To the Graduate Council:

I am submitting herewith a dissertation written by Gloria A. Reece entitled, “Text legibility for web documents and low vision.” I have examined the final copy of this dissertation for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Doctor of Education, with a major in Instruction Curriculum Leadership.

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TEXT LEGIBILITY FOR WEB DOCUMENTS AND LOW VISION

A Dissertation

Presented for the

Doctor of Education

Degree

The University of Memphis

Gloria Anne Reece

December 2002

Dr. Gloria 05/27/09
A. Reece 04:59:07

Dedication

This dissertation is dedicated to my husband

John H. Reece, Ph.D.

and my parents

Mallory N. and Rebecca L. Hunt

whose love and devotion have helped me accomplish my educational and career goals.

In Memory

S. D. McPherson, M.D.

for contributions to research and practice in ophthalmology

Acknowledgements

Like all research efforts, of which this one is no exception, many hearts, minds, and hands have helped me accomplish this research goal. It has been an honor to have Dr. Deborah L. Lowther as my committee chair. I would like to thank other members of my committee, Drs. Linda Bol, Emily A. Thrush, and Richard N. Van Eck for their guidance.

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At the completion of my master's program in the spring of 1994, Dr. Howard J. Scheiber of Solaris Communications in Nutley, NJ, strongly encouraged me to pursue a doctoral program and my interests in typograpahical research and instructional design and technology. His advice to read the work in Miles A. Tinker's annotated bibliography on text legibility studies (published in 1966) laid the theoretical grounding for this work.

Secondary sources for the literature review spanned three disciplines: instructional design, technical communication, and vision literature. Consequently, colleague, Dr. David Armbruster (Scientific Editor, The University of Tennessee Health Sciences Library) made

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Abstract

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The preferences of normal readers and low–vision readers for two typeface characteristics, serif presence and emphasis, on electronic displays were investigated. The ultimate goal was to gain insight to aid designers in producing legible, effective electronic displays for a wide audience. The effects of three characteristics of low–vision readers, severity of vision loss, region of eye affected by the primary disorder, and the type of vision loss produced by the primary disorder were considered. Strong preferences for sans serif and Roman (i.e., no italics) typefaces were identified and were found to be similarly distributed among the various categories of participants.

Participants in the study viewed a sequence of computer screens that displayed a pair of words in typefaces that differed in one of the two characteristics and selected the typeface that was most legible. The data for each typeface characteristic were analyzed for overall preferences and for any differences in preferences between categories of participants.

One hundred seventy–seven reduced vision readers and 54 normal readers participated in the study. The reduced vision readers were grouped into eight categories according to the possible values of the three characteristics, and samples of each category were obtained. Additional, higher–level, categories were constructed for use in the analysis of the data.

Participants in all categories preferred sans serif typefaces over serif typefaces and Roman typefaces over italic typefaces. Only slight evidence for variation of these

preferences across all eight participant categories were found. Additional comparisons of pairs of categories that differed in only one of the participant characteristics indicated no significant variation of the distributions.

These results differed from expectations based upon previous studies that were based primarily upon paper displays and normal readers and exhibited varying, conflicting results. The results from this study establish that typeface characteristics for electronic displays have a strong influence on legibility and must be considered separately from legibility for paper documents. Additionally, sans serif, Roman typefaces are strongly recommended for use in electronic documents for both normal readers and reduced vision readers.

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CHAPTER 1

Background and Review of the Literature

Introduction

Electronic displays of information pervade everyday life. The most obvious examples of such displays are, of course, personal computer monitors; however, electronic displays are found in countless other applications as well. Some common examples are airport information monitors, traffic warning and control boards, interactive self–service financial transaction terminals, appliance controls, and automobile dashboard gauges and controls.

This proliferation of electronic displays is especially apparent in education because of the widespread application of computers. Today, computers are present in most classrooms, beginning with the earliest grades, and they are found at all stages of the learning process in a wide variety of roles. Some examples are as follows:

- Computer–Based Instruction (CBI) tools and other electronic delivery of instructional materials,
- Information retrieval tools, such as on–line library catalogs, electronic data bases, electronic publications, or the World Wide Web (WWW),
- Productivity tools, such as word processors, spreadsheets, and databases, and
- Distance learning applications in higher education and lifelong learning.

The ubiquitous presence of electronic displays means that they must be usable by the widest audience possible. Moreover, this usability is legally required by the 1998 ammendments to Section 508 of the Rehabilitation Act of 1973. One result of this mandate

is the Section 508 standard, which specifies that federal agencies' electronic and information technology be accessible to people with disabilities.

Again, this requirement is particularly acute in educational applications. Designers of instructional materials, or tools that may be used in instruction, must strive to make those items available to people with differing abilities as well as to a mainstream audience, and this requirement certainly holds true for elements that contain electronic displays.

When designing electronic displays for a broad audience, a principal concern is for people with either subnormal visual acuity or abnormal visual field, who are denoted here as "reduced vision readers"[1] and are more likely to experience difficulty in reading the displays than would "normal readers." A characteristic of the display that is merely an annoyance to a normal reader may cause the same display to be completely unusable by someone with reduced vision.

Such visual impairments are a common problem. More than 100 million Americans wear corrective lenses (glasses or lenses (contacts or interocular)), and one out of every twenty Americans suffers from a reduced vision problem (Attebo, Mitchell, & Smith, 1996; Stoto, Behrens, & Rosemont, 1990). According to The Lighthouse International (1997–2004, 1999), self reports of Americans 45 years of age or older (13.5 million adults) note some form of visual impairment while wearing corrective lenses. These statistics include normal, binocular viewing or reading situations and include blindness problems in one or

1. Several additional terms, including "low vision," "partially sighted," "subnormal readers," "visually impaired" and "visually challenged," have been used in other work to refer to such individuals. Similarly, we will use the term "normal readers" to refer to people who have both normal visual acuity and visual field, while other work may also refer to such individuals as "normally sighted" or "fully sighted."

both eyes. Moreover, it is possible that careful choices during the design process can enhance the effectiveness of the electronic document for many reduced vision readers.

Many attributes of an electronic display may influence its effectiveness for any audience, but legibility of text (perception of short, cohesive "bursts" of text) is, arguably, the most critical factor. Almost all electronic displays contain critical textual information, and, frequently, the display consists of text only. Moreover, text legibility is highly important to reduced vision readers because difficulty in reading often is the first, or most severe, result of their vision loss. Text legibility is, in turn, highly dependent upon the typeface that is employed, but the selection of an appropriate typeface can be a formidable task. Over 30,000 commercial typefaces were available recently (Strizver, 1999).

Despite the importance of electronic displays, designers have few specific guidelines to aid them in the creation of effective displays either for normal readers or for reduced vision readers. Most previous studies of text legibility have been based upon paper (printed) documents, and very few have included reduced vision readers in their subjects. Very little attention has been given to empirical studies on typographical design principles for on–screen documents intended for an audience that includes reduced vision readers. Hence, a common design approach has been to extend the methods used for paper–based documents to electronic displays regardless of the expected audience.

Even in printed materials, however, discrepancies exist in the application of typographical guidelines and actual printed product by genre (letter, journal article, magazine, memo, newsletter, newspaper, policy manuals, technical report, tutorial), thus indicating that "conventional wisdom" also served as a strong guide in the design of

documents for normal readers (Van Der Waarde, 1999). Thus, we have the paradox of text legibility design principles: Design principles for printed materials for normal readers may be applied to on–screen designs; however, even under the best of circumstances, designers must make judicious decisions (and possibly compromises) about text legibility principles based upon their design experiences, conventional wisdom, empirical knowledge, purpose of the document, audience, and mode of delivery (Reece, 1992, 1993–1994; Reece & Scheiber, 1993). Practitioners have found that the use of heuristics that include evaluations by people who use the documents are helpful in clarifying design issues (Black, 1990; Hartley, 1994; Shriver, 1997; Wright, Lickorish, & Hull, 1990). Van Der Waarde (1999) suggested an inventory method that may be useful in developing test materials for new studies on legibility of printed materials.

This research will be directed toward gaining understanding and knowledge that can be used in addressing this lack of guidelines for designing effective electronic displays. The focus of the study will be the relationship between characteristics of typefaces in electronic displays and text legibility and the effect of reduced vision upon that relationship. Moreover, it is restricted to computer display screens since they are the most common form of electronic text display, particularly in educational applications. This work will be an advancement toward the ultimate of goal of a set of guidelines that will aid designers in producing on–screen displays that are effective for both normal readers and reduced vision readers.

Three background areas are relevant to this research: a) legibility of text in printed documents and the associated typography and document design issues, b) design and

legibility of electronic displays, and c) eye disorders associated with reduced vision and their relationship to text perception. This chapter will survey key literature findings associated with these three topics in separate sections herein.

Legibility and Printed Documents

The term legibility refers to the degree to which text can be comprehended or understood. Examples of general definitions include the "ease and speed of reading" (Tinker, 1965, p. 120), the "effectiveness of typography in communicating the text code" (Arditi & Cagenello, 1992, p. 324), and typographic clarity (Haley, 1999). However, there is no agreement on a detailed definition of the term. Those definitions may vary according to the specific application and may be based upon measurements such as perception at a distance or speed of reading (Arditi & Cagenello, 1992; Tinker, 1965).

In some instances, different terms may be employed according to the amount of text that is being read, and this usage may be contradictory. For example, some researchers use the separate term, "visibility," to refer specifically to the perceptibility of isolated elements of text, i.e., letters or words, rather than the body of the text as a whole (Rubinstein, 1988). Yet, in another instance, "readability" is defined as the ease of reading large amounts of text, and "legibility" denotes the perception of short, cohesive "bursts" of text, which include headlines or other delimiters, signs, and "buttons" in many electronic displays (Williams & Tollett, 1998). Such perception is critical for navigation or wayfinding, which often is the key factor in the effective use of electronic displays of text. Hence, this form of legibility is the subject of this work.

Additionally, high legibility may not always be the goal of a particular design. For example unusual “swash” (fancy) typefaces may be used to make a typographic statement (Haley, 1999). In such cases, the primary intent is to make the text stand out and draw the viewer to it rather than to convey information through perception of the content of the text.

Regardless of the specific definition, legibility can be difficult to measure because it may involve the interaction of several factors. Because of the complexity of that interaction, isolation of the individual variables for measurement may be difficult, and moreover, the collective effect of the variables may be very different from the effects considered individually (Rubinstein, 1988).

The earliest work on type legibility dates back more than one hundred–fifty years (Spencer, 1968), and more than 300 studies, covering a wide variety of topics related to the legibility of type, have been reported since 1925 (Cornog, Rose, & Walkowicz, 1964; Rehe, 1974; Spencer, 1968; Tinker, 1963). These studies involved several diverse fields, such as ophthalmology, education, journalism, graphic design, information design, and instructional design (Arditi, 1996; Arditi & Knoblauch, 1994, 1996; Felker, Pickering, Charrow, Holland, & Redish, 1981; Hartley, 1978; Hartly, 1994; Hartley & Burnhill, 1977; Hartley, Burnhill, & Fraser, 1974a; Hartley, Fraser, & Burnhill, 1974b; Hartley & Jonassen, 1985; Hartley, Young, & Burnhill, 1975; Luckiesh & Moss, 1941; Pett & Wilson, 1996; Tinker, 1963; Tinker & Paterson, 1944; The Lighthouse, 1995a–b; Tschichold, 1967; United States Government Printing Office, 1951; White, 1987; Wrolstad, 1960). Most of this work has dealt with print media for normal readers. Moreover, Paterson and Tinker (1929, 1931, 1932, and 1940) generally are credited with

conducting the most exhaustive experimental studies on typography for that media and audience. At least 64 studies and more than 103 descriptive (not studies) publications on legibility have been performed in vision, education, and technical communication disciplines.

In many instances, the results from these studies differed depending upon the methods and audiences that were used. For example, in a very early study, Sanford (1888) used distance and short exposure methods to examine the legibility of lowercase letters for normal readers and found that the results varied according to the method used and that the legibility of some letters could be improved by increasing size and differentiating the characteristics of the letters. As a result, he recommended the use of serif typefaces. Roethlein (1912), Burtt and Basch (1923), and Pyke (1926) also found differences in legibility. In contrast, Paterson and Tinker (1932) found that typefaces in common use were equally legible. Subsequently, Webster and Tinker (1935) note the difference in the findings and point out that since Roethlein (1912), Burtt and Basch (1923), and Pyke (1826) each used different typefaces and methods, the results are not highly comparable. For example, Burtt and Basch (1923) specifically studied the effect of stroke contrast using three typefaces, Bodoni, Baskerville Roman, and Cheltenham, and an audience of seven college–level students taking psychology courses. They concluded that the greatest legibility differences occur when typefaces containing light strokes are used. In contrast, Paterson and Tinker's experiment used a normal reading situation and examined the effect of ten typefaces on reading rate using an audience of 900 college students. The participants

in the last four studies were normal readers, but the vision level of the participants in the Sanford study is not known.

This variation in results may also appear in work by the same researcher. For example, in a later print–based study, Paterson and Tinker (1940) found that when type with italic emphasis quality is compared to type with Roman (i.e., non–italic) quality, the speed of reading decreases by 2.7%. An additional study (Tinker, 1954) found that both visibility and readability were adversely affected by use of the slanted text, promoting reduced visibility of words, which also retarded reading speed. Again, the participants were normal readers.

This study is concerned with the effect of two specific typeface characteristics, presence of serifs and use of italic emphasis, on legibility; however, many additional typographical factors, such as type proportions and interletter spacing, type size, type style, interword spacing, line width and length, and contrast of type with background, can affect legibility. We now present findings from key research on six factors: (a) proportional and fixed width type, (b) type size, (c) typography contrast qualities, (d) weight (tone) quality, (e) emphasis quality, and (f) serif presence. The discussion concludes with a brief summary of findings on other relevant issues affecting legibility.

Proportional and Fixed Width Type

The amount of space that is used to print characters in proportional spaced (or pitch) type varies according to the actual width of the character, while the same amount of space is used for all characters in fixed–width type. Hence, narrow characters in fixed–width type may be surrounded by significant blank space. Previously, fixed–width type was common

in electronic displays and printed matter generated by computers; however, proportional spaced type is commonly used in both print and electronic displays today. Arditi, Knoblauch, and Grunwald (1990) examined the legibility of these two type spacings and reported that proportional spacing was better in reading situations where medium and large character sizes were involved. Fixed pitch, however, was superior for characters that approached the acuity limit of the audience. The participants in the study were limited to the authors and several naive volunteers, and no authentic assessment of participant visual acuity was conducted.

Type Size

The relationship between type size and legibility can be expected to be positive (larger type size corresponding to greater legibility) to some degree. Using a convenience sample of 15 adults, Tullis, Boynton, and Hersh (1995) address the font size problem for electronic materials and recommend that designers avoid using small fonts (6 to 7 points). Erdman and Neal (1968) found that word legibility increased as character size and resolution increased. Similarly, Paterson and Tinker (1940) found that 6–point Roman type is read 5% slower than 10–point Roman type. Both studies used normal readers.

Typography Contrast Qualities

Adequate contrast between the type and the background is necessary for the type to be legible. Type size is one of the factors that determines contrast. Other key factors that affect contrast include type weight or tone (emphasis quality), illumination and color, spatial variation (kerning, tracking, leading, and alignment), and repetition (Roberts, 1966).

In general, better illumination is associated with greater legibility of print. For example, Tinker (1952) found that increasing illumination made it easier for normal readers to read 6–point italic type.

The effect of type and background color on legibility has been investigated by several researchers. Many of these studies examined the differences in legibility between "normal" (i.e., dark type on light background) and "reverse" (i.e., light type on dark background) print and found that normal print produced the greater legibility (Ernst, 1977; Hackman & Tinker, 1957; Holmes, 1931; Paterson & Tinker, 1932; Paterson & Tinker, 1940; Sanner, 1974; Snowberg, 1971; Start, 1989; Taylor, 1934). All of the participants in these studies were normal readers.

This preference for normal print over reverse print may not be of overriding importance. Taylor (1934) also examined the relationship of other factors, such as type size, typeface, word form, and context, to the differences between normal and reverse print and found that a sans serif typeface was equally legible for both normal and reverse print except when a very small type face was used. Similarly, Robinson (1975) concludes that given proper lettering size and projection standards, brightness contrast is more important to legibility than the background color. Pett (1993) also concludes that letter size and adequate contrast are the most important criteria if reverse print is used.

The required level of contrast also is uncertain. Hackman and Tinker (1957) advocate that a maximum brightness contrast should be used in printed materials for optimum legibility. Conversely, Luckiesh and Moss (1941) examine the visibility of print on various

grades of white paper and did not find any strong preferences for extremely bright contrast when optimum print quality was used.

Findings on the use of color in backgrounds or text are less conclusive. In an early experiment, Summer (1932) found that a grey background produced the greatest legibility when using colored text. Tinker and Paterson (1944) found that the legibility of colored inks on differently colored paper was influenced by the luminance difference (contrast) between the text and background. Gustin (1991, 1992) noted color preferences among projected visuals using reverse print. Later, Pett and Wilson (1996) report that legibility is better if colors in the middle of the spectrum are used.

Weight (Tone) Quality

Boldface type is used often in titles and headings for impact and to distinguish those elements from the remainder of the text; however, boldface may not produce type that is more legible. Tinker and Paterson (1942) show that normal readers prefer “Regular” type to bold; however, later studies (Brockmann, 1986; Tinker, 1963) indicate that these readers prefer typefaces with greater contrast (those that appear bolder). Current practice in print media indicates that the most easily read type in any family is that of medium weight (Ernst, 1977). Ernst argues that large amounts of text set in forms such as boldface are difficult and tiring to read and cause loss of value in contrast for normal readers. Such techniques, she notes, will have greater impact when used in moderation.

Emphasis Quality

Italics are a common method for emphasizing portions of a body of text. Again, the results from previous research have been somewhat contradictory. In speed of reading

studies, Tinker and Paterson (1942) and Tinker (1966) found that use of italics retarded reading rates for normally–sighted readers and that those readers preferred “Regular” type over italic as well as bold. Similarly, Becker, Heinrich, von Sichowsky, and Wendt (1970) found preferences for non–italic type over italic type in printed media. Brockmann (1986) also noted that italicized print is read more slowly by normal readers and should be restricted to reading events where emphasis is needed. In contrast, a study of a different context, the communicability of the emotional connotation of type, found that the use of italics seems to actively engage normal readers for longer timeframes than the Roman or Regular form of the typeface (Morrison, 1977, Morrison, Ross, O’Dell, Schultz, & Higginbotham–Wheat, 1989; Tannenbaum, Jacobson, & Norris, 1964).

