with computers.

### *Research Design*

The study was a 2 x 4 repeated measures design that divided the subjects according to visualization ability (low or high) as measured by the VZ2 and used four screen color configurations (Treatment 1, Treatment 2, Treatment 3, Treatment 4 (See Table 1).

The selected color combinations of white and black and white and blue represented the defaults of the two most commonly used word processing packages. White and black simulated the Microsoft Word™ environment; white and blue simulated the WordPerfect™ environment. Black and white, and blue and white represented the reverse combinations. In addition, the black and white depicted hard copy.

### *Sample*

The convenience sample for this study consisted of 90 undergraduate students enrolled in a college of business at a major Pennsylvania university. This sample consisted of four sections (identified as A, B, C, D) of students in two different courses. To avoid instructor influence, graduate assistants assigned to the researchers discussed the study with the subjects, secured their written permission, and conducted the experiment.

**Table 1: Visualization Ability and Treatment Levels**

Visualization ability	Treatment 1	Treatment 2	Treatment 3	Treatment 4
Low	White bkgd/ black text	Black bkgd/ white text	Blue bkgd/ white text	White bkgd/ blue text
High	White bkgd/ black text	Black bkgd/ white text	Blue bkgd/ white text	White bkgd/ blue text

### *Administration of VZ2 Instrument*

Graduate assistants administered the first part of the VZ2, a paper-folding test developed by Ekstrom, French, and Harman, to those who signed a consent form. Sein, Olfman, Bostrom, and Davis have used the VZ2 to measure visualization ability in adult samples. The test-retest reliability of VZ2 has been found to be .84 (Sein, Olfman, Bostrom, & Davis, 1993). This spatial ability test consisted of ten questions and required three minutes to complete. In order to maintain subject anonymity, the subjects were identified by letter and number. The researchers used this information to later collate visualization scores with proofread documents.

## **Materials and Instrumentation**

### *Error Detection Environment*

The four documents containing embedded errors were keyed and saved on the network server. The documents, business letters and text paragraphs, were taken from the materials used as part of the department's exemption exam for the Keyboarding & Document Formatting class. Subjects were randomly assigned to computer terminals. The researchers preset the monitors to the specifications which included: white text on a black background (Treatment 1), black text on a white background (Treatment 2), blue text on a white background (Treatment 3), and white text on a blue background (Treatment 4). These color configurations simulate the background and foreground color combinations identified as either monochrome or color. Each subject read the assigned documents from the computer monitor without the benefit of a hardcopy. Subjects were allowed ten minutes to proofread each document and invoke the overstrike feature of WordPerfect to mark the error(s). The subjects proofread four documents (numbered 1, 2, 3, and 4) as they were displayed on one of the screen color configurations (See Table 2).

### *Treatment of Data*

A review of the hardcopy documents revealed that of the 90 subjects, five returned data that were unusable because they did not follow directions for printing the proofread documents.

The remaining 85 subjects were then divided into groups of high visual ability ("high visuals") and of low visual ability ("low visuals") based on scores on the spatial ability test (VZ2). High visuals were those subjects who scored at least one-half a standard deviation (0.98) above the mean (5.16), and low visuals were those who scored at least one-half a standard deviation (0.98) below the mean (5.16).

This division of subjects had previously been used by researchers performing similar studies (Sein, et al., 1993) to eliminate those scores too close to the mean. This procedure helps to increase the heterogeneity of the scores. According to Hinkle, Wiersma, and Jurs (1988, p. 116), "if the researcher is looking for relationships between variables...there must be enough variation or heterogeneity in the scores to allow a relationship to manifest itself." This process eliminated 29 (34%) subjects from the study. Hence, 56 subjects remained after the scoring of the spatial ability test. Data were collapsed under each treatment and then tabulated.

## **Findings**

This study was conducted to examine the interaction of the color configuration of the computer monitor and visualization ability on the user's aptitude for detecting typographical errors in screen text.

The conclusions and recommendations that follow are based on the findings of this study; they serve as the basis for further research.

**Table 2: Treatment Rotation Design**

Group	Treatment 1	Treatment 2	Treatment 3	Treatment 4
A	Document 1	Document 2	Document 3	Document 4
B	Document 2	Document 3	Document 4	Document 1
C	Document 3	Document 4	Document 1	Document 2
D	Document 4	Document 1	Document 2	Document 3

1. None of the treatments was statistically significant in relation to visualization ability as measured by the VZ2. Pearson’s Product Moment Correlation calculated on the relationship between the visual ability and the number of errors is reflected in Table 3. At the .05 level, the correlation of low visuals and the number of errors detected in Document 4 is greater than any of the other correlations. However, the correlation of low visuals and high visuals to the number of errors detected in each document is not statistically significant.

Pearson’s Product Moment Correlation calculated on the relationship of visual ability and each of the four treatments is presented in Table 4. At the .05 level, the correlation of high visuals to the four treatments is greater than the correlation of low visuals to the four treatments. However, the correlation of low and high visuals to the four treatments is not statistically significant.