Slanted text is another form of emphasis and is related to italics. Slanted typefaces are growing in popularity as is evidenced by new type designs that mimic handwriting. Reports on the legibility of slanted text are not currently available; results similar to those for italics are implied by the similarity of the forms.

Serif Presence

A fundamental distinguishing characteristic of typefaces is the presence or absence of serifs, which are lines (“feet”) that cross the main stroke of a character (Barnum & Carliner, 1993; Beach, 1988; Haley, 1980, 1998, 1999; White, 1987). Typefaces that have such crossings are called serif fonts, and fonts without them are known as sans serif fonts. Many designers believe that serifs provide guidance for readers along a line of type (Beach, 1988), and the consideration of the presence of serifs in selecting fonts is considered to be key to achieving effective designs for print materials (Barnum & Carliner, 1993). Current

typographical design practice supports the use of both serif and sans serif fonts in designs as a means of achieving greater contrast (Fleming & Levie, 1978; Fleming & Levie, 1993; Strizver, 1999; Turnbull & Baird, 1980; Williams, 1994).

Again, experimental evidence regarding the legibility of serif and sans serif fonts was somewhat contradictory (Morrison, 1977; Morrison et al. 1989). Crosland and Johnson (1928) reported that letters with serifs were more legible than those without serifs in paper documents; however, Tinker (1932), indicates that familiar typefaces (serif or sans serif) were equally legible. In later work, Brockmann (1986) noted that typefaces with serifs were read faster than those without serifs and studies by Tinker (1963) and Becker, Heinrich, von Sichowsky, and Wendt (1970) both found that readers preferred serif fonts over sans serif fonts. In contrast, Poulton (1969) found a sans serif font to be more legible by older people in skimming tasks. Tannenbaum et al. (1964) indicated that one sans serif typeface attracts more attention than two serif faces, and Morrison et al. (1989) also found preferences for sans serif typefaces. The reading experience and visual acuity of the participants in the Poulton study are unknown, and Morrison (1986), notes that Poulton's results may have been influenced by the participants' prior knowledge and experience regarding typography and design.

Other Issues

Tinker and Paterson (1942) found that normal readers prefer lowercase letters to all capitals. Additionally, Crosland and Johnson (1928) found that variations of interletter spacing did not cause noticeable differences in legibility of letters.

Context is a concern when studying legibility. Biggs (1968) notes that readers may tend to prefer those typefaces that are most familiar to them; however, familiarity of content may have a more direct impact upon legibility. Taylor (1934) found that legibility for normal readers may be increased by contextual cues in the stimulus materials. Earlier, Tinker (1932) concluded that words are more legible than individual letters and that the top halves of words are more legible than the bottom halves. Similarly, Erdman and Neal (1968) concluded that word familiarity was important in determining legibility, and they emphasized that redundancy in individual letters is a contributing factor to familiarity regardless of whether those letters are contained in meaningful words or in randomized nonsense words. DeBord–Schulze (1997) also points out the importance of redundancy in reading, noting its absence when words are presented in all uppercase form. Such results cause Morrison (1986) to suggest that stimulus materials in typography studies may confound the experiment and to recommend the use of randomized letters to form nonsensical words (Morrison, 1986; Weaver, 1949). That approach, however, differs from the majority of experimental studies in text legibility. Current work suggests that researchers construct studies and, hence, stimulus materials that are synonymous with those found in normal reading situations (Eperjesi, Fowler, & Kempster, 1995; Tomasi & Mehlenbacher, 1999). Moreover, speed of reading tests have been a very popular mechanism for examining legibility (Lewis, 1969, 1972; Tinker, 1932, 1963, 1966). Hence, meaningful words have been used in most studies.

Legibility and Electronic Displays

It is often argued that electronic documents require design techniques that are different from those used for print–based documents (Hartley, 1987; Morrison et al. 1989; Sullivan & Manning 1997; Tomasi & Mehlenbacher, 1999). The issue becomes even more controversial when dealing with multimode documents (i.e., documents that are from a single source and are intended for delivery in more than one mode, such as print, on–line, multimedia, etc.) (Reece, 1992; Reece & Scheiber, 1993; Reece, 1993–1994).

The differing requirements for print–based and electronic documents result from at least eight characteristics: (a) space and usage, (b) resolution, (c) color, (d) contrast, brightness, and effect of ambient conditions, (e) viewing limitations, (f) display distortions, (g) aging, and (h) appearance control.

- Space and usage—The space available for an electronic display usually differs from that of a print–based document in both amount and arrangement. Text alignment, interword spacing, and text line formations all may require special consideration for electronic displays.
- Resolution——Items on both print and electronic displays are created by placing very small dots on a background. In an electronic display, the background also is composed of dots. If the dots are small enough and spaced closely enough, then the viewer's vision system perceives them as a continuous element. Hence, the size and spacing of the dots bounds the smallest size of element that can be displayed and also affects the sharpness of the boundaries of the element. Dot pitch is measured in dots per inch (dpi), and a higher pitch is almost always desirable. Even the cheapest printers available now are capable of producing a pitch of 600 dpi, and 1200 dpi, or more is common in any non–personal application. Current electronic displays, however, are limited to slightly more than 100 dpi.
- Color—The option of color is now nearly universally available on electronic displays. Print–based documents often are limited to black and white.

- Contrast, brightness, and effect of ambient conditions—The available contrast and brightness of electronic displays is limited; hence, their effectiveness may be reduced in brightly lit environments. This phenomenon is particularly troublesome with Cathode Ray Tubes (CRTs), which are the basis of common computer monitors. The contrast and brightness of print–based documents usually increases as the ambient light intensifies.

- Viewing limitations—Electronic displays may limit the user to certain viewing orientations. For example, Liquid Crystal Displays (LCDs) in laptop computers may be visible over only a limited viewing angle. Print–based documents usually do not have such limitations.

- Display distortions—Electronic displays, particularly CRTs, also may exhibit other distortions. Geometric distortions may cause such effects as bending, rotation, break–up, or improper proportioning of elements in the display or loss of part of the display. Improper rendering of colors also may be a problem with electronic displays. In particular, poor convergence, which is a misalignment of the primary colors used to create each color display dot, may cause not only color changes, but also distortion of boundaries and double imaging ("ghosting") that make the display unusable. Again, these problems usually do not occur in print–based documents.

- Aging—Electronic displays, again particularly CRTs, may deteriorate as they grow older and, hence, may become more likely to exhibit one or more of the above effects that were not present when the display was new. Print–based displays also age; however, the effect is typically either a gradual, general degradation of the document as a whole or a problem, such as tearing, that renders the document unusable.

- Appearance control—In some instances the viewer may have control over aspects of the appearance of an electronic display. This control may result from adjustment of controls, such as brightness and contrast on a computer monitor, or from altering parameters, such as background color or display size, in a computer program that drives the display. Print–based documents cannot be altered.

Despite these differences, the specific issues associated with electronic displays have received little attention in comparison to the work devoted to the design of legible, printed documents. Hence, a common approach to designing electronic displays has been to simply

extend existing print–based principles and apply them to electronic displays (Williams, 1994; Williams & Tollett, 1998). Legibility is one such design issue that has been addressed in this manner. Moreover, most of the work associated with electronic displays has been directed toward normal readers rather than reduced vision readers.

As with print–based documents, the common general recommendations for electronic displays emphasize good contrast between the background and the type. Careful selection of background and type color are important (Vanderheiden, Chisholm, Ewers, & Dunphy, 1997). Additionally, the typeface should be "clean" and readily distinguished from the background (Williams, 1994; Williams & Tollett, 1998). Suggestions for more specific guidelines tend to be sparse and to vary as described in the following.

Proportional and Fixed Width Type

Proportional typefaces usually are recommended over fixed–width fonts (Beldie, Pastoor, & Schwartz, 1983; Jones, 1989). Fixed width typefaces may reduce the clarity and readability of narrow characters because of increased white space around the character and limitations in the character size due to the dot pitch (Jones, 1989). Additionally, proportional typefaces may yield a more efficient use of limited character space than fixed width typefaces, thus allowing more information to be displayed on an electronic display (Jones, 1989). It has been suggested that the selection of a proportional typeface may override other factors, such as presence of serifs, in determining legibility for electronic displays (Beldie, Pastoor, & Schwartz, 1983; Jones, 1989).

Emphasis Quality

As more typefaces become available to designers, the use of slanted or italic typefaces in electronic displays can be expected to increase; however, guiding recommendations for their usage are limited. Some sources have suggested their use for key guiding elements, such as linked elements in web pages (Jones, 1989), and some high–level guidelines without specific principles have been offered (Jones, 1993). Moreover, studies of the legibility of such typefaces in electronic displays for any audience has not been performed.

Serif Presence

Recommendations on the selection of serif or sans–serif fonts for electronic displays have been somewhat mixed and based upon guidelines for paper–based materials. Suggestions for use of typefaces with serifs, particularly for dense regions of text, are common (Bigelow & Day, 1983; Craig, 1971, Craig & Meyer, 1980, Craig & Meyer, 1992, Craig & Bevington, 1999; Gerstner, 1974; Haley, 1980; Hartley, 1978; Laundy, 1980; Marcus, 1982, 1984a–b, 1983; Mueller–Brockmann, 1981; Rehe, 1974; Ruder, 1977; Trollip, 1986; Vignelli, 1976; Williams, 1994; Williams & Tollett, 1998). However, fonts with serifs may not translate well when shown on a display of different resolution from the one used for the design (Darnell, 1998). Additionally, fine strokes, such as serifs, may not be distinguished easily on some electronic display screens because of the dot size (Marcus, 1992). Moreover, a common desirable characteristic that is associated often with serif fonts is the enhancement of “tracking” between associated letters in text during reading, but it has been suggested that sans serif fonts can track as well as serif fonts and that the inclusion of serifs for tracking is not necessary for a well–designed font (Haley, 1998). As a result, a

common recommendation today is to use a mixture of typefaces. In a common compromise, typefaces with serifs are suggested for ordinary, body text, and sans serif typefaces are recommended for navigational text items, such as headings and other delimiters, labels, lists, or button labels (Marcus, 1992; Williams, 1994; Williams & Tollett, 1998).

Legibility and Reduced Vision

The legibility problem becomes even more complicated when reduced vision readers are considered (Arditi, 1994; Stueben & Vockell, 1993). The need to address accessibility issues is now focusing interest on that group. Moreover, the importance of text legibility and typographical factors in the design of materials for reduced vision readers is recognized (Hartley, 1994).

Reduced vision readers suffer some degree of visual impairment that is not correctable by means such as contact lenses, eyeglasses, or surgery (The Lighthouse International, 1997–2004). This impairment may result in a number of problems during reading, such as seeing double images, losing place or moving from one line to another when reading words on a line, skipping lines surrounding the intended reading position, seeing words as being spread apart, or seeing letters or symbols as moving about (Meares, 1980).

Reduced vision readers may use a variety of means to compensate for the difficulties that they experience in reading. In some instances, they may use the same material as normal readers with customizations that accommodate their needs. For example, they might modify the choice of fonts or background colors in an electronic display to accommodate their reading preferences (Burgstahler, 1999; DeBord–Schulze, 1997;

National Technology Access Program, 1998; Trace, 1997–2004; Vanderheiden, Chisholm, & Ewers, 1997a–b). In more severe cases, however, reduced vision readers may be limited to reading text that is very large, held very close, or highly magnified (Bergman, 1994 – 1997). Specialized equipment, such as magnifying readers for printed documents or screen reading software (Burgstahler, 1999; DeBord–Schulze, 1997) for computer displays, may be required. Such software normally results in the display of a limited number of characters of text a line at a time and requires the use of large computer monitors (Fine & Peli, 1996).

Some "screen reader" systems take a different approach by interpreting the visual display and producing an audio description for the user instead of making the screen more visible to the user. In order to maximize the utility of such systems, the display must include additional descriptive information about the contents of non–text elements, such as graphics, for the screen reader. This additional information is then transferred to the user as part of the description. For example, web pages may include "alternative text," which is recommended for accessible design (DeBord–Schulze, 1997; Reece, 2001; Reece, 2002a–c; Vanderheiden, Chisholm, & Ewers, 1997a–b). If the additional information is not available, the screen reader system may produce a generic description, such as "graphic," which is of little or no value to the user. Reece (2001, 2002) recommends including descriptions of the element and its relationship to the other content of the page in order to produce an accessible document.

It is clear that text legibility is a particular concern for reduced vision readers. While some studies of this issue have been performed, they have been directed almost exclusively toward printed documents rather than electronic displays.

Additionally, it has long been suggested that studies consider the type of eye disorder that causes the reduced vision problem (Prince, 1957; Shaw, 1969). This need arises because of the differing effects of various disorders. Two such examples are macular disease, which may cause difficulty in near reading tasks (Corn & Koenig, 1996), and retinitis pigmentosa, which may cause loss of color perception and difficulty in focusing (DeBord–Schulze, 1997; Thomas, 1997; The Lighthouse International, 1997–2004).

Classifications and Sources of Reduced Vision

Reduced vision cases can be classified by either the characteristics of the eye disorder that causes the condition or the severity of the resulting visual impairment. Such categories are sufficient for this discussion; however, Appendix A provides a more detailed discussion of eye disorders and their relationship to reduced vision.

A grouping of eye disorders that can cause reduced vision is given in Table 1. The first level groups, denoted as resolution categories, are based upon the region of the eye that is affected by the disorder. These groups are known as resolution problems of the anterior segment (affecting the front part of the eye) and resolution problems of the posterior segment (affecting the back part of the eye). This grouping is important because the elements of the eye in these two regions differ greatly and perform very different functions. The anterior portion focuses and processes the incoming light rays to form an image on the sensing elements of the posterior region, which then transmit the resulting information to the brain.

Table 1. Resolution Categories and Eye Problems[a]

Resolution Category	Subgroup Classification for the WebText Study Based Upon Vision Function Loss	Types of Eye Problems Associated with Resolution Categories and Subgroups
Anterior Segment	Primary	Problems with the cornea, anterior chamber, iris, or lens; hereditary corneal dystrophies; aniridia; cataracts
	Secondary	Amblyopia (non–pathological due to strabismus or adverse refractive error); nystagmus (primary etiology); pathological myopia; traumatic changes
Posterior Segment	Primary	Central scotomas, cone dystrophies, diabetic retinopathy, macular diseases (includes macular degeneration), pars plantis, retinal edema
	Secondary	Albinism, color deficiencies, glaucoma, branch vein occlusion, ischemic optic neuropathy, retinitis pigmentosa, traumatic changes

a. Brief definitions of each eye problem listed in this table are included in Appendix A.

The secondary, or subgroup, classes for each resolution category are based upon the principal type of vision loss that results from the eye disorder. Disorders in the primary subgroups cause loss of the ability to perceive specific information or detail and disorders in the secondary group cause a loss of general vision capability. Primary disorders in the anterior segment (anterior–primary) are associated with the loss of resolution capability, while secondary disorders in the anterior segment (anterior–secondary) cause a loss of visual field (the area that can be perceived). Similarly, primary disorders in the posterior segment (posterior–primary) cause loss of central vision (vision in the center of the visual field, which is associated with detail), and secondary disorders in the posterior segment

(posterior–secondary) cause other types of vision loss, including reduction of the visual field and an overall loss of the ability to sense light and perceive objects.

Reduced Vision Legibility Studies

Most early work on legibility for reduced vision readers deals with improving printed materials for children (Shaw, 1969). Only a few studies (Prince, 1957, 1958, 1959, 1960, 1964, 1967) addressed print for reduced vision in child and adult populations.

One of the earliest experiments to show that the needs of reduced vision readers may differ from those of normal readers was conducted by Kuntz and Sleight (1949). They found that people with reduced visual acuity benefited much more from an increase in target brightness than did readers with normal acuity.

Prince (1957, 1959, 1960, 1964, 1967) provides some of the earliest recommendations regarding typographical factors in the preparation of materials for reduced vision readers. In the earliest work, he found that reduced vision readers recognize lowercase letters in the form of familiar words (called “word pictures”) much more easily than letters in other contexts due to the readers filling in information from the context to produce an appropriate interpretation (Prince, 1957). Additionally, he noted that material with additional kerning (interletter spacing) was read more easily than densely packed text by such readers. Later, he determined that readers with subnormal vision also prefer text with increased interword spacing and leading (i.e., interline spacing) (Prince, 1959).

Next, Prince (1960) examined the preferences of reduced vision readers for printed material backgrounds of various grey densities. He found preferences but was not able to establish conclusive relationships between those preferences and the participants’ ocular

conditions. It is notable that all of the nearsighted (myopic) participants preferred low contrast backgrounds.

Finally, in a hypothetical discussion, Prince (1967) suggests that experienced reduced vision readers may prefer serif typefaces over sans serif typefaces. Moreover, he argued that these preferences may differ between adult and children reduced vision readers. This phenomenon would be expected because adults who have been active readers will have much more experience than children.

The work by Shaw (1969) is a key study of legibility and reduced vision readers. This research was the first to examine print for reduced vision readers by direct observation. It examined the effect of typographical changes on the ease with which reduced vision readers could read continuous text on paper. Variations of typeface (serif and sans serif), type weight (bold and medium), and type spacing (interletter, interword, and interline) were examined. Familiar words from standardized lists used in schools were arranged in semantically anomalous random sentences to avoid the effect of clues of context.

Shaw found that type size is one of the most important factors for adult reduced vision readers, with those participants exhibiting preferences for sizes larger than 10 to 12 points. The relative size and weighting of the typeface were secondary contributing factors to legibility when considered collectively. The study also showed that other differences in typeface seem to have little effect of legibility, although there was some preference for sans serif faces. This preference, however, may have been related to the reading experiences of the participants; only 15% of the participants classified themselves as “serious” readers. Researchers have also suggested that typography that is familiar is also easy to read (Gill,

1931; Kicko, 1990; Wendt, 1970). Burt (1960) found that fonts that are legible for normal readers are those that are also familiar. Additionally, Prince (1966) noted that reduced vision readers who had well–established behavior patterns for reading traditional typefaces before the onset of vision deterioration tended to prefer these same traditional typefaces, although they may not be clearly discernable.

Additionally, spacing variations do not seem to affect legibility. Moreover, the typographical changes appeared to help adults more than children. Finally, the use of word and phrase units was important.

Additionally, Shaw (1969) found relationships between the pathological conditions that caused the reduced vision and the preferences. Participants with glaucoma preferred bolder type and were most affected by typographical changes, especially size and weight. Participants with cataracts were helped more by increases in weight than increases in size, while this characteristic was reversed for participants with myopia. Finally, participants with age–related macular degeneration (AMD) were helped by increases in size and a change to a sans serif typeface. Moreover, there were no cases in which typographical changes were helpful to one group and detrimental to the others. It must also be noted that Shaw's work did not include a control group; hence, her preferences from a group of reduced vision readers cannot be compared to those of normal readers.

Several studies on the psychophysics of reading have been conducted using both normal and reduced vision readers. These studies have addressed such topics as font and reading rates (Legge, Peli, Rubin, & Schleske, 1985; Univeristy of Minnesota Laboratory for Low Vision Research, 1998), font and contrast sensitivity function on reading (Legge,

Rubin, & Luebker, 1987), influence of fonts in normal and reduced vision reading acuity (Mansfield, Legge, & Bane, 1996; 1996–2004), recognition of characters within the visual span at a glance as related to reading speed deficits (Legge, Ahn, Klitz, & Luebker, 1997), and reading speed related to page navigation problems associated with using magnifiers (Beckmann & Legge, 1996; den Brinker, 1994; den Brinker & Beek, 1996; den Brinker & Bruggeman, 1996; DeBord–Schulze, 1997; Fine, Kirschen, & Peli, 1996).

Lightstone (1997) found that spectral filters were helpful to some patients during reading tasks. Additionally, Eperjesi, Fowler, and Kempster (1995) discovered that color contrast may assist subnormal readers in object recognition rather than enhance reading and that dark letters on white background may be preferred.

Few studies that included reduced vision readers involved electronic displays. Much of this work centered around the effect of color upon legibility. Legge and Rubin (1986) explored the relationship of color to legibility of text on a television monitor in a distance reading task. Neutral–density and Wratten color filters were placed over the monitor as participants read material. The results indicated that for this task, wavelength alone did not play a significant role. Moreover, when wavelength is a factor, these researchers suggested that the legibility tends to be optimal for green or grey. Similarly, few studies, however, have examined other typographical issues associated with text legibility on electronic displays for an audience with reduced vision. In one notable study, Fine and Peli (1995) examine the effects of spatial filtering on reading rate, the effects of character size, and the effects of luminance using a monitor and a low vision magnifier. They concluded that some

reduced vision readers may benefit more from increased luminance from the use of larger characters.

Currently, studies do not provide guidance for selecting typefaces to produce legible electronic displays for reduced vision readers. Any available recommendations result from extending either print–based studies or studies using normal readers to this situation. Additionally, studies have not examined any associations that may exist between the source of the reduced vision and legibility of text on electronic displays.

This Research

This review of previous work indicates that legibility of electronic displays for an audience of reduced vision readers is an issue of critical importance, particularly in education, yet guidelines for designing effective displays for this audience was not available. Moreover, much of the information that is available was derived by extending print–based studies. This extension may not be valid, and, furthermore, the results from print–based studies often disagree.

This research addresses that unresolved issue. The purpose of the study is to determine if reduced vision readers exhibit preferences for typeface (serif or sans serif) or emphasis (italic or Roman) attributes of text that are different from the preferences of normal readers and, additionally, if the preferences of reduced vision readers are associated with the type or severity of their visual disorder. This experimental work is the first to investigate these issues using the approach of direct observation in a normal reading situation.

Two hypotheses are tested by this study:

1. Reduced vision readers with functional vision loss resulting from resolution problems will not exhibit definitive preferences for serif presence (i.e., any preferences for serif or sans–serif typefaces will not be strong), and those preferences will not be related to the participants' visual disorder characteristics. Hence, we also expect that the preferences of the normal readers (i.e., the control group) will be similar to those of the reduced vision readers. This prediction is based upon the variation in results from previous researchers.

2. Reduced vision readers with functional vision loss resulting from resolution problems will exhibit preferences for Roman over italic typefaces, and this preference will not be related to the participants' visual disorder characteristics. Again, we also expect that the preferences of the normal readers (i.e., the control group) will be similar to those of the reduced vision readers. This prediction is based upon the previous findings that the use of italics tends to impede reading for normal readers (Tinker, 1966; Tinker & Paterson, 1942). Moreover, the presence of any visual disorder will not reduce this impediment.

The data were collected using a sequence of computer screen displays. Each screen contained a different familiar word that was displayed in two typefaces that differed in either typeface contrast (serif or sans–serif), emphasis (Roman or italic). The sequence of screens contained multiple instances of each type of comparison using different pairings of fonts on each screen. Before beginning to view the sequence, each participant selected a preferred background color and typesize which was then used in displaying the remaining screens. The participant's preference for one of the typefaces was recorded for each screen.

This work examined five key research questions:

1. What kinds of typeface contrast (i.e., serif or sans serif) do readers with resolution problems find easiest to read in web documents?

2. What font emphasis qualities (i.e., italic or Roman) do readers with resolution problems find easiest to read in web documents?

3. How do the preferences of reduced vision readers differ from those of normal readers?

4. How does severity of the participant's vision loss affect preferences for readers with resolution problems?

5. How does the type of eye problem affect preferences for readers with resolution problems?

All participants were adults. A control group of normal readers was included. The reduced vision participants were classified by the severity of their vision loss (mild or moderate–to–severe) and by the two characteristics of their principal vision disorder, resolution category (anterior or posterior) and subgroup (primary or secondary).

The responses were analyzed for differences in the responses from the groups of participants using the Pearson Chi Square test. The tests were performed separately for the responses related to each of the two typeface characteristics. Similarly, individual analyses were performed for each of the three variables used to categorize the participants. Additionally, in each case, tests were performed on sub populations delineated by a particular value for one or more of the other two characterizing variables. For example,

dependence of the typeface contrast upon degree of vision loss was tested first using the entire population. Then, the test was performed on each of the sub populations:

- Participants with any anterior disorder
- Participants with an anterior–primary disorder
- Participants with an anterior–secondary disorder
- Participants with any posterior disorder
- Participants with a posterior–primary disorder
- Participants with a posterior–secondary disorder

CHAPTER 2

Method

Overall Structure of Study

This study collected data on preferences for characteristics of typefaces on electronic displays from participants with various types and degrees of reduced vision and then analyzed those data to determine if statistically significant differences in those preferences between the classes of participants existed. The data were collected by recording participants' preferences for words presented in different typefaces in a series of computer screen displays. The participants included reduced vision readers with various types of eye disorders and severities of vision loss as well as a control group of normal readers. Differences in the responses of the various groups of participants were then identified and examined for significance using standard statistical significance tests. The following sections describe the participant profile, the data collection procedures and instruments, and the data analysis methods.

Participants

All participants in the study were volunteers. The general qualifications for all participants were:

- Be at least 18 years of age as recommended by the referring doctor;
- Have binocular corrected (i.e., using glasses or contact lens) visual acuity;
- Have either sufficient visual acuity to qualify as a control participant or visual acuity and a visual disorder appropriate for one of the categories described below;

- Be functionally literate; and
- Be capable of viewing 24 electronic screen displays of word pairs and responding according to preference during a 10 to 20 minute session.

At the first level, the participants were divided into a control group (normal readers) and a group of reduced vision readers. The criterion for this division was:

- **Control**—Have a visual acuity of .5M or better (20/20 or better)[1]
- **Reduced Vision**—Have a visual acuity of .6M to 8M (20/30 to 20/400)

Next, the reduced vision participants were classified into resolution categories, denoted as anterior and posterior, based upon the region of the eye that is affected by the primary type of eye disorder exhibited by the participant. Each of these categories was in turn divided into subcategories, denoted as primary and secondary, based upon the type of vision loss that results from the eye disorder. Hence, the four subgroups for the reduced vision participants were anterior–primary, anterior–secondary, posterior–primary, and posterior–secondary. These groupings were formed according the classification of the primary eye disorders that was given in Table 1.

Finally, each subcategory was divided, according to the degree of vision loss of the participants. This breakdown was according to definitions by the World Health Organization (WHO, 2001). The criterion was:

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1. All visual acuities were determined using the standard Lighthouse Near Acuity Chart.

- **Mild**—Have a visual acuity of .6M to 1.2M (20/30 to 20/60)
- **Moderate–Severe**—Have a visual acuity of 1.4M to 8M (20/70 to 20/400)

This ordering of participant characteristics is given in Table 2.

Table 2. Ordering of Participant Characteristics

Normal Readers	Reduced Vision Readers							
	Anterior				Posterior			
	Primary		Secondary		Primary		Secondary	
	Mild	ModSev.	Mild	ModSev.	Mild	ModSev.	Mild	ModSev

Participants were recruited using several methods, including mailings, posters, flyers, public service radio announcements, and direct solicitation. The most successful method, particularly for reduced vision participants, was direct solicitation of these individuals as they arrived in optometrist's or ophthalmologist's offices for eye care.

Data Collection

Sites

Data were collected at three sites:

- **Southern College of Optometry (SCO)**—A teaching and research facility, which has a large optometry clinic. Data for most of the control group were collected at this site. Additionally, a few reduced vision participants were obtained from the patients at this clinic.
- **Charles Retina Institute (CRI)**—A large clinic, which specializes in retinal problems and has both ophthalmologists and optometrists on staff. This site supplied approximately one–half of the reduced vision participants.

- **UT Medical Group (UTMG)**—The ophthalmology unit of the clinical practice group of the faculty of The University of Tennessee–Memphis, which is a large medical school. Approximately one–half of the reduced vision participants were obtained from this location.

All of these sites are located in Memphis, Tennessee. Data were collected over the period May 1999 to February 2000; however, the collection was performed at only one site at a time. A single test setup, as described below, was moved between these sites over this period.

These sites were selected because they provided a large base of prospective reduced vision participants and because of the cooperation of the clinic operators. These doctors provided space within their clinics for conducting the data collection and access to their patients. Additionally, they assisted in identifying potential participants among the patients, provided training and oversight for the acuity measurement step, and assisted in the proper classification of reduced vision participants according to their eye disorder as described above.

Patient participants at the clinics were obtained by personal solicitation during their scheduled office visits. All of these participants were classified as reduced vision readers. Additionally, participants from the student body at Southern College of Optometry were obtained through posted announcements and direct solicitation by cooperating members of the faculty. Almost all of these participants were members of the control group. Finally, a small number of "external" participants, who were contacted through such methods as posters and were not associated with the clinics as patients or students, were processed at each clinic. These participants included both normal readers and reduced vision readers.

A secure, quiet, private area was provided at each clinic for the data collection. These rooms were: a student laboratory (SCO), an examination room (CRI), and a contact lens fitting room (UTMG). The data collection required sufficient space for the computer system (described in the platform section below), with the monitor placed at standard desktop height, and seating for the participant allowing proper viewing of the computer screen (described in procedure section below). All of the rooms met these requirements. Each room provided background illumination in accordance with its normal use, which was not altered. Other activities did not take place in these areas during the data collection operations.

Procedure

All data collection and processing activities were conducted in strict accordance with the guidelines approved by the Institutional Review Boards (IRBs) of each cognizant institution (The University of Memphis, Southern College of Optometry, and The University of Tennessee–Memphis). Approval documents from each institution are given in Appendix B.

At each clinic, daily rosters of scheduled patient visits were reviewed in consultation with the clinic doctors and staff to identify prospective participants who exhibited visual acuities and eye disorders that fulfilled the study criteria. As these patients arrived throughout the day, they were approached and their voluntary participation was solicited. Data were then collected from those prospects who agreed to participate before any medical exam or procedures took place and before any medications were administered.

The collections involving SCO students or external participants were performed during individual appointments that were scheduled for the convenience of the participants. Additionally, permission for such appointments that involved external participants was obtained from the cognizant doctor at the clinic in advance of the participant's arrival.

In all cases, the data were collected from each participant individually. Each data collection required approximately fifteen to twenty minutes and consisted of three stages: preliminary activities, viewing and responding activities, and closing activities.

Preliminary Activities

The preliminary activities began with an explanation of the purpose and procedures of the study to the participant. Any questions from the participant were answered at that time. An informed consent form was then reviewed, and the participant's signature was obtained if they agreed to continue (see Appendix B). If a participant did not wish to continue, they were thanked for their time, and the session was terminated.

If the participant continued, various demographic information (name, address, telephone number, date of birth, gender, and, if available, e–mail address) was obtained from the participant and recorded (see Appendix C). In addition the name, description, and ICD–9 code (Practice Management Information Corporation, 1998) for the participant's current dominant eye disorder (both eyes) was obtained for the reduced vision participants. This information was used for classification of the participant as described in the profile section. It was obtained from the participant and was later verified against the participant's history with the assistance of the clinic staff and doctor. In some instances, this verification

required review of a complex ocular history by the doctor to ensure an accurate classification.

The final preliminary activity was to measure and record the participant's near visual acuity at a standard distance of 40 cm. (approximately 16 inches) using the Lighthouse Near Acuity Chart (a metric–based acuity test for near distance with standardized conversions to other acuity measurement systems). Measurements obtained from this chart can be converted easily into other forms as needed. The acuity was measured for each eye individually and for both eyes together and was used to classify the degree of the participant's near vision loss. This measurement was taken with the participant using their current reading aids (eyeglasses, contact lenses, telescopic lenses, and hand–held magnifiers, etc.) that they normally use for reading tasks, and the participant continued to use those aids for the subsequent viewing and responding activities.

Viewing and Responding Activities

The viewing and responding activities were the core of the data collection operation (see Appendix D). The participant's text preferences were recorded during this task (see Tables D1–D2).

At the start of the viewing and responding activities, the participant was seated in front of a computer screen at a distance of 40 cm. (see Table D–1)[2]. A small number of participants, primarily those with severe vision loss, were unable to view the screen comfortably at that distance. In those cases, the participant was allowed to adjust to their

2. Details of the computer hardware and software are given in the instrument discussion below.

preferred location for reading the computer screen. The new distance to the screen was recorded, and the participant remained at that position during the remainder of the viewing and responding activities.

Twenty–eight screens were then presented in sequence to the participant (Appendix E). As each screen was presented, the participant was asked to respond to specific questions, and the display was advanced to the next screen after the response. All responses were verbal, and advancement between screens was under the control of the examiner. The participant was not required to interact with the computer. The ordering of the screens was fixed, and no backtracking or other changes in the presentation were allowed. The screens were:

- An opening screen
- A background and contrast selection screen
- A typesize selection screen
- Twenty–four word pair screens
- A closing screen

Details of the screens are discussed in the instrument section, and images of the screens are given in Appendix D.

The opening screen contained a graphic of the study logo and a welcome greeting. A response was not required for this screen.

The background and contrast selection screen was used to allow the participant to select a preferred background color and contrast appearance to be used for the subsequent

displays. This selection was incorporated into the process as a means of isolating the participant's typeface preferences later in the process. The goal was to eliminate, or at least reduce, the effect of the background and contrast color by allowing the participants to select their preferred environment. The active area of this screen was divided into three equally–sized vertical regions, each in a different background color, with text displayed in the center of each region in a contrasting color. These colors and contrasts were black text on white background (standard video), black text on grey background (neutral video), and white text on black background (reverse video).

After viewing the screen, the participant was asked to select their region of their preferred background and contrast. Their response was recorded, and all subsequent screens were then displayed using their selection.

Finally, the reading distance from the participant to the screen was rechecked by a measurement before advancing to the typesize selection screen.

The typesize selection screen was used to allow the participant to select a preferred typesize. In this screen, text was displayed in each of five different typesizes (8, 12, 16, 24, and 36 point). The participant was asked to select the text in the smallest typesize that they could comfortably read. This preferred typesize was recorded and then used for displaying the text in the word pair screens. This step was a second isolation mechanism that attempted to reduce the effect of the typesize on the preferences.

Both the background and typesize selection steps were adapted from Shaw (1969), who manually customized typesizes for each participant in a study that also used direct observation and an audience of reduced vision readers.

Again, a measurement to validate the reading distance from the participant to the screen was performed before advancing.

The word pair screens were the key portion of the data collection operation. Each of these screens contained a word displayed in each of two typefaces. For each screen, these typefaces differed in either one or both of two characteristics, emphasis (Roman or italic) and serif presence (serif or sans serif). As each screen was displayed, the participant was asked to select the word from the pair that was most legible to them, and their choice was recorded.

A final measurement check of the reading distance from the participant to the screen was performed after the last word pair screen was viewed.

The final screen, after the word pair screens, was the closing screen. This screen was similar to the opening screen. It contained a graphic of the study logo and a message thanking the individual for participating in the study. Again, responses were not required for this screen.

Closing Activities

During the closing activities, the participants were given another opportunity to ask questions. Each participant was presented with one or more of various tokens of gratitude. Possible tokens included: a coffee mug with the study logo, color acetate overlays for reading assistance, and bold line writing paper with 20/20 pens for writing assistance. Along with the tokens, each participant received a “thank–you” letter that also provided information on the appropriate use of the items for assisting reduced vision readers and locations of related, useful internet resources.

Instruments

The computer platform for all data collections consisted of the following elements:

Hardware

The computer hardware was a standard personal computer:

- Dell XPS R450 personal computer–450 MHz processor; 128 MByte RAM; 1024 x 768 pixel, 24 bit graphics display
- Dell 19–inch Trinitron color monitor
- Standard keyboard and mouse

This system provided ample computation capability for the data collection operation. Additionally, the large, high–quality monitor provided a clear and high contrast display of the text in all required typesizes, fonts, and colors.

Software

The following standard, off–the–shelf software was used to present the screens to the participants:

- Microsoft Windows NT 4.0™ [3] Workstation operating system
- Netscape Navigator,™ [4] version 4.72 web browser
- Bitstream WebFont Maker™ [5] font processing software

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3. Microsoft Windows NT is a registered trademark of Microsoft Corporation.

4. Netscape Navigator is a registered trademark of Netscape Corporation.

5. WebFont Maker is a registered trademark of Bitstream Incorporated.

All screens were constructed as web pages in the Hypertext Mark–up Language (HTML) and were viewed using Netscape. Web pages were used for the screen displays because they are very common and they allowed the desired displays to be created easily. For many people, the first and, perhaps, most frequently encountered computer display is a web page. Additionally, web pages may include essentially any element that can be displayed on a computer screen.

During the data collection, the HTML source code for the screen pages remained on the local disk of the computer and was read from there, rather than across a network connection from a remote server. This arrangement simplified the system by eliminating the need for a separate server and network connection. Moreover, the time lag in display caused by reading web pages across a network or telephone connection was avoided, and the transition between screens was nearly instantaneous.

The WebFont Maker^{TM} software was used in order to provide convenient and accurate display of the desired typefaces on the screens and to provide access to a large, rich set of potential typefaces. In a web page without the use of the WebFont Maker^{TM} software, the actual display of text characters is controlled by the computer on which the user is running the browser program (e.g., Netscape^{TM}) and is limited to the typefaces that are installed on that computer. Moreover, the author of the web page has no control, or even knowledge, of the typefaces that are available on any viewer's computer. The author may specify in the HTML source that text is to be displayed in a particular typeface; however, if that typeface is not available on the viewer's computer, the browser will substitute another typeface. A very common approach of web page authors is to simply specify typefaces using "logical"

forms (e.g, standard, bold, or italic), which are then displayed as system–dependent defaults on any particular computer. Alternately, an image graphic containing a picture of the exact text and typeface to be displayed can be created by the author and downloaded as part of the page. This method, however, is used infrequently because of the extra effort required to create the image, the inflexibility of the display, and the increased download time caused by the image.