Further, the results of the f-test on the variance of low visuals and high visuals with the total number of errors found is reflected in Table 5. Again, at the .05 level, the results were not statistically significant. The result of the one-tail t-test also was not statistically significant at the .05 level. The low N (56) may have accounted for the lack of statistical significance.

Hence, the study results did not support research question #1 “Is there a relationship between visualization ability and color configuration of the computer monitor in terms of proofreading ability?”

2. Subjects identified as high visuals found 157 errors in Treatment 4—white background/blue text and 130 errors in Treatment 3—blue background/white text (See Table 6).

3. Subjects identified as low visuals found 107 errors in Treatment

4—white background/blue text and 86 errors in Treatment 2—black background/white text.

4. Subjects identified as either low or high visuals were more accurate when the color combination involved a light background with dark text. They found a total of 506 errors when viewing a light background with dark text. On the other hand, both groups were least accurate when the color combination contained a dark background with light text. They found a total of 458 errors when viewing a dark background with light text.

5. Low visuals found 35 percent fewer total errors than high visuals. Hence, research question #2 “Is there a difference in the proofreading abilities of users who have higher visual ability than those who have lower visual ability” is supported.

### Conclusions

None of the findings was statistically significant with regard to the interaction of visualization ability with proofreading ability and color

**Table 3: Correlation of Visual Ability and Number of Errors**

	Document 1 Errors	Document 2 Errors	Document 3 Errors	Document 4 Errors
Low Visuals	-.0040	.1642	.1084	.3886
R-squared	.00002	.0269	.0118	.1510
High Visuals	.1512	-.0013	.0352	.0814
R-squared	.0229	.000002	.0012	.0066

**Table 4: Correlation of Visual Ability and Treatment**

	T1 White bkgrd/ black text	T2 Black bkgrd/ white text	T3 Blue bkgrd/ white text	T4 White bkgrd/ blue text
Low Visuals	.1939	-.2105	.1775	.2659
R-squared	.0376	.0443	.0315	.0707
High Visuals	-.2794	.3272	.2870	-.1618
R-squared	.0781	.1070	.0824	.0262

**Table 5: Variance of Visual Ability and Total Errors Detected**

n <sub>1</sub>	n <sub>2</sub>	f-value	p	α=.05	t-value	p	α=.05
22	32	.6939	2.04		.0818	1.6760	

configurations. While previous research identified the VZ2 as an instrument for measuring visualization ability, another instrument may be more appropriate in research studies involving the combination of variables as was used in this study.

Individuals, whether identified as high or low visuals, exhibited the greatest proofreading ability when working with dark text on a light background. Thus, this finding verified the use of light backgrounds with dark text by the major computer software manufacturers, including Microsoft and Corel. Detecting errors online was more apt to be more successful when the user was reading dark text on light background.

Those individuals identified as low visuals found fewer errors when proofreading online documents. Thus to achieve greater success, students identified with low visual ability would benefit from additional proofreading tools, such as working with hard copy or working with a partner.

## Recommendations

As the use of computers continues to increase in popularity in both educational and business environments, the problem of efficient human interaction with computers must be addressed. This study sought to address the efficiency of humans proofreading computer-displayed documents. A statistical significance was not found among the variables; therefore, the following recommendations are made.

1. Replicate the study increasing N to reach conclusions that are more generalizable. This study was, perhaps, restricted by the low N (85) that would have made it difficult to generalize the results even if statistical significance had been found.
2. Replicate the study using other text and background

configurations. The four color combinations selected represented the screen configurations and the reverse of the two most popular word processing packages used in both business and education. Because it is a simple process to change color combinations on a computer monitor, more needs to be known about what effect color has on user performance.

3. Pre-test subjects using standardized paper and pencil tests to check for cognitive abilities, i.e., reading, color recognition. In this study, subjects were not pre-tested to determine the level of these skills, and, therefore, the interaction of these abilities and the variables could not be determined.
4. Measure visual ability using another standardized instrument. The VZ2 is a recognized instrument used in similar studies. However, a different instrument may measure visual acuity more relevantly as it relates to color and proofreading.

**Table 6: High Visuals by Treatment**

Treatment	T1 White bkgd/ black text	T2 Black bkgd/ white text	T3 Blue bkgd/ white text	T4 White bkgd/ blue text
Number of errors	150	146	130	157

**Table 7: Low Visuals by Treatment**

Treatment	T1 White bkgd/ black text	T2 Black bkgd/ white text	T3 Blue bkgd/ white text	T4 White bkgd/ blue text
Number of errors	92	86	96	107

**Table 8: Percent of Total Errors by Treatment**

Treatment	T1 White bkgd/ black text	T2 Black bkgd/ white text	T3 Blue bkgd/ white text	T4 White bkgd/ blue text
Percent of errors	25%	24%	23%	28%

**Table 9: Total Errors by Visual Ability**

Treatment	Low visuals	High visuals
Number of errors	381	583

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