The WebFont Maker™ software overcomes this limitation by providing a mechanism for downloading descriptions of specific typefaces as part of the web page at the expense of increased time for download and display. To accomplish this operation, a web page author processes a desired typeface using the WebFont Maker™ software to create a special file, known as a "portable font resource" (PFR). The author then incorporates a special reference command to the PFR file into the HTML source for the page and specifies the typeface for text display as desired. When the page is displayed on the viewer's computer, the browser downloads the specified PFR file (or reads it from a local file if the page sources are local, as in this study) and then uses that information to accurately create the desired typeface wherever it is used on the page.

A WebFont Maker™ PFR uses an "outline" mechanism, similar to TrueType™ [6] and Adobe PostScript™ [7], to specify the appearance of the typeface[8]. This approach specifies

6. TrueType is a registered trademark of Microsoft Corporation.

7. Adobe PostScript is a registered trademark of Adobe Systems Incorporated.

8. TrueType™ is used by the Microsoft Windows™ operating system to display text in many common application programs. Adobe PostScript™ is used to create printed pages in many laser, and other high quality, printers.

the outline boundaries of each character in the typeface as a mathematical equation. The browser creates a character in a particular typeface by "drawing" the outline at the desired location using the equation and then filling in the interior region. The specifications of the equations are compact; hence, the amount of data required to describe a particular typeface is smaller than in other methods. Moreover, the mathematical equation for each character can be scaled; hence, the browser can construct an accurate rendering of a character in any desired typesize, subject to the limitations of the display screen, from a single equation. Other effects, such as rotation, also are possible, but were not used in this study.

Additionally, the WebFont Maker^{TM} package provided over 200 typefaces, which can be processed into PFRs and incorporated into web pages. These typefaces included a very wide range of styles and combinations of typeface characteristics. This set served as the source for typefaces with the required characteristics for this study, some of which were not readily available otherwise. Details of the criteria employed in choosing the typefaces, the identities and characteristics of the selected typefaces, and the application of the typefaces are discussed in the "Screen Details" section later in this chapter.

Word Selection

The words in the text on the screens were required to be familiar and readily recognized so that the participants' responses were based upon typeface characteristics and were not influenced by difficulty in reading an unfamiliar word. This approach was similar to that of Shaw (1969), who used familiar words in a random context. However, the words also had to be sufficiently complex that the responses were based upon viewing of the whole word rather than single letter preferences. To achieve these goals, the words used in this study

were taken from a suggested inventory of basic reading words (Johns, 1997). Thirty–eight words were selected randomly from a list of 120 words for readers from pre–kindergarten to fourth grade. Hence, any participant with a basic functional literacy level could be expected to be familiar with the words. The complexity issue was addressed by using only two–syllable words.

Screen Details

The HTML source for the screen pages was created using a standard word processing tool (Microsoft Word). Each screen was a single page. Transitions between screens were accomplished using HTML "hot links;" i.e., sensitized area on the screens, which advanced the display to the proper next screen when activated by a mouse click. Such links often are displayed as buttons or similar regions; however, they were hidden on the screens in this study to avoid distraction of the participants. All navigation of the displays during the data collections was handled by the examiner, who was cognizant of the location of the link regions on each screen and, thus, was able to activate the link and advance the screen without additional reference. Additionally, the hot links provided a convenient method for managing the participants' selections for background and contrast and typesize.

Screen captures of a complete sequence of screens are given in Appendix E. This sequence reflects the selection of black on white background and contrast and 16–point typesize. Sequences for any other background and contrast and typesize selections were identical except for those characteristics.

The complete set of screens for the study contained three pages for typesize selection, with each page matching one of the possible background and contrast values. Additionally,

complete sets of twenty–four pages for the word pair screens were constructed in each of the fifteen possible combinations of background and contrast and typesize values. The ordering of the screens was determined automatically by each participant's selections as follows:

- The background and contrast selection screen contained three links, corresponding to the possible background and contrast values (black text on white background, black text on grey background, or white text on black background). When the participant selected a preferred background and contrast, the researcher activated the link associated with that choice, which advanced the display to the typesize selection screen having the preferred background and contrast.
- Similarly, each typesize selection screen contained five links, corresponding to the possible typesize values (8, 10, 12, 16, 24, or 36 points). When the participant selected a preferred typesize, the researcher activated the link associated with that choice, which advanced the display to the first word pair screen in both the preferred background and contrast and typesize.
- Each word pair screen contained a single link, which in all screens except the last, advanced to the next word pair screen in that sequence The link from the last screen in all sequences advanced to the closing screen.

The background and contrast selection screen is shown in Figure 1; it allows the participant to select a preferred background color and contrasting color for the text from three possible choices (black text on white background, black text on grey background, or white text on black background). These options were used in order to span the range of viewing conditions from what is considered "normal" (i.e., black text on white background)

to the “opposite” condition (i.e., white text on black background). The case of grey background represents a “mid–point” between those two extremes.

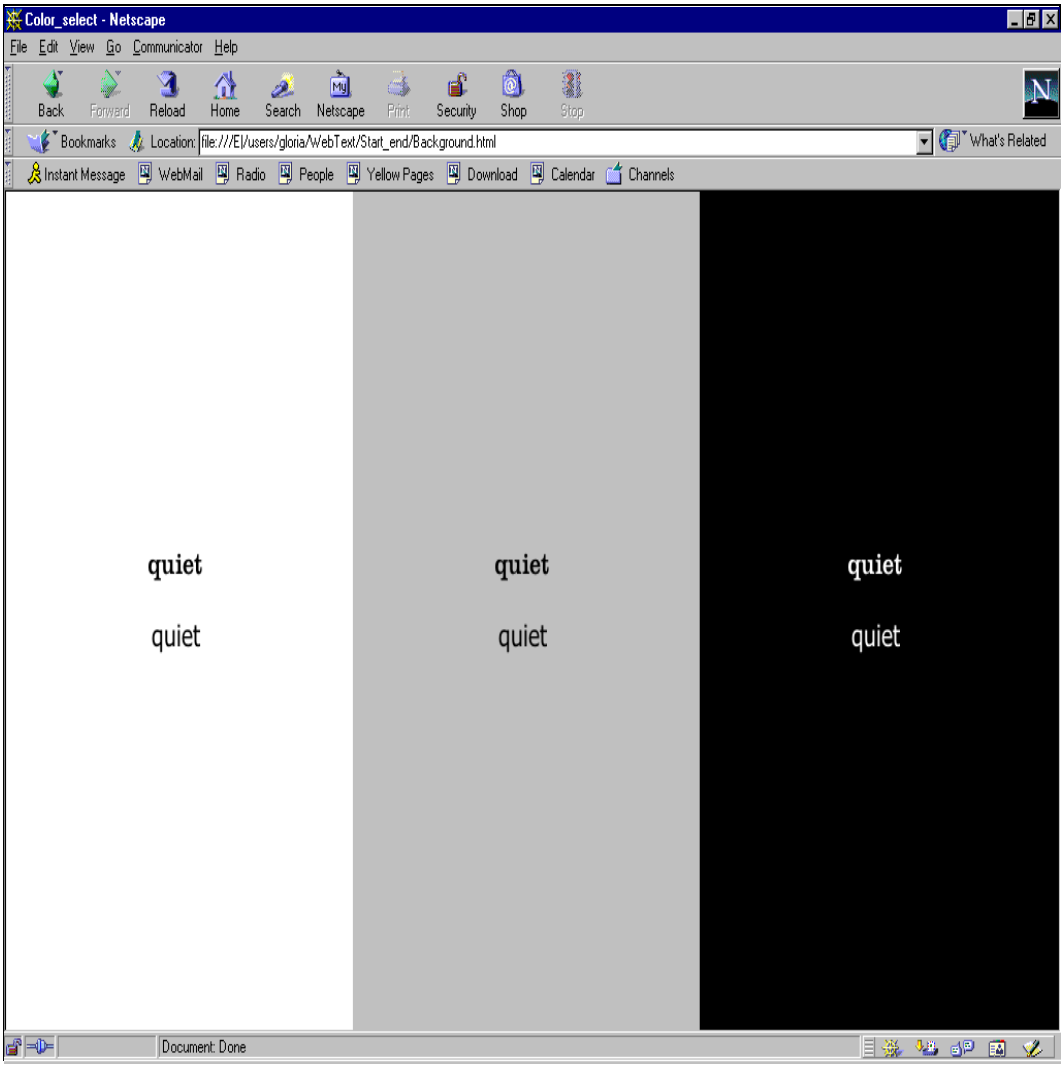

Figure 1. Background and color selection screen for WebText test

Each of the three sections of the screen displayed a word in both serif (Clarendon) and sans serif (Tahoma) typefaces. Both typefaces were Roman (i.e., no italics) since this form is more common. The same word and typefaces were used in each section of the screen,

and these two typefaces were not used in any of the subsequent word pair screens. The text size was 16 points because that value is in the middle of the range of possible sizes on the typesize selection screen. The two words were arranged vertically in the middle of each section.

The typesize selection screen with black text on white background is shown in Figure 2. The three typesize selection screens were identical except for the background and contrast settings, which matched the choices from the background and contrast selection screen. Similar to the background and contrast selection screen, the typesize selection screens displayed a word in a pair of typefaces in each of the five possible typesize selections. The same word was used in all cases, and the two typefaces were the same as on the background and contrast screen. The five word pairs were centered horizontally on the screen, varying from smallest on top to largest on bottom. The five typesize selections (8, 12, 16, 24, and 36 point) are common, standard sizes and were chosen for two reasons:

- They span the range of typesizes that are commonly encountered on computer displays.
- They correspond to The Lighthouse Near Acuity Test values of 1M, 2M, 3M, and 4M as closely as possible. The participants were asked to select the smallest typesize that they could read; i.e., a typesize near their acuity level. Thus, these typesizes represent regular breakpoints in those levels. Moreover, they represent acuity levels from both the mild and moderate–severe vision loss categories. Only one typesize, 36 point, was not an exact match. The exact point size for 4M is 32; however, 36 point was used since that typesize is commonly found in actual displays.

In addition we note that this step accomplished by this screen is adapted from the approach of Shaw (1969), who used a set of typesizes ranging from 12 point to 24 point. The principal

difference is that Shaw manually selected the typesize setting based upon acuity measurements, while we allow the participant to select the typesize.

Figure 2. Typesize selection screen on white background for WebText test

Figure 3 shows a sample word pair screen from the sequence with black type on white background and 16 point type.[9] Each of the word pair screens displayed a word in two different typefaces arranged as a vertical pair and using the participant's selections for contrast and background and typesize. The word and typeface sequences for the twenty–four screens were identical in all instances.

9. A complete set of screens, including all twenty–four word pair screens, is shown in Appendix D.

The two typefaces on each of these screens differed in one or both of the characteristics of interest, serif presence (i.e., serif or sans serif) and emphasis (i.e, Roman or italic). Hence, there were four categories of typefaces: Serif Roman, Sans Serif Roman, Serif Italic, and Sans Serif Italic. Typefaces were not paired with another from the same category, so there were six possible combinations of typeface categories, forming three classes of characteristic variations on a screen as shown in Table 3. This work focused on the cases of variation of one characteristic at a time. The class of both characteristics varying was included for completeness and interest, but data from those screens were not part of the main analysis process.

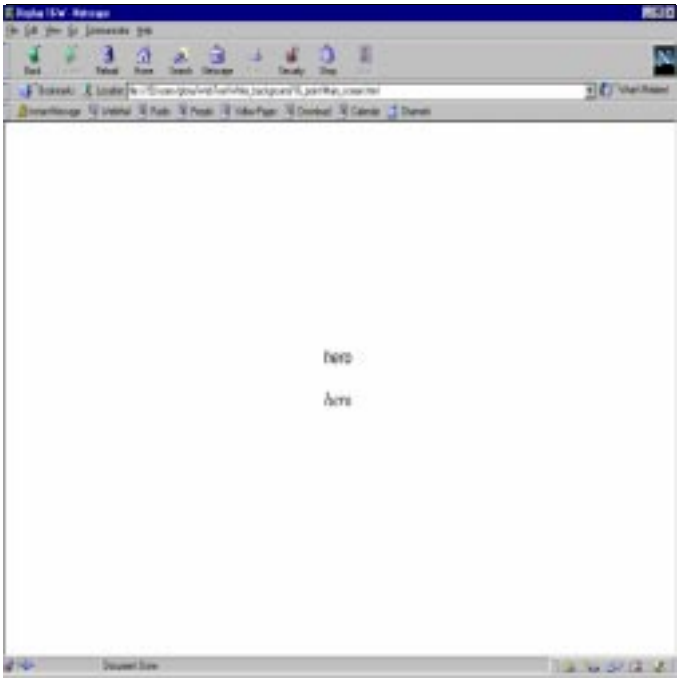

Figure 3. Example word pair screen for Webtext test using black text on white background

.

Table 3. Possible Combinations of Typeface Categories and Resulting Classes of Characteristic Variations

	Characteristic Variation Class					
	Constant Emphasis, Varying Serif		Constant Serif, Varying Emphasis		Both Characteristics Varying	
Typeface Category Combination on screen	Serif Roman	Serif Italic	Serif Roman	Sans Serif Roman	Serif Roman	Sans Serif Roman
	Sans Serif Roman	Sans Serif Italic	Serif Italic	Sans Serif Italic	Sans Serif Italic	Serif Italic

The typefaces used on the word pair screens were manually selected from the pool supplied as part of the WebFont Maker™ software package. The typefaces were required to have a common familiar appearance, to be available in forms both with and without emphasis (i.e., Roman and italic forms), and to be free of "swash" (fancy), alternate characters, custom ligatures, logotypes, or other trendy characteristics. Four basic typefaces, two with serifs and two without serifs, that met these requirements were identified: Century Schoolbook (serif), Times New Roman (serif), Arial (sans serif), and Zurich (sans serif). All four of the typefaces are frequently encountered on PCs, either as part of the operating system or in a common application program. Including both emphasis forms resulted in a total of eight typefaces, two in each characteristic category:

- **Serif Roman**—Century Schoolbook (Roman) and Times New Roman (Roman)
- **Serif Italic**—Century Schoolbook (italic) and Times New Roman (italic)
- **Sans Serif Roman**—Arial (Roman) and Zurich (Roman)
- **Sans Serif Italic**—Arial (italic) and Zurich (italic)

These eight typefaces then produced four instances of each of the possible typeface category combination groups in Table 3, for a total of 24 screens, with eight in each characteristic variation class.

The presentation ordering of the word pair information to the participants was randomized in two ways. First the ordering of the typeface categories of the word pair on the screen was reversed for half of the screens in each of the typeface category combination groups. For example, in the Serif Roman–Sans Serif Roman group, two of the four screens had the upper word of the pair screen presented in the serif Roman typeface and the other two screens had the upper word presented in the sans serif Roman typeface. Within each group, the two screens on which the ordering was reversed were selected randomly. Second, the ordering of the 24 screens in the word pair sequence was randomized. After the randomization, the same ordering was used for all participants.

Recording Instruments

Appendix D illustrates the sheets used to record the participant data. One of these forms was completed by the examiner for each participant. A unique, sequential WebText identification number was assigned to each participant as part of the data record and was used to identify each participant during the data analysis. The data were then transcribed from these forms into a computer data base, which served as a repository and allowed convenient and rapid extraction of information for the analysis process.

Data Analysis

The goal of the analysis was to identify differences between the preferences of the various categories of participants and determine if those differences were statistically

significant, i.e., to test for homogenous distribution of the preferences. The two–way Pearson Chi Square test (Ross, 1982) is the common method of choice for such analyses and was used here where possible. Alternately, the Goodman procedure (Marascuilo & Serlin, 1988) was used in instances in which the Chi Square test was not applicable because of the nature of the sampling as described below.

Assembly of Response Data

The preferences for each of the two typeface characteristics of interest were processed separately but identically. Hence, the preference responses were divided into two groups according to which characteristic differed between the two typefaces in the word pair on the screen.[10] The first group was the responses from screens on which the serif presence differed but the emphasis was constant (i.e., Serif Roman–Sans Serif Roman and Serif Italic–Sans Serif Italic in Table 3). Similarly, the second group consisted of the responses from screens on which the emphasis differed but the serif presence was constant (i.e., Serif Roman–Serif Italic and Sans Serif Roman–Sans Serif Italic in Table 3). Each group of responses for a single typeface characteristic was then divided according to the participant characteristics and tested for homogeneity of the preference responses across the resulting categories of participants.

The participant categories were constructed by sequential application of the three participant characteristics: severity of loss, region of eye affected, and type of loss. This process forms several categories in multiple levels. The succession of levels from top to

10. As noted previously, for completeness, the data collection also included screens on which both typeface characteristics differed; however, those screens were not included in the analysis.

bottom represents a finer division of the population as additional characteristics are constrained. Moreover, the categories will change if the order of application of the characteristics is changed.

One possible ordering of the characteristics in this process is depicted in Table 3; then, the categories that result from that division are given in Table 4. The names of these categories describe the characteristic values that are common for all of the participants in a category. For example, all participants in the Anterior Primary category had an eye disorder that affected the anterior region and had a primary type of vision loss. Additionally, the categories of reduced vision readers at each level can be collected into pairs from left to right, with the two categories in each pair differing in exactly one of the specified characteristics. The Anterior Primary Mild and Anterior Primary Moderate–Severe categories form one such pair; they differ in severity but are identical in region and type of vision loss. Each pair suggests a comparison of preference distributions that is of interest.

Table 4. Participant Categories Resulting from Division Order

Normal Readers	Reduced Vision Readers							
	Anterior				Posterior			
	Anterior Primary		Anterior Secondary		Posterior Primary		Posterior Secondary	
	Ant. Prim. Mild	Ant. Prim. ModSev.	Ant. Sec. Mild	Ant. Sec. ModSev.	Post. Prim. Mild	Post. Prim. ModSev.	Post. Sec. Mild	Post. Sec. ModSev.

Altering the order in which the characteristics are applied in the division process will still produce four levels of categories, but the categories or ordering may differ from those in Table 3. The eight categories in the lowest–level will always be the same as Table 4;

however, the order of those categories across the row, and hence the pairings, will be different. Similarly, different characteristic orders may produce intermediate levels with the same categories but different orderings. In other cases, new intermediate categories may result. These new categories and different orderings of categories suggest additional comparisons of interest. Details of the possible orderings or participant characteristics and the resulting categories, and pairings are given in the "Results" chapter.

Homogeneity Tests

The sampling process must be considered carefully when selecting the appropriate homogeneity test. The participants were selected with the goal of collecting an adequate sample of the normal readers and the eight lowest–level categories derived from the reduced vision readers. Hence, the participants represent random samples of each of those individual categories, and the Chi Square test can be applied across all nine categories to determine if the distributions of responses are homogeneous. This "omnibus" test determines only whether or not the distributions of preferences are homogeneous across all nine categories. It does not indicate the source of a non–homogeneous distribution.

As noted in the discussion of data assembly, many pairings of categories at all levels are possible and are of interest as possible sources of any non–homogeneous distributions that are identified by the omnibus test. However, the higher–level categories, up to and including the reduced vision readers, are aggregates of the individually–sampled lowest level categories. Therefore, the participants in the higher–level categories do not represent a random sample of those categories, and the Chi Square test cannot be used to perform

comparisons of those categories. The Goodman procedure is an appropriate choice for such comparisons (Marascuilo & Serlin, 1988).

The Goodman procedure is executed by forming and testing "contrasts." A contrast is a linear combination of the lowest–level categories with the stipulation that the weights used in the combination must sum to zero. Therefore, some of the weights must be positive and some must be negative. Thus, two aggregate categories are formed: one from the lowest–level categories that are assigned non–zero positive weights, and the second from the lowest–level categories with non–zero negative weights. The distributions of these two aggregate categories are then compared for homogeneity using a value that is calculated from the original distributions and population sizes and is tested against the square root of the Chi Square critical values.

There are an infinite number of possible contrasts for any problem; however, usually only a subset are of interest. The simplest contrasts are "pairwise" contrasts that simply compare two of the lowest–level categories at a time. Next, contrasts that combine selected groups of the lowest–level categories with equal weightings form the aggregate groups of the upper levels that we wish to compare. Finally, more complex contrasts, with unequal weightings, may be formed but are not meaningful in this study.

The Goodman procedure does not ensure a complete identification of the source, or sources, of non–homogeneous distributions. A "successful" omnibus result indicates that no significant distribution difference will be found in any contrast, while a "failure" means that at least one contrast will exhibit a non–homogeneous result (i.e., will be significant). Since the number of possible contrasts is infinite, an exhaustive test using the Goodman

procedure is impossible. Testing a finite set of contrasts of interest will indicate if any of those contrasts are among the significant contrasts but may identify all, some, or none of the significant contrasts.

The homogeneity testing process for each font characteristic is then summarized as:

1. Perform the possible divisions of the participants to construct the various categories and pairings at each level. Identify the contrasts of interest.
2. Perform the omnibus Chi Square test across the nine lowest levels.
3. If the Chi Square result indicates homogeneity, stop.
4. If the Chi Square result indicates non–homogeneity, form and test all contrasts of interest using the Goodman procedure.

The following chapter details the results of these operations.

CHAPTER 3

Results

Participant Counts and Categories

Two hundred thirty–one people participated in the study. One hundred, seventy–seven of the participants were reduced vision readers, and the remaining 54 were normal readers. The following six tables illustrate the various combinations of categories of participants that result from the decomposition of the reduced vision readers as described in the "Methods" chapter. We produce each table using one of the possible orderings for the application of the three participant characteristics in the decomposition operation. We indicate the number of participants in each category using parenthesis in each cell. These tables and the order of application of the participant characteristics that produced them are:

- **Table 5—**region, type of loss, severity
- **Table 6—**region, severity, type of loss
- **Table 7—**type of loss, region, severity
- **Table 8—**type of loss, severity, region
- **Table 9—**severity, region, type of loss
- **Table 10—**severity, type of loss, region

The distinct categories of participants at each level can be extracted from the tables above. First, we note that the "Normal Readers" category may be considered to be a member of all levels, if appropriate. After eliminating repeated categories, the categories derived from the "Reduced Vision Readers" category at each level of division are:

Table 5. Participant Categories Resulting from Decomposition by Region, Type of Loss, Severity

Normal Readers (54)	Reduced Vision Readers (177)							
	Anterior (74)				Posterior (103)			
	Anterior Primary (60)		Anterior Secondary (14)		Posterior Primary (65)		Posterior Secondary (38)	
	Ant. Prim. Mild (38)	Ant. Prim. ModSev. (22)	Ant. Sec. Mild (8)	Ant. Sec. ModSev. (6)	Post. Prim. Mild (33)	Post. Prim. ModSev. (32)	Post. Sec. Mild (29)	Post. Sec. ModSev. (9)

Table 6. Participant Categories Resulting from Decomposition by Region, Severity, Type of Loss

Normal Readers (54)	Reduced Vision Readers (177)							
	Anterior (74)				Posterior (103)			
	Anterior Mild (46)		Anterior ModSev. (28)		Posterior Mild (62)		Posterior ModSev. (41)	
	Ant. Prim. Mild (38)	Ant. Sec. Mild (8)	Ant. Prim. ModSev. (22)	Ant. Sec. ModSev. (6)	Post. Prim. Mild (33)	Post. Sec. Mild (29)	Post. Prim. ModSev. (32)	Post. Sec. ModSev. (9)

Table 7. Participant Categories Resulting from Decomposition by Type of Loss, Region, Severity

Normal Readers (54)	Reduced Vision Readers (177)							
	Primary (125)				Secondary (52)			
	Anterior Primary (60)		Posterior Primary (65)		Anterior Secondary (14)		Posterior Secondary (38)	
	Ant. Prim. Mild (38)	Ant. Prim. ModSev. (22)	Post. Prim. Mild (33)	Post. Prim. ModSev. (32)	Ant. Sec. Mild (8)	Ant. Sec. ModSev. (6)	Post. Sec. Mild (29)	Post. Sec. ModSev. (9)

Table 8. Participant Categories Resulting from Decomposition by Type of Loss, Severity, Region

Normal Readers (54)	Reduced Vision Readers (177)							
	Primary (125)				Secondary (52)			
	Primary Mild (71)		Primary ModSev. (54)		Secondary Mild (37)		Secondary ModSev. (15)	
	Ant. Prim. Mild (38)	Post. Prim. Mild (33)	Ant. Prim. ModSev. (22)	Post. Prim. ModSev. (32)	Ant. Sec. Mild (8)	Post. Sec. Mild (29)	Ant. Sec. ModSev. (6)	Post. Sec. ModSev. (9)

Table 9. Participant Categories Resulting from Decomposition by Severity, Region, Type of Loss

Normal Readers (54)	Reduced Vision Readers (177)							
	Mild (108)				Moderate–Severe (69)			
	Anterior Mild (46)		Posterior Mild (62)		Anterior ModSev. (28)		Posterior ModSev. (41)	
	Ant. Prim. Mild (38)	Ant. Sec. Mild (8)	Post. Prim. Mild (33)	Post. Sec. Mild (29)	Ant. Prim. ModSev. (22)	Ant. Sec. ModSev. (6)	Post. Prim. ModSev. (32)	Post. Sec. ModSev. (9)

Table 10. Participant Categories Resulting from Decomposition by Severity, Type of Loss, Region

Normal Readers (54)	Reduced Vision Readers (177)							
	Mild (108)				Moderate–Severe (69)			
	Primary Mild (71)		Secondary Mild (37)		Primary ModSev. (54)		Secondary ModSev. (15)	
	Ant. Prim. Mild (38)	Post. Prim. Mild (33)	Ant. Sec. Mild (8)	Post. Sec. Mild (29)	Ant. Prim. ModSev. (22)	Post. Prim. ModSev. (32)	Ant. Sec. ModSev. (6)	Post. Sec. ModSev. (9)

- **First Level:** Reduced Vision Readers
- **Second Level:** Anterior, Posterior, Primary, Secondary, Mild, Moderate–Severe
- **Third Level:** Anterior Primary (Ant.Prim.), Anterior Secondary (Ant.Sec.), Posterior Primary (Post.Prim.), Posterior Secondary (Post.Sec.), Anterior Mild (Ant.Mild), Anterior Moderate–Severe (Ant.ModSev.), Posterior Mild (Post.Mild), Posterior Moderate–Severe (Post.ModSev.), Primary Mild (Prim.Mild), Primary Moderate–Severe (Prim.ModSev.), Secondary Mild (Sec.Mild), Secondary Moderate–Severe (Sec.ModSev.)
- **Fourth Level:** Anterior Primary Mild (Ant.Prim.Mild), Anterior Primary Moderate–Severe (Ant.Prim.ModSev.), Anterior Secondary Mild (Ant.Sec.Mild), Anterior Secondary Moderate–Severe (Ant.Sec.ModSev.), Posterior Primary Mild (Post.Prim.Mild), Posterior Primary Moderate–Severe (Post.Prim.ModSev.), Posterior Secondary Mild (Post.Sec.Mild), Posterior Secondary Moderate–Severe (Post.Sec.ModSev.)

For convenience, abbreviations given in the parentheses above will be used for the longer category names.

Responses

Raw preference response data for the typeface characteristics will be presented in Tables 11 and 12. The preference responses in each table are listed for nine participant categories: the normal readers and the eight fourth–level categories derived from the reduced vision readers. Preference responses for serif presence (i.e., preference for serif or sans serif typefaces) are given in Table 11. The emphasis characteristic (Roman or italic) was identical for the two typefaces on each screen. The final two columns list the number of times that the sans serif typeface was preferred over the serif typeface and the number of times that the serif typeface was preferred over the sans serif typeface respectively. The total number of these responses for each category in each table is eight times the number of

participants in the category because eight different screens with the same type of typeface characteristic variation were presented to each participant. Additionally, the percentage of the total responses represented by each preference count is given in the table. The participants in all categories strongly preferred the sans serif typeface, but some variations in the percentages are evident.

Table 11. Serif Presence Preferences

	Participant Category	Number of participants	Preference Responses	
			Sans Serif over Serif	Serif over Sans Serif
Normal Readers (Control)	Normal Readers	54	383 (88.66%)	49 (11.34%)
Reduced Vision Readers	Anterior Primary Mild (Ant.Prim.Mild)	38	290 (95.39%)	14 (4.61%)
	Anterior Primary Moderate–Severe (Ant.Prim.ModSev.)	22	164 (93.18%)	12 (6.82%)
	Anterior Secondary Mild (Ant.Sec.Mild)	8	56 (87.50%)	8 (12.50%)
	Anterior Secondary Moderate–Severe (Ant.Sec.ModSev.)	6	46 (95.83%)	2 (4.17%)
	Posterior Primary Mild (Post.Prim.Mild)	33	243 (92.05%)	21 (7.95%)
	Posterior Primary Moderate–Severe (Post.Prim.ModSev.)	32	224 (87.50%)	32 (12.50%)
	Posterior Secondary Mild (Post.Sec.Mild)	29	206 (88.79%)	26 (11.21%)
	Posterior Secondary Moderate–Severe (Post.Sec.ModSev.)	9	66 (91.67%)	6 (8.33%)

Similarly, preference responses for emphasis characteristic (i.e., preference for Roman or italic typefaces) with identical serif presence characteristics for the two typefaces on

each screen are given in Table 12. The format of this table is identical to Table 11. Again, all categories exhibited a strong preference for one characteristic value, Roman, over the other value, italic, but with variations in the distributions of responses. Moreover, the range of the variation is larger than for the serif presence preferences.

Table 12. Emphasis Characteristic Preferences

	Participant Category	Number of participants	Preference Responses	
			Roman over Italic	Italic over Roman
Normal Readers (Control)	Normal Readers	54	312 (72.22%)	120 (27.78%)
Reduced Vision Readers	Anterior Primary Mild (Ant.Prim.Mild)	38	204 (67.11%)	100 (32.89%)
	Anterior Primary Moderate–Severe (Ant.Prim.ModSev.)	22	133 (75.57%)	43 (24.43%)
	Anterior Secondary Mild (Ant.Sec.Mild)	8	53 (82.81%)	11 (17.19%)
	Anterior Secondary Moderate–Severe (Ant.Sec.ModSev.)	6	35 (72.92%)	13 (27.08%)
	Posterior Primary Mild (Post.Prim.Mild)	33	186 (70.45%)	78 (29.55%)
	Posterior Primary Moderate–Severe (Post.Prim.ModSev.)	32	173 (67.58%)	83 (32.42%)
	Posterior Secondary Mild (Post.Sec.Mild)	29	172 (74.14%)	60 (25.86%)
	Posterior Secondary Moderate–Severe (Post.Sec.ModSev.)	9	59 (81.94%)	13 (18.06%)

The selections for typesize and background color are given in Table 13 and Table 14 respectively. The format of these tables is similar to the preference data in Tables 11 and 12, with the data listed for nine participant categories. There were five possible choices for

Table 13. Typesize Selections

	Participant Category	No. of people	Typesize Selections				
			8 pt.	12 pt.	16 pt.	24 pt.	36 pt.
Normal Readers (Control)	Normal Readers	54	6 (11.11%)	33 (61.11%)	15 (27.78%)	0 (0.00%)	0 (0.00%)
Reduced Vision Readers	Anterior Primary Mild (Ant.Prim.Mild)	38	5 (13.16%)	23 (60.53%)	4 (10.53%)	3 (7.89%)	3 (7.89%)
	Anterior Primary Moderate–Severe (Ant.Prim.ModSev.)	22	0 (0.00%)	4 (18.18%)	9 (40.91%)	5 (22.73%)	4 (18.18%)
	Anterior Secondary Mild (Ant.Sec.Mild)	8	1 (12.50%)	4 (50.00%)	2 (25.00%)	0 (0.00%)	1 (12.50%)
	Anterior Secondary Moderate–Severe (Ant.Sec.ModSev.)	6	0 (0.00%)	0 (0.00%)	3 (50.00%)	1 (16.67%)	2 (33.33%)
	Posterior Primary Mild (Post.Prim.Mild)	33	4 (12.12%)	19 (57.58%)	8 (24.24%)	2 (6.06%)	0 (0.00%)
	Posterior Primary Moderate–Severe (Post.Prim.ModSev.)	32	0 (0.00%)	8 (25.00%)	12 (37.50%)	7 (21.87%)	5 (15.62%)
	Posterior Secondary Mild (Post.Sec.Mild)	29	3 (10.34%)	13 (44.83%)	7 (24.14%)	6 (20.69%)	0 (0.00%)
	Posterior Secondary Moderate–Severe (Post.Sec.ModSev.)	9	0 (0.00%)	3 (33.33%)	1 (11.11%)	2 (22.22%)	3 (33.33%)

typesize: 8–point, 12–point, 15–point, 24–point, and 36–point, and there were three possible choices for background color: white with black type, grey with black type, and black with white type. These data were not included in the analysis in this study.

Omnibus Chi Square Tests

In the omnibus Chi Square tests for homogeneity, separate Chi Square values for the serif presence preferences (χ^2_{SP}) and the emphasis preferences (χ^2_{EP}) were calculated

Table 14. Background Color Selections

	Participant Category	No. of People	Background Color Selections: White with Black Type	Grey with Black Type	Black with White Type
Normal Readers (Control)	Normal Readers	54	24 (44.44%)	20 (37.04%)	10 (18.52%)
Reduced Vision Readers	Anterior Primary Mild (Ant.Prim.Mild)	38	11 (28.95%)	9 (23.68%)	18 (47.37%)
	Anterior Primary Moderate–Severe (Ant.Prim.ModSev.)	22	9 (40.91%)	4 (18.18%)	9 (40.91%)
	Anterior Secondary Mild (Ant.Sec.Mild)	8	2 (25.00%)	0 (0.00%)	6 (75.00%)
	Anterior Secondary Moderate–Severe (Ant.Sec.ModSev.)	6	2 (33.33%)	3 (50.00%)	1 (16.67%)
	Posterior Primary Mild (Post.Prim.Mild)	33	4 (12.12%)	15 (45.45%)	14 (42.42%)
	Posterior Primary Moderate–Severe (Post.Prim.ModSev.)	32	4 (12.50%)	11 (34.37%)	17 (53.12%)
	Posterior Secondary Mild (Post.Sec.Mild)	29	5 (17.24%)	11 (37.93%)	13 (44.83%)
	Posterior Secondary Moderate–Severe (Post.Sec.ModSev.)	9	1 (11.11%)	1 (11.11%)	7 (77.78%)

across the sample distributions for all nine categories in Tables 11 and 12, respectively. The results were:

- Serif presence preference – $\chi^2_{SP} = 18.55$
- Emphasis preference – $\chi^2_{EP} = 15.22$

Each Chi Square value was then compared to the Chi Square critical value, $\chi^2_{\nu\,:\,1-\alpha}$. Two common values for α, 0.05 and 0.1, were used. These values were selected because

they produce a very small likelihood of making a Type I error (i.e., concluding that the preference distributions were not homogeneous when, in fact, they were homogeneous). The data were examined using both values in order to examine the sensitivity of our conclusions to the value of this parameter. Since the degrees of freedom value, ν, was eight for this problem, the resulting critical values were $\chi^2_{8:0.95} = 15.51$ and $\chi^2_{8:0.9} = 13.36$ from standard tables (Marascuilo & Serlin, 1988). Hence, we find that:

- At $\alpha = 0.1$, we reject the null hypothesis for both the serif preferences and the emphasis preferences. Thus, we conclude that the distribution differences of the lowest–level categories are significant for both typeface characteristics, and for each, at least one contrast will show a difference in the Goodman test.
- At $\alpha = 0.05$, we reject the null hypothesis for the serif preferences and retain it for the emphasis preferences. Thus, we conclude that the distribution differences of the serif preference responses are significant and that the emphasis characteristic responses do not show significant differences. At least one contrast will show a significant difference in the Goodman test on the serif preferences, but no contrast will show a significant difference in the Goodman test on the emphasis preferences. Hence, the Goodman test results for the emphasis preferences are not considered for this case. Additionally, we note that the margin for retaining the null hypothesis for the emphasis preferences is very small.

Contrast (Goodman Procedure) Tests

The contrasts in the Goodman procedure compare two categories of participants. For each contrast, a value, Z, is calculated from the distributions of the categories and the weights used to construct them. The absolute value of that result, $|Z|$, is then compared to $S^* = \sqrt{\chi^2_{\nu:1-\alpha}}$, where the critical value is the same as in the omnibus test (Marascuilo & Serlin, 1988).

For each case in which the null hypothesis was rejected, a set of selected Goodman contrasts was tested. Each contrast performed a test on two participant categories, which were either one of the lowest–level categories or a combination of two or more of those categories. In "pairwise contrasts," each category in the contrast was identically one of the lowest–level categories from the omnibus analysis. "Complex contrasts" compared two aggregate categories, each formed by combining distinct lowest–level categories.

An infinite number of possible contrasts can be constructed; however, we want to perform only those comparisons that are meaningful in the context of this problem. The contrasts of interest may be identified by noting that we wish to examine the effects of each of the three participant characteristics individually. Therefore, the categories of participants that are compared in a contrast must be defined by specification of the same characteristics and must differ only in the value of one of those characteristics. Such contrasts are formed by pairings of the categories at each level (row) in Tables 5 through 10. Furthermore, the set of contrasts was organized into three groups according to which characteristic value differed, as described in the following sections.

Severity Contrast Analysis

The composition of the contrasts of interest at each level when considering severity is given in Table 15. The composite participant counts and response statistics for the aggregate categories in each contrast are described in the table; however, the Goodman calculation uses the numbers from the lowest–level categories.

There are four pairwise contrasts of the lowest–level categories. All three characteristics are specified for each category in these contrasts, but only the severity characteristic differs between the categories in a contrast.

Table 15. Composition of contrasts for severity analysis (Sheet 1 of 2)

Contrast	No. of people	Serif Preference Responses		Emphasis Preference Responses	
		Sans Serif over Serif	Serif over Sans Serif	Roman over Italic	Italic over Roman
Pairwise (Lowest Level) Contrasts					
Ant.Prim.Mild –	38	290 (95.39%)	14 (4.61%)	204 (67.11%)	100 (32.89%)
Ant.Prim.ModSev.	22	164 (93.18%)	12 (6.82%)	133 (75.57%)	43 (24.43%)
Ant.Sec.Mild –	8	56 (87.50%)	8 (12.50%)	53 (82.81%)	11 (17.19%)
Ant.Sec.ModSev.	6	46 (95.83%)	2 (4.17%)	35 (72.92%)	13 (27.08%)
Post.Prim.Mild –	33	243 (92.05%)	21 (7.95%)	186 (70.45%)	78 (29.55%)
Post.Prim.ModSev.	32	224 (87.50%)	32 (12.50%)	173 (67.58%)	83 (32.42%)
Post.Sec.Mild –	29	206 (88.79%)	26 (11.21%)	172 (74.14%)	60 (25.86%)
Post.Sec.ModSev.	9	66 (91.67%)	6 (8.33%)	59 (81.94%)	13 (18.06%)
Third Level Complex Contrasts					
Ant.Mild –	46	346 (94.02%)	22 (5.98%)	257 (69.84%)	111 (30.16%)
Ant.ModSev.	28	210 (93.75%)	14 (6.25%)	168 (75.00%)	56 (25.00%)
Post.Mild –	62	449 (90.52%)	47 (9.48%)	358 (72.18%)	138 (27.82%)
Post.ModSev.	41	290 (88.41%)	38 (11.59%)	232 (70.73%)	96 (29.27%)
Prim.Mild –	71	533 (93.84%)	35 (6.16%)	390 (68.66%)	178 (31.34%)
Prim.ModSev.	54	388 (89.81%)	44 (10.19%)	306 (70.83%)	126 (29.17%)
Sec.Mild –	37	262 (88.51%)	34 (11.49%)	225 (76.01%)	71 (23.99%)
Sec.ModSev.	15	112 (93.33%)	8 (6.67%)	94 (78.33%)	26 (21.67%)
Second Level Complex Contrasts					
Mild –	108	795 (92.01%)	69 (7.99%)	615 (71.18%)	249 (28.82%)
ModSev.	69	500 (90.58%)	52 (9.42%)	400 (72.46%)	152 (27.54%)
Norm.Read. –	54	383 (88.66%)	49 (11.34%)	312 (72.22%)	120 (27.78%)
Mild	108	795 (92.01%)	69 (7.99%)	615 (71.18%)	249 (28.82%)
Norm.Read. –	54	383 (88.66%)	49 (11.34%)	312 (72.22%)	120 (27.78%)
ModSev.	69	500 (90.58%)	52 (9.42%)	400 (72.46%)	152 (27.54%)

Table 15. Composition of contrasts for severity analysis (Continued) (Sheet 2 of 2)

Contrast	No. of people	Serif Preference Responses		Emphasis Preference Responses	
		Sans Serif over Serif	Serif over Sans Serif	Roman over Italic	Italic over Roman
Top Level Complex Contrasts					
Norm.Read. –	54	383 (88.66%)	49 (11.34%)	312 (72.22%)	120 (27.78%)
Red.Vis.Read.	177	1295 (91.45%)	121 (8.55%)	1015 (71.68%)	401 (28.32%)

The four complex contrasts from the third level compare aggregate categories that exhibit a variation in severity and also specify exactly one of the other two characteristics.

The aggregate categories in the complex contrasts at the second level exhibit a variation in severity but do not specify either of the other two characteristics. Within the “Reduced Vision Readers” category, the other two characteristics are assumed to be “non–zero,” and a single second–level contrast of Mild–ModSev. is suggested. It is also meaningful to make comparisons with the “Normal Readers” category at this level. To do so, we extend the “Normal Readers” category to the second level and view it as having a severity value of “none,” with the other two characteristics unspecified. Hence, we have two additional contrasts, Norm.Read.–Mild and Norm.Read.–ModSev. as given in Table 15.

Finally, there is a single first–level contrast, Norm.Read.–Red.Vis.Read. This contrast is the same for all of the characteristic analyses; therefore, it is listed here and is not repeated in the later tables.

The results of testing these contrasts is given in Table 16 where we provide *Z* values for both the serif preferences and the emphasis preferences.

Table 16. Contrast Results for Severity Analysis

Contrast	Z (Serif Preference)	Z (Emphasis Preference)
Pairwise Contrasts		
Ant.Prim.Mild − Ant.Prim.ModSev.	0.98425	−2.0086
Ant.Sec.Mild − Ant.Sec.ModSev.	−1.65321	1.24300
Post.Prim.Mild − Post.Prim.ModSev.	1.71242	0.70934
Post.Sec.Mild − Post.Sec.ModSev.	−0.74447	−1.45431
Third Level Complex Contrasts		
Ant.Mild − Ant.ModSev.	0.13398	−1.38022
Post.Mild − Post.ModSev.	0.95909	0.45166
Prim.Mild − Prim.ModSev.	2.28040	−0.74346
Sec.Mild − Sec.ModSev.	−1.64504	−0.51747
Second Level Complex Contrasts		
Mild − ModSev.	0.93156	−0.52736
Norm.Read. − Mild	−2.13434	0.25139
Norm.Read. − ModSev.	−0.97880	−0.08429
Top Level Complex Contrasts		
Norm.Read. − Red.Vis.Read.	−1.65031	−0.52736

Region Contrast Analysis

The contrasts of interest when considering the region of the eye affected by the participants' disorders are formed in a similar manner as when considering severity. The difference is that the characteristic that varies in each contrast is now the region. Again, there are four pairwise contrasts at the lowest level, four complex contrasts at the third

level, three complex contrasts at the second level, and one complex contrast at the first level. The first level contrast is identical to the severity analysis and is not repeated here. The composition of the contrasts is given in Table 17, and the results of the Goodman calculation are presented in Table 18.

Table 17. Composition of Contrasts for Region Analysis (Sheet 1 of 2)

Contrast	No. of people	Serif Preference Responses		Emphasis Preference Responses	
		Sans Serif over Serif	Serif over Sans Serif	Roman over Italic	Italic over Roman
Pairwise (Lowest Level) Contrasts					
Ant.Prim.Mild –	38	290 (95.39%)	14 (4.61%)	204 (67.11%)	100 (32.89%)
Post.Prim.Mild	33	243 (92.05%)	21 (7.95%)	186 (70.45%)	78 (29.55%)
Ant.Sec.Mild –	8	56 (87.50%)	8 (12.50%)	53 (82.81%)	11 (17.19%)
Post.Sec.Mild.	29	206 (88.79%)	26 (11.21%)	172 (74.14%)	60 (25.86%)
Ant.Prim.ModSev. –	22	164 (93.18%)	12 (6.82%)	133 (75.57%)	43 (24.43%)
Post.Prim.ModSev.	32	224 (87.50%)	32 (12.50%)	173 (67.58%)	83 (32.42%)
Ant.Sec.ModSev. –	6	46 (95.83%)	2 (4.17%)	35 (72.92%)	13 (27.08%)
Post.Sec.ModSev.	9	66 (91.67%)	6 (8.33%)	59 (81.94%)	13 (18.06%)
Third Level Complex Contrasts					
Ant.Mild –	46	346 (94.02%)	22 (5.98%)	257 (69.84%)	111 (30.16%)
Post.Mild	62	449 (90.52%)	47 (9.48%)	358 (72.18%)	138 (27.82%)
Ant.ModSev. –	28	210 (93.75%)	14 (6.25%)	168 (75.00%)	56 (25.00%)
Post.ModSev.	41	290 (88.41%)	38 (11.59%)	232 (70.73%)	96 (29.27%)
Ant.Prim. –	60	454 (94.58%)	26 (5.42%)	337 (70.21%)	143 (29.79%)
Post.Prim.	65	467 (89.81%)	53 (10.19%)	359 (69.04%)	161 (30.96%)
Ant.Sec. –	14	102 (91.07%)	10 (8.93%)	88 (78.57%)	24 (21.43%)
Post.Sec.	38	272 (89.47%)	32 (10.53%)	231 (75.99%)	73 (24.01%)
Second Level Complex Contrasts					
Ant. –	74	556 (93.92%)	36 (6.08%)	425 (71.79%)	167 (28.21%)
Post.	103	739 (89.68%)	85 (10.32%)	590 (71.60%)	234 (28.40%)
Norm.Read. –	54	383 (88.66%)	49 (11.34%)	312 (72.22%)	120 (27.78%)
Ant.	74	556 (93.92%)	36 (6.08%)	425 (71.79%)	167 (28.21%)

Table 17. Composition of Contrasts for Region Analysis (Continued) (Sheet 2 of 2)

Contrast	No. of people	Serif Preference Responses		Emphasis Preference Responses	
		Sans Serif over Serif	Serif over Sans Serif	Roman over Italic	Italic over Roman
Norm.Read. – Post.	54 103	383 (88.66%) 739 (89.68%)	49 (11.34%) 85 (10.32%)	312 (72.22%) 590 (71.60%)	120 (27.78%) 234 (28.40%)

Table 18. Contrast Results for Region Analysis

Contrast	Z (Serif Preference)	Z (Emphasis Preference)
Pairwise Contrasts		
Ant.Prim.Mild – Post.Prim.Mild	1.63069	–0.86060
Ant.Sec.Mild – Post.Sec.Mild.	–0.27967	1.57061
Ant.Prim.ModSev. – Post.Prim.ModSev.	2.02377	1.83070
Ant.Sec.ModSev. – Post.Sec.ModSev.	0.95770	–1.14939
Third Level Complex Contrasts		
Ant.Mild – Post.Mild	1.94694	–0.75265
Ant.ModSev. – Post.ModSev.	2.22998	1.11825
Ant.Prim. – Post.Prim.	2.84621	0.40294
Ant.Sec. – Post.Sec.	0.50024	0.56692
Second Level Complex Contrasts		
Ant. – Post.	2.94127	0.07818
Norm.Read. – Ant.	–2.90415	0.15247
Norm.Read. – Post.	–0.55328	0.23293

Type of Loss Contrast Analysis

In this set of contrasts, the varying characteristic is the type of vision loss. The process is the same as the other two cases, and we again form four pairwise contrasts at the lowest

level, four complex contrasts at the third level, three complex contrasts at the second level, and one complex contrast at the first level, which is not repeated in the tables.

This set of contrasts is defined in Table 19, and the results of the Goodman procedure are given in Table 20.

Table 19. Composition of Contrasts for Type of Loss Analysis

Contrast	No. of people	Serif Preference Responses		Emphasis Preference Responses	
		SansSerif over Serif	Serif over SansSerif	Roman over Italic	Italic over Roman
		Pairwise (Lowest Level) Contrasts			
Ant.Prim.Mild –	38	290 (95.39%)	14 (4.61%)	204 (67.11%)	100 (32.89%)
Ant.Sec.Mild	8	56 (87.50%)	8 (12.50%)	53 (82.81%)	11 (17.19%)
Post.Prim.Mild –	33	243 (92.05%)	21 (7.95%)	186(70.45%)	78 (29.55%)
Post.Sec.Mild.	29	206 (88.79%)	26 (11.21%)	172 (74.14%)	60 (25.86%)
Ant.Prim.ModSev. –	22	164 (93.18%)	12 (6.82%)	133 (75.57%)	43 (24.43%)
Ant.Sec.ModSev.	6	46 (95.83%)	2 (4.17%)	35 (72.92%)	13 (27.08%)
Post.Prim.ModSev. –	32	224 (87.50%)	32 (12.50%)	173 (67.58%)	83 (32.42%)
Post.Sec.ModSev.	9	66 (91.67%)	6 (8.33%)	59 (81.94%)	13 (18.06%)
		Third Level Complex Contrasts			
Prim.Mild –	71	533 (93.84%)	35 (6.16%)	390 (68.66%)	178 (31.34%)
Sec.Mild	37	262 (88.51%)	34 (11.49%)	225 (76.01%)	71 (23.99%)
Prim.ModSev. –	54	388 (89.81%)	44 (10.19%)	306 (70.83%)	126 (29.17%)
Sec.ModSev.	15	112 (93.33%)	8 (6.67%)	94 (78.33%)	26 (21.67%)
Ant.Prim. –	60	454 (94.58%)	26 (5.42%)	337 (70.21%)	143 (29.79%)
Ant.Sec.	14	102 (91.07%)	10 (8.93%)	88 (78.57%)	24 (21.43%)
Post.Prim. –	65	467 (89.81%)	53 (10.19%)	359 (69.04%)	161 (30.96%)
Post.Sec.	38	272 (89.47%)	32 (10.53%)	231 (75.99%)	73 (24.01%)
		Second Level Complex Contrasts			
Prim. –	125	921 (92.10%)	79 (7.90%)	696 (69.60%)	304 (30.40%)
Sec.	52	374 (89.90%)	42 (10.10%)	319 (76.68%)	97 (23.32%)
Norm.Read. –	54	383 (88.66%)	49 (11.34%)	312 (72.22%)	120 (27.78%)
Prim.	125	921 (92.10%)	79 (7.90%)	696 (69.60%)	304 (30.40%)
Norm.Read. –	54	383 (88.66%)	49 (11.34%)	312 (72.22%)	120 (27.78%)
Sec.	52	374 (89.90%)	42 (10.10%)	319 (76.68%)	97 (23.32%)

Table 20. Contrast Results for Type of Loss Analysis

Contrast	Z (Serif Preference)	Z (Emphasis Preference)
Pairwise Contrasts		
Ant.Prim.Mild − Ant.Sec.Mild	1.83376	−0.86060
Post.Prim.Mild − Post.Sec.Mild.	1.22381	1.57061
Ant.Prim.ModSev. − Ant.Sec.ModSev.	−0.76771	1.83070
Post.Prim.ModSev. − Post.Sec.ModSev.	−1.08008	−1.14939
Third Level Complex Contrasts		
Prim.Mild − Sec.Mild	2.52492	−2.33647
Prim.ModSev. − Sec.ModSev.	−1.30675	−1.73311
Ant.Prim. − Ant.Sec.	1.22841	−1.91152
Post.Prim. − Post.Sec.	0.15177	−2.18933
Second Level Complex Contrasts		
Prim. − Sec.	1.29280	−2.80702
Norm.Read. − Prim.	−1.97237	1.00927
Norm.Read. − Sec.	−0.58791	−1.49481

The two threshold values for comparison are $S^*_{0.05} = \sqrt{\chi^2_{8:0.95}} = 3.94$ and $S^*_{0.1} = \sqrt{\chi^2_{8:0.9}} = 3.66$. We compare the values of $|Z|$ for the serif presence preferences from Tables 16, 18, and 20 to both $S^*_{0.1}$ and $S^*_{0.05}$ and the values for the emphasis preferences to $S^*_{0.1}$ only. We find that none of the contrast results exceed the threshold values. Moreover, we note that this result was true in the case of the serif presence preferences for both $\alpha = 0.1$ and $\alpha = 0.05$, even though the omnibus Chi Square test rejected the null hypothesis for both of these levels of significance. Thus, we conclude that

both preference distributions are homogeneous for each pair of categories tested in this set of contrasts and any preference differences are not due to individual actions of the three participant characteristics.

CHAPTER 4

Discussion

Introduction

In this chapter, we will evaluate and interpret the results of the study. First, we will examine the data distributions and the results from the homogeneity tests to determine the preferences of the various categories of participants and the significance of any apparent variations. Next, these findings will be analyzed and compared to the hypotheses for this study. The limitations of the study and potential ways to address those bounds will then be considered. Finally, we will summarize the findings and derive recommendations for electronic display design and possible additional investigations.

Preference Distributions

The first examination of the distributions of the responses reveals two initial observations:

- The participants exhibited an overwhelming preference for sans serif typefaces over serif typefaces in all categories at all levels. This preference ranged from 87% to 95%.
- The participants exhibited a strong preference for Roman typefaces over italic typefaces in all categories at all levels. This preference ranged from 67% to 82%.

Thus, we conclude that the preferences are universal and that the preference for sans serif appears to be stronger than the preference for Roman. We note, however, that the preferences exhibited a range of up to 15% across the participant categories. The key question is then are these differences among participant categories statistically significant?

For example, does the difference between the responses from the “Primary” category (69.60%–Roman) and of the “Secondary” category (76.68%–Roman) indicate a true stronger preference for Roman typefaces among the primary category of participants? The homogeneity tests provide the answer to this question.

Homogeneity Findings

When evaluating the homogeneity results, we must consider carefully the nature of the test operation, the meaning of the test outputs, and the effects of the choice of the value of the level of significance, α. The Chi Square and Goodman tests do not provide absolute answers regarding the nature of the underlying distributions. Rather, we draw a conclusion based upon probabilistic evidence by comparing the output value of the test to a threshold (the critical value), and our conclusion may be incorrect. We may reject a null hypothesis that is true even though it is very unlikely (a Type I error), or we may retain a false null hypothesis (a Type II error).

Decreasing the likelihood of one of the types of errors causes an increase in the likelihood of the other type. Selection of a higher value for α causes a lower critical value and, hence, a reduced chance of making a Type II error since we will reject the null hypothesis in more instances. At the same time, rejecting the null hypothesis more frequently means that a Type I error becomes more likely. Similarly, a smaller value for α results in a higher critical value, a reduced chance of a Type I error, and an increased risk of a Type II error. In this study, we wish to have strong confidence in any conclusion of differences in the preferences (i.e., rejection of the null), but, at the same time, we want to avoid overly diminishing the likelihood of identifying those differences. Our two values for

α, 0.05 and 0.1, are common choices that produce a reasonable compromise between these two conflicting aims.

Conclusions from Omnibus Chi Square

The omnibus Chi Square test rejected the null hypothesis for the serif presence preferences using both values for α and for the emphasis preferences using $\alpha = 0.1$ only. We conclude that there is some difference in the distribution of responses for both emphasis and serif presence. However, for emphasis, this evidence is not strong and depends upon the value of α.

By rejecting a null hypothesis in the omnibus test, we are concluding only that we believe that some significant difference exists between the distributions of the preferences of all nine of the lowest–level categories. The source of that difference is not identified.

Conclusions from Goodman Contrasts

None of the contrasts indicated significant differences in preferences between the pair of participant categories that were compared. Thus, we conclude that there are no significant differences in preferences for either typeface characteristic as a result of any of the three participant characteristics acting individually. Moreover, these results are supported by the fact that they were identical for our two typical values for α in the case of serif presence.

The results of the omnibus test and the Goodman contrasts are not contradictory as might appear. From the omnibus test, we know only that one or more members of the infinite set of possible contrasts will reveal a non–homogeneity between the two tested categories in the Goodman test (Marascuilo & Serlin, 1988). An exhaustive test of all

contrasts is not possible. Furthermore, there is no assurance that the non–homogeneous contrast, or contrasts, will be present in any specific subset of contrasts that we test.

Therefore, the source of the differences in preferences indicated by the omnibus Chi Square test remains unknown. The differences may be due to contrasts that represent interactions between multiple simultaneous differences in participant characteristics, which are outside of the focus of this study. Alternately, they may result from contrasts that represent complex combinations of the lowest–level categories that are not meaningful in this context.

Comparison to Research Issues and Analysis

The purpose of this work was to determine if the reduced vision readers exhibit preferences for either of the two typeface characteristics on electronic displays that are different from those of normal readers and whether any such differences are associated with the type or severity of the participants' visual disorder. We have found that:

- Reduced vision readers and normal readers exhibited similar, strong preferences for each typeface characteristic.
- Neither the type of disorder nor the severity acting alone caused preference differences within the reduced vision readers.

These findings address the five research questions for this project that were given in the "Introduction" chapter:

1. What kinds of typeface contrast (i.e., serif or sans serif) do readers with resolution problems find easiest to read in web documents?

   Sans serif typefaces were very strongly preferred by all categories of reduced vision readers.

2. What font emphasis qualities (i.e., italic or Roman) do readers with resolution problems find easiest to read in web documents?

   Roman typefaces were preferred by all categories of reduced vision readers, but the strength of preference appears to be less than for sans serif typefaces.

3. How do the preferences of reduced vision readers differ from those of normal readers?

   No significant differences between the preferences of reduced vision and of normal readers were observed.

4. How does severity of the participant's vision loss affect preferences for readers with resolution problems?

   The severity analysis indicated no significant variations in preferences according to severity of vision loss.

5. How does the type of eye problem affect preferences for readers with resolution problems?

   The region and type analysis results showed no significant variations for either of these two participant characteristics.

Moreover, we now can address the two specific hypotheses for the study that were proposed in the "Introduction" chapter:

1. Reduced vision readers with functional vision loss resulting from resolution problems will not exhibit definitive preferences for serif presence (i.e., any preferences for serif or sans–serif typefaces will not be strong), and those preferences will not be related to the participants' visual disorder characteristics. Hence, we also expect that the preferences of the normal readers (i.e., the control group) will be similar to those of the reduced vision readers.

2. Reduced vision readers with functional vision loss resulting from resolution problems will exhibit preferences for Roman over italic typefaces, and this preference will not be related to the participants' visual disorder characteristics. Again, we also expect that the preferences of the normal readers (i.e., the control group) will be similar to those of the reduced vision readers.

The very strong preferences among all categories readers in this study for sans serif typefaces contradicts the first prediction from Hypothesis 1. However, our results confirm the second prediction of similar serif preferences for both normal readers and reduced vision readers. In contrast, our findings of very strong preferences for Roman typefaces over italics among all categories support both predictions of the second hypothesis.

To analyze these results, we first note that the predictions were based upon results from previous research and none of those studies were identical to this one. It is likely that the deviation of our findings from the predictions results from differences in media, audience, or methods between this study and the previous work. Moreover, we note that the results of those previous studies were not uniform.

Our prediction that the preferences would not be strong for either serif or sans serif typefaces was based upon the variety of results from previous studies. Most previous studies that were paper–based have suggested using serif typefaces (Becker, Heinrich, von Sichowsky, & Wendt,1970; Brockmann,1986; Crosland & Johnson, 1928; Sanford, 1888; Tinker, 1963). None of those studies considered electronic displays, and none appear to have included reduced vision readers in the participants.

Several sources also suggest using serif typefaces on electronic displays (Craig, 1971, Craig & Meyer, 1980; Craig & Meyer, 1992, 1999; Gerstner, 1974; Haley, 1980; Hartley, 1978; Laundy, 1980; Marcus, 1982, 1984a–b, 1983; Trollip & Sales, 1986; Williams, 1994; Williams & Tollett, 1998). However, many of those recommendations are based upon design experience and heuristic extension of print–based practices to electronic displays rather than experimental studies. Moreover, the recommendations did not consider reduced vision readers.

Differences in methods and measurements are another significant factor. These differences arise from the variety of reading tasks and the resulting different definitions of legibility. The concern here was for personal preferences among isolated word pairs, as might be encountered in searching, "way finding" or similar navigational tasks, rather than readability or speed. Much of the previous work used other tests, such as reading rate (Brockmann,1986; Tinker, 1963) or short exposure (i.e., rate of perception) (Sanford, 1888). Reading rate tests involve the visual processing and comprehension of blocks of text, which is a different form of perception than in this work. Similarly, rates of perception are not necessarily related to preferences.

In contrast, some previous paper–based studies did not recommend serif over sans serif typefaces. For example, Paterson and Tinker (1932) found typefaces to be equally legible; however, they used a reading rate test. Crosland and Johnson (1928), Poulton (1969), and Morrison et al. (1989) also suggest sans serif typefaces.The use of sans serif typefaces in navigational applications, such as graphical button labels, has been suggested by Williams

(1994), Williams and Tollett (1998), and Marcus (1992). Such isolated text items represent scenarios similar to the tests in this study.

The deviation of the serif presence results in this study from the predictions of the hypothesis and from the results of many of the previous studies indicates that extension of those results to the scenario of this study is not valid. The uniform preference for sans serif fonts among all categories of participants indicates that the audience was not a factor in the deviation even though the previous studies generally did not include reduced vision readers. Additionally, the previous studies did not show a strong pattern of variation in serif presence preferences according to methodology or task. For example, Paterson and Tinker (1932) did not find a preference for serif typefaces using a reading test in one study, but Tinker (1963) did find such a preference using a reading test. Hence, we also eliminate those items as causes of the deviation. The only remaining potential factor is the electronic display in this study. We note that the previous results supporting serif typefaces on paper were broad, although not unanimous. In contrast, the evidence supporting serif typefaces on electronic displays was not validated with experiments. Therefore, we conclude the deviation was due to the electronic display. Thus, results for serif presence, and the recommendations that follow, cannot be extended from paper–based applications to electronic displays.

In addition, the uniform serif presence preferences across all categories of participants in this study indicate that serif presence is a very significant issue on electronic displays. The simple presence or absence of serifs alone appears to be the overriding factor regardless of any difference in perception resulting from loss of vision.

The previous studies from which the emphasis predictions were formulated were paper–based and used normal readers, but they exhibited near–universal agreement in recommending Roman typefaces over italics (Becker, Heinrich, von Sichowsky, & Wendt, 1970; Brockmann, 1986; Paterson & Tinker, 1940; Tinker, 1954, 1966; Tinker & Paterson, 1942). Moreover, those recommendations appear to result more from a general reduction of legibility associated with italic typefaces than from the specific medium, method, or audience. Italic typefaces have been shown to be more effective than Roman typefaces in special applications, such as actively engaging readers, (Morrison, 1977; Morrison et al. 1989; Tannenbaum, Jacobson, & Norris, 1964); however, that property is associated with attracting and holding attention, not legibility. Thus, the previous results for emphasis extended well to electronic displays and to reduced vision readers.

Limitations of The Study

All studies are subject to bounds resulting from either design decisions or external factors during the course of the study. Four such constraints on this study may be identified.

First, the typesize and background color were allowed to differ for each participant. This freedom was intentional; the goal was to allow each participant to select their optimal viewing conditions and minimize the effect of typesize or background color on their preferences. It can be argued, however, that allowing this freedom introduces uncontrolled variables into the process. We note, however, that the effects of typesize and color may vary according to the categories of participants, particularly for the reduced vision readers. Hence, enforcing a typesize and color selection across all participants could introduce a

bias into the results. Additional studies that repeat the process using the various possible fixed settings for typesize and color would help resolve this issue.

Second, the existing data on typesize and background color selections cannot readily be used to examine the effects of those selections on legibility. The lowest–level participant categories could be further subdivided according to the typesize and background color selections, and the omnibus Chi Square test and the Goodman contrasts could then be applied. The results likely would not be valid because of the resulting large number of lowest–level categories. Many of the categories would be expected to be either very lightly populated or empty. Additionally, we could not regard the data as constituting valid samples of all of the new categories. A study that is correctly formed to evaluate the effects of typesize or background color would vary the single parameter under test across the screens while fixing all other factors (including the text and typefaces) on all screens.

Third, we note that the study considered only a single scenario and method of evaluating legibility. This fact limits the extent to which the results can be compared to the previous studies. Again, repeating the study using other legibility measures, such as reading rate tests, would appear to be of value.

Fourth, the sample size for the various lowest–level categories was not uniform. In particular, the numbers of participants in three of the categories having a secondary loss type were minimal and were significantly less than the numbers for the other categories. In such cases, it was very difficult to obtain samples from these categories, and it appears that the underlying populations may be small. Such a result could occur if the categories are defined by specific types of eye disorders that are relatively uncommon. Repeating the

study with a larger sample of the participants in those categories would be desirable. Alternately, a redefinition of the categories might be used to produce categories with larger populations.

Final Conclusions and Recommendations

This study has addressed a significant gap in knowledge regarding legibility of text on electronic displays. As noted in the introduction chapter, reduced vision affects a very larger number of people (Attebo, Mitchell, & Smith, 1996; Stoto, Behrens, & Rosemont, 1990; The Lighthouse International, 1998–2002, 1999). Concurrently, electronic displays of text are inescapable, particularly in education. Despite these conditions, little definitive information was available on either the general topic of text legibility on electronic displays or the specific topic of text legibility for reduced vision readers. Most previous studies were based upon text on paper and used normal readers. The result was that designers of educational, or other, materials for electronic displays had little definitive guidance for creating legible displays that were usable by a broad audience. Many of the common techniques were somewhat ad–hoc and were derived by extending guidelines from paper–based documents for normal readers without validation of the practice (Reece, 1992, 1993–1994; Reece & Scheiber, 1993; Van Der Waarde, 1999). Moreover, studies that served as the basis for the paper–based guidelines sometimes disagreed (Morrison, 1977; Morrison et al.1989).

This study has addressed these issues in three ways:

- It has established that text legibility on electronic displays must be considered as a separate topic from legibility on paper. Few previous studies considered the issue of electronic displays.The universal, very strong preference of the

participants in this study for sans serif type differs from the variety of results found in paper–based studies that sometimes recommended the use of serif typefaces (Becker, Heinrich, von Sichowsky, & Wendt, 1970; Brockmann, 1986; Crosland & Johnson, 1928; Morrison, 1977; Morrison et al. 1989; Poulton, 1969; Tinker, 1932, 1963). Moreover, there is strong evidence that this difference is due to the electronic display. Hence, the extension of guidelines based upon paper to electronic displays without validation is a poor practice.

- It has found that the preferences for serif presence and emphasis on electronic displays are not strongly influenced by severity of vision loss, region of the eye disorder, or type of vision loss of reduced vision readers, while no previous studies that test this issue have been reported. No significant variations in the preferences due to any of these characteristics were identified by the analysis. This result indicates that these typeface characteristics are very important for all readers and that a single legibility guideline for each characteristic may be used to address legibility across a broad audience containing both normal readers and reduced vision readers.

- It has produced guidelines regarding serif presence and emphasis for choosing typefaces for electronic displays and a broad audience, which are based upon analysis of the display and the audience, rather than ad–hoc extensions of paper document guidelines. This study is the first one to produce such recommendations. Designers for electronic displays should use sans serif typefaces and Roman emphasis wherever possible. Serif typefaces or italic emphasis should be employed only if absolutely required and only after careful consideration and evaluation of the rationale and the results.

Many opportunities for further research are suggested by the results of this study. Several such efforts, including repeating the study with a fixed typesize and background color and using different measurements of legibility, and examining the effects of typesize and background color of the typeface preferences were suggested to address the limitations of the study and would be particularly valuable. The effects of varying the typesize and background color on the preferences also should be investigated. Such a study would fix all factors (including the text and typefaces) on all screens while varying the parameter under test across the screens and collecting the measurement of legibility.

Several studies involving the acuity level of the participants also are of interest. For example, the study could be repeated with using a typesize for each participant that is determined from the participant's measured acuity level. Comparisons of measurements of participants's acuity level using electronic displays to measurements obtained with traditional means could provide insight into the effects of electronic displays for various categories of users. A variation on this test could collect multiple acuity measurements from a participant using an electronic display and various typefaces in order to determine the possible effect of typeface characteristics on acuity.

Additional methods of evaluating legibility are needed for comparison with other work and because of the extremely wide range of situations in which electronic displays may be found. Tests that involve reading of text passages are critical in evaluating computer displays. Additional tests could measure the effects of typeface characteristics on the ability to locate and comprehend text in complicated backgrounds (which might range from complex graphical user interfaces displays such as electronic maps). Perception speed can be an important parameter for some types of electronic displays, such as message boards or electronic displays in automobiles.

Many other characteristics of typefaces and electronic displays that were beyond the scope of this work also may influence legibility and should be investigated. These characteristics include boldface typefaces (Brockmann, 1986; Ernst, 1977; Tinker, 1963; Tinker & Paterson, 1942), typeface size (Erdman & Neal, 1968; Paterson & Tinker, 1940), proportional typefaces (Arditi, Knoblauch, & Grunwald, 1990), background and typeface contrast (Ernst, 1977; Hackman & Tinker, 1957; Holmes, 1931; Paterson & Tinker, 1932,

1940; Sanner, 1974; Snowberg, 1971; Start, 1989; Taylor, 1934) and color (Summer, 1932; Tinker & Paterson, 1944; Gustin, 1991, 1992; Pett & Wilson, 1996), display size, resolution, type of electronic display and viewing conditions (e.g., location, distance, viewing angle).

Finally, the interaction between multiple characteristics of the display or of the viewers may be a significant issue as noted in this study and by Rubenstein (1988). The potential range of such studies is extremely broad. Specific needs will likely be defined as a result of initial studies of individual characteristics.

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APPENDICES

Appendices A–E

APPENDIX A

Human Vision System and Eye Disorders

Human Vision System and Eye Disorders

Introduction

The human vision system is similar to a common camera. Incoming light rays are processed by optical elements (the cornea and iris in the vision system; the lens and aperture opening in the camera) to produce an image on a sensor (the retina in the vision system; the film or video sensor in the camera) which is then processed and interpreted (the optic nerve and brain in the vision system; the chemical processing of the film or the cabling and electronics in the camera).

The optical elements in the eye are located in the front (anterior) portion. The cornea, which is a clear tissue below the front surface of the eye, serves as the focusing lens. It focuses the light rays to produce a clear, sharp image as does the lens in a camera. The iris, which is the ring that gives the eye its distinctive color, serves as the aperture control by regulating the size of the pupil (the dark opening to the interior of the eye behind the cornea). The lens opening in a camera functions in a similar manner.

The retina is the sensor in the eye. It consists of two types of elements, rods and cones, which are distributed on the inner surface of the eye. These two types of elements are associated with different aspects of vision (high light level versus low light level and color versus greyscale). In addition, their density is highest near the central region of the visual field, thus producing the greatest resolution of detail in that area with lesser resolution in the peripheral vision regions. The network of rods and cones in the retina is connected to the optic nerve, which exits at the rear of the eye at a point known as the “blind spot”

because no sensing elements are located there. The signals produced in the retina by the incident light travel along the optic nerve to the brain.

Additionally, the eye is served by a network of muscles, blood vessels, and nerves in the same manner as any other part of the body. The nerves and muscles are particularly important since they control such operations as movement, focusing, and pupil opening, which are essential to the proper operation of the eye.

Disorders Related to Low Vision

The vision system is subject to numerous disorders because of its complex structure. These disorders may be either pathological (i.e., resulting from disease) or traumatic (i.e., resulting from injury). All portions of the vision system may be affected, and a wide range of types and degree of vision loss may result. Finally, a single disorder, or similar disorders, may have the capacity to cause multiple types or locations of vision problem, either individually or, in some instance, simultaneously.

In "Chapter 3" (see Table 1) we list the eye disorders of interest in this study and their association with the resolution categories and subgroup classifications for categorizing participants. The disorders associated with the anterior segment and the primary subgroup are:

Hereditary corneal distrophies are problems relating to the cornea of unknown origin that have produced some change in the structure of the cornea and may or may not interfere with vision (Vaughan, Asbury, & Riordan–Eva, 1995).

Aniridia is congenital absence of all or part of the iris (Thomas, 1997).

A **cataract** is opacity of the lens and/or its capsule (Thomas, 1997).

Additional problems with the cornea, anterior chamber, iris, or lens include: **Dislocated lens**, a partial or complete dislocation of the lens (Vaughan, Asbury, & Riordan-Eva, 1995); **Keratoconus**, a cone-shaped protrusion of the center of the cornea (Thomas, 1997); **Keratitis**, an inflammation of the cornea (Thomas, 1997), and **Presbyopia**, the normal loss of elasticity of the lens associated with aging (Thomas, 1997).

The disorders associated with the anterior segment and the secondary subgroup are:

Amblyopia, in general terms, is a reduction or dimness in vision and can have several forms: (a) **crossed** (amblyopia of one eye), (b) **deprivation** (non–use and secondary when associated with cataract (opacity of the lens or eye) or ptosis (a dropping of the eye or eyelid)), (c) **ex–anopsia** (dis–use) and associated with convergent squint or very poor visual acuity, (d) **reflex** (irritation to the peripheral area of the eye, (e) **strabismic** (amblyopia secondary to misalignment of the eyes where the brain suppresses the visual image from the deviating eye to prevent double–vision. In the WebText study, we will examine amblyopia of non–pathalogical origin (due to strabismus or adverse refractive error) (Thomas, 1997).

Nystagmus is a "… constant, involuntary, cyclical movement of the eyeball" in any direction (Thomas, 1997, p. 1328–1329). It appears in twenty–one different forms: (a) **aural** (eye movement affecting intricate communication passages (labyrinth) of the ear, (b) **Cheyne's** (rhythmic), (c) **convergence** (slow to rapid adduction of the eyes), (d) **dissociated** (one eye that is not synchronized with that in the other eye, (e) **end–position** (eyes turn to extreme positions), (f) fixation (when eyes gaze), (g) **gaze–invoked** or rebound (holding eyes in an eccentric position), (h) **jerk** (rhythmic), (i) **labyrinthine**

(disease of the labyrinthine vestibular apparatus, (j) **latent** (occurs upon covering of one eye), (k) **lateral** (horizontal movement of the eyes from side to side (l) **miner's** (associated with darkness), (m) **opticokinetic** (a rhythmic jerk when looking at constantly moving objects), (n) **pendular** (movement equal in both directions associated with loss of bilateral congenital central vision that occurs by two years of age), (o) **post rotatory** (occurs when the body is rotated and then stops), (p) **rebound** (gaze–invoked), (q) **retraction** (drawing of the eye backward into orbit, (r) rhythmic (slow eye movement followed by rapid jerking), (s) **rotatory** (rotation about visual axis), (t) **seesaw** (in-turning eye moves up and opposite eye moves down followed by eyes moving in opposite directions, (u) **vertical** (involuntary up and down movements), (v) **vestibular** (disease relating to vestibular area of the ear), and (w) **voluntary** (a learned, rapid oscillation of eyes) (Thomas, 1997).

Pathological myopia is malignant, progressive myopia that causes retinal detachment and blindness (Thomas, 1997).

The disorders associated with the posterior segment and the primary subgroup are:

Central scotomas are blind gaps in the visual field and have nine different forms: (a) **absolute** (blindness in the visual field); (b) **annular** (a zone that encircles the fixation point that may or may not be closed and leaves the fixation point in tact; (c) **arcuate** (an arc–shaped scotoma near the blind spot of the eye); (d) **central** (depressed vision involving the point of fixation as in lesions of the macula); (e) **centrocecal** (an oval–shaped vision defect that affects the point of fixation and the blind spot of the eye); (f) **color** (color blindness in a limited area of the visual field); (g) **eclipse** (blindness caused by solar eclipse); (h) **flittering** (see scintillating); (i) **scintillating** (an irregular outline in the visual field that

may occur following mental or physical labor, during migraine headaches, or eyestrain (Thomas, 1997).

Cone distrophies are problems relating to the outer layer of the retina where color perception occurs (Thomas, 1997).

Diabetic retinopathy (non–proliferative and proliferative forms) is a leaking of retinal blood vessels which affects the macula or entire retina and vitreous (The Lighthouse, 1995). This eye problem is associated with diabetes (associated with inadequate production of insulin) although not all diabetics experience retinal changes (Thomas, 1997; Vaughan, Asbury, & Riordan–Eva, 1995).

Macular diseases refer to diseases of the macula and include nine forms: (a) **age–related macular degeneration** (nonexudative and exudative); (b) **central serous chorioretionpathy** (serous detachment of the sensory retina caused by focal leakage of fluid); (c) **macular edema** (swelling and thickening of the macula by intraretinal fluid affecting intraocular inflammatory diseases, retinal vascular diseases, retinal degenerations, etc.); (d) **inflammatory disorders** involving the macula; (e) **angioid streaks** (jagged, tapering lines that radiate from the peripapillary retina into the macula and peripheral fundus); (f) **myopic macular degeneration,** and (g) **epiretinal macular membranes**; (h) **traumatic maculopathy**; and (i) **macular distrophies** (X–Linked Juvenile Retinoschisis, rod–cone distrophies (Fundus Albipunctatus, Fundus Flavimaculatus (Stargardt's Disease), and Vitelliform Distrophy (Best's Disease) (Vaughan, Asbury, & Riordan–Eva, 1995).

Macular degeneration is the leading cause of visual impairment in people over 60 and is the degeneration of the macular area of the retina of the eye and results in loss of central vision. The most common form is age–related macular degeneration. The cause of macular degeneration is unknown (Thomas, 1997).

Pars plantis is an inflammation of the peripheral part of the retina. Its distinguishing characteristics are aggregations of inflammatory cells on the anterior, inferior retina (Thomas, 1997).

Retinal edema is swelling of the retina.

The disorders associated with the anterior segment and the secondary subgroup are:

Albinism is a non–pathalogical, genetic eye problem that results from lack of pigment in the eyes. Oftentimes, it is also accompanied by astigmatism, photophopbia and nystagmus. These conditions may occur with albinism because the chrorid is not protected from light due to insufficient pigment (Thomas, 1997).

Color deficiencies refer to eye problems relating to color perception.

Glaucoma is the condition of excessive pressure inside the eye.

Branch vein occlusion is the blockage of a smaller vein (Thomas, 1997).

Ischemic optic neuropathy is a pathological change in the optic nerves causing local, temporary deficiency of blood supply (Thomas, 1997).

Retinitis Pigmentosa is a chronic, inherited, progressive disease that is onset in early childhood and is characterized by degeneration of the retinal epithelium (rods, atrophy of the optic nerve, and pigmentary changes in the retina) that cause loss of night vision and an constricted visual field (Thomas, 1997).

The effects of these conditions vary widely. For example, cataracts may cause hazy views so that glaring lights are problematic (Ray & Ray, 1998). Diabetic retinopathy can cause blurring, distortion, or sensitivity to glare in the central field of view without impairing peripheral vision (The Lighthouse, 1995). Macular degeneration may cause a blur in the center of the field of view (The Lighthouse, 1995) or reduction of the ability to distinguish colors (Thomas, 1997). The number of characters that can be recognized at a glance by these individuals may be limited (Legge, Ahn, Klitz, & Luebker, 1997). Other conditions, such as presbyopia or amblyopia, may cause a loss of the ability to focus on fine detail. As a result, individuals with specific problems may perceive information differently depending upon their condition (Ray & Ray, 1998; The Lighthouse, 1995).

Additionally, individuals with differing disorders may employ a variety of means to assist in vision–based activities. Persons with amblyopia may use text enlargers or control background contrast (Arditi & Knoblauch, 1994; Knoblauch & Arditi, 1994) or may use color coding strategies (Eperjesi, Fowler, & Kempster, 1995). Similarly, readers with age-related macular degeneration also may find enlarged text or color coding to be helpful (Shaw, 1969). Time of day may affect the ability of people with diabetic retinopathy to perform near tasks. Additionally, these individuals may use magnifying devices, illumination controllers, absorptive lenses, or reading slits.

Four of these conditions, macular degeneration, diabetic retinopathy, glaucoma, and cataracts have been identified as the leading causes of reduced vision (Bailey, 1991). More recently, Attebo, Mitchell, and Smith (1996) noted that ocular trauma, and amblyopia also are significant causes of reduced vision.

APPENDIX B

IRB and Informed Consent Documentation for Participating Institutions for the WebText Study:

The University of Memphis
Charles Retina Institute
Southern College of Optometry
The University of Tennessee, Memphis

IRB Documentation and Proposed Informed Consent Documentation for the WebText Study at The University of Memphis

THE UNIVERSITY OF MEMPHIS
Committee for the Protection of Research Participants
Application to Conduct Research with Human Subjects

DIRECTIONS: All research involving data collection or other investigations using human subjects must be reviewed and approved by the University's institutional review board, the Committee for the Protection of Research Participants, prior to beginning any such research. In order to obtain approval, complete and submit this application to the Committee, c/o Susie Hayes, IRB Coordinator, Research Support Services, Administration 315, The University of Memphis, Memphis, TN 38152. Electronic submission to *slhayes@memphis.edu* or on diskette is strongly encouraged and is likely to result in a quicker review process.

Use this page as a cover sheet for the application and follow the instructions on the pages that follow in completing the application. If revisions are made to an application currently under review, please clearly indicate any changes.

Depending on the level of potential risk to subjects, as determined by the Committee, the application may be subject to full Committee review, expedited review, or exempted from the review process. Please allow up to four weeks for a response from the Committee. For questions or further information, call Susie Hayes at 678–2533.

Name: **Gloria A. Reece** Phone: **(901) 388–3453** Fax: **Not applicable**

Department: **Education** E–mail: **g–reece@memphis.edu**

Faculty Adviser (if student): **Dr. Deborah L. Lowther**

Project Title: **An investigation of the legibility of on–screen text for web documents for a low vision population**

Project Start Date: **May 1, 1998**

If project is being submitted for external funding, provide the following information:

Proposal Submission Date:

Sponsoring Agency:

SUBJECT CHARACTERISTICS:

Number of Subjects: About **100** (about **25 in each category)** Age Range: **18 years and older**
(Consent of parent/guardian required if under 18)

Subjects include (check all that apply):

[ ] Pregnant females [ ] Prisoners [ ] Students [ ] Athletes

[ ] Cognitively impaired [ ] HIV + [ ] Minors (under 18) X Other: Low vision adults

PROJECT DESCRIPTION: Attach a short narrative which includes a description of the planned research project and procedures to be used. Please number the pages of this and any other attachments. In addition, provide a response to each of the items below.

The participants will view samples of on–screen text designed for web delivery and provide feedback on their preferences.

How will the subjects be recruited? Please attach copy of any advertisements, transcripts of radio or other media announcements, or other recruitment mechanisms.

The participants will be primarily recruited via referral from physicians and other professionals who have contact with them.

List/describe any medical or other conditions that might exclude a subject from participation.

A high degree of vision loss would exclude individuals from participating in the study. Additionally, one's inability to interact and respond.

Describe any possible risks (physical, psychological, emotional, social, vocational, financial, etc.) that might be experienced by the subject. If blood is to be drawn from a subject, include the qualification of the person drawing it, such as physician, nurse, phlebotomist, etc. If you plan to use frozen blood in the future, subject's consent must be obtained.

None

Describe potential benefits to the subjects.

The subjects will benefit by having stated some opinion about their text preferences for the study which may be used by product developers to create future on–screen displays that are more usable by the subjects.

Describe compensation or incentives for subjects. What arrangements will be made for early withdrawal? List alternative ways for subjects to earn credit if participation is part of school course.

The incentive for participants would be to have an opportunity to help create improved products.

Early withdrawal is not an issue because of the small number of contact sessions. The subject can simply choose to not participate.

Describe how confidentiality and privacy of subjects' responses are to be ensured. (If project involves drugs or medical devices, records must be open to FDA inspection, and the subjects must be informed of this provision.)

Participant responses will be anonymous. Names will be collected only for verifying participation. No participant will be identified by her or his name in analysis or discussions.

Describe any provisions made for cultural and/or language problems that might arise.

Issues will be addressed one at a time as they arise. The researcher has a strong background in conducting research studies and is a trained professional communicator who has experience in managerial communication and language and linguistics, including graduate courses in issues relating to language, culture, and society.

Describe any arrangements for medical or psychological referral in case of incidental problems.

Any incidents will be handled by a standard call to emergency personnel.

Medical condition verification will be provided voluntarily and used only to determine suitability for participation.

Describe any equipment to be used.

Computer equipment available in the College of Education computer labs will be available for the study.

Describe any known uses of data beyond the scope of this project. The subjects must consent to any other use of the data.

Currently, there are no known uses of data beyond the scope of this project. The work is a traditional academic work. Given conclusive results, proposals for conference proceedings and journal papers are expected to be generated from this work.

INFORMED CONSENT: Informed consent to participate in the research project is required of all research involving human subjects and must include the elements listed below. Such consent must be given by the subject and/or parent/guardian if the subject is under 18. Informed consent is usually obtained using a written consent form but other presentation methods may be utilized depending on the nature of the research and/or the characteristics of the subjects. If a written, signed consent form will not be obtained, explain why and attach a description of how informed consent will be obtained and documented.

The written informed consent form should describe what the subject will actually experience, including the duration of the session and number of sessions, using language appropriate to the educational level of the subject and that can be understood by the subject. Required elements of informed consent are listed below:

(a) a statement that the study involves research, an explanation of the purposes of the research and the expected duration of the subject's participation, a description of the procedures to be followed, and identification of any procedures which are experimental;
(b) a description of any reasonably foreseeable risks or discomforts to the subject;
(c) a description of any benefits to the subject or to others which may reasonably be expected from the research;
(d) a disclosure of appropriate alternative procedures or courses of treatment, if any, that might be advantageous to the subject;
(e) a statement describing the extent, if any, to which confidentiality of records identifying the subject will be maintained;
(f) for research involving more than minimal risk, an explanation as to whether any compensation and an explanation as to whether any medical treatments are available if injury occurs and, if so, what they consist of, or where further information may be obtained;
(g) an explanation of whom to contact for answers to pertinent questions about the research and research subjects' rights, and whom to contact in the event of a research–related injury to the subject;
(h) a statement that participation is voluntary, refusal to participate will involve no penalty or loss of benefits to which the subject is otherwise entitled, and the subject may discontinue participation at any time without penalty or loss of benefits to which the subject is otherwise entitled.
(i) a statement that information collected in this study will be kept confidential within the limits allowed by law
(j) a statement that The University of Memphis does not have any funds budgeted for compensation for injury, damages, or other expenses, and
(k) an explanation that for answers to questions regarding the research and the research subjects' rights, the Chair of the Committee for the Protection of Human Research Participants should be contacted at 678–2533.

Informed Consent (Draft of body of proposed letter):

I agree to participate in a research project that will use my opinions regarding the legibility of typefaces for the display of text in web documents. The goal is to determine the effects of various type characteristics on legibility in order to aid designers in developing computer displays that can be used more readily by persons with either of two eye disorders: amblyopia (with and without retinopathy of prematurity) or macular degeneration (includes Stargardt's Disease). As a participant in this study, I

will respond to interactive displays of type options by stating my preferences for various characteristics of the text samples as provided by the researcher. Additionally, I agree to provide responses to a brief questionnaire on the topic. The expected duration for completion of these tasks is 30 to 60 minutes.

There are no foreseeable risks or discomforts anticipated in this research. I will benefit by having stated some opinion about my text preferences for the study which may be used by product developers to address universal access issues relating to display of on–screen text for web delivery. I understand that my participation in the project is entirely voluntary; I have the right to decline to participate or discontinue participation at any time during the project; no penalty or loss of benefits to which I am otherwise entitled will occur.

The purpose and nature of the project has been explained to me. I understand that the sessions may be video– and/or audio–recorded for the purpose of accurately reporting data for this study. In addition, paper documents will be used for data collection in the study. Those documents will also be collected by the moderator for the purpose of accurately reporting data for this study. Furthermore, I also understand that results of this work may be published in academic journals and other methods of publication, and presented at education meetings and lectures. My understanding is that in all publications, complete anonymity will be maintained and that the publications will not mention my real name.

I understand that I may ask questions at any time during the observation. For questions relating to the specific design and management of the study, I may contact Gloria Reece (phone: (901) 388–3453 or via e–mail: g–reece@memphis.edu). For additional questions about the project, I may also contact Dr. Deborah L. Lowther of The University of Memphis, Memphis, TN 38152 (internet: lowther.deborah@coe.memphis.edu). For an explanation of or answers to questions regarding the research and the research subjects' rights, I may contact the University's Chair of the Committee for the Protection of Human Research Participants at (901) 678–2533. In the unlikely event of any injury as a result of this research effort, no reimbursement, compensation, or free medical care is offered by Gloria A. Reece and/or The University of Memphis.

ANNUAL REVIEW: Approval of this application is effective for one year. In submitting a request for annual review, please include a report of the status of the project indicating the following:

1. the number of subjects initially enrolled in the research and what number remained;

2. a description of any adverse events or unanticipated problems involving risks to subjects or complaints about the research;

3. a summary of any recent literature, findings, or other relevant information associated with the research.

Informed Consent for The WebText Study at The University of Memphis

I agree to participate in a research project that will use my opinions regarding the legibility of typefaces for the display of text in web documents. The goal is to determine the effects of various type characteristics on legibility in order to aid designers in developing computer displays that can be used more readily by persons with either of two eye disorders: amblyopia (with and without retinopathy of prematurity) or macular degeneration (includes Stargardt's Disease). As a participant in this study, I will respond to interactive displays of type options by stating my preferences for various characteristics of the text samples as provided by the researcher. Additionally, I agree to provide responses to a brief questionnaire on the topic. The expected duration for completion of these tasks is 30 to 60 minutes.

There are no foreseeable risks or discomforts anticipated in this research. I will benefit by having stated some opinion about my text preferences for the study which may be used by product developers to address universal access issues relating to display of on–screen text for web delivery. I understand that my participation in the project is entirely voluntary; I have the right to decline to participate or discontinue participation at any time during the project; no penalty or loss of benefits to which I am otherwise entitled will occur.

The purpose and nature of the project has been explained to me. I understand that the sessions may be video– and/or audio–recorded for the purpose of accurately reporting data for this study. In addition, paper documents will be used for data collection in the study. Those documents will also be collected by the moderator for the purpose of accurately reporting data for this study. Furthermore, I also understand that results of this work may be published in academic journals and other methods of publication, and presented at education meetings and lectures. My understanding is that in all publications, complete anonymity will be maintained and that the publications will not mention my real name.

I understand that I may ask questions at any time during the observation. For questions relating to the specific design and management of the study, I may contact Gloria Reece (phone: (901) 388–3453 or via e–mail: g–reece@memphis.edu). For additional questions about the project, I may also contact Dr. Deborah L. Lowther of The University of Memphis, Memphis, TN 38152 (internet: lowther.deborah@coe.memphis.edu). For an explanation of or answers to questions regarding the research and the research subjects' rights, I may contact the University's Chair of the Committee for the Protection of Human Research Participants at (901) 678–2533. In the unlikely event of any injury as a result of this research effort, no reimbursement, compensation, or free medical care is offered by Gloria A. Reece and/or The University of Memphis.

Signature of Participant	Date
Signature of Witness	Date
Signature of Principal Investigator	Date

Informed Consent for The WebText Study at Charles Retina Institute

I agree to participate in a research project that will use my opinions regarding the legibility of typefaces for the display of text in web documents. The goal is to determine the effects of various type characteristics on legibility in order to aid designers in developing computer displays that can be used more readily by persons with resolution eye problems in these groups: anterior (cornea and/or lens and other) or posterior (retina and/or other) segment. As a participant in this study, I will respond to interactive displays of type options by stating my preferences for various characteristics of the text samples as provided by the researcher. The expected duration for completion of these tasks is 20 to 30 minutes.

There are no foreseeable risks or discomforts anticipated in this research. I will benefit by having stated some opinion about my text preferences for the study, which may be used by product developers to address universal access issues relating to display of on–screen text for web delivery. I understand that my participation in the project is entirely voluntary; I have the right to decline or discontinue participation at any time during the project; no penalty or loss of benefits to which I am otherwise entitled will occur.

The purpose and nature of the project has been explained to me. I understand that the sessions may be audio–recorded for the purpose of accurately reporting data for this study. In addition, paper documents will be used for data collection in the study. Those documents will also be collected by the moderator for the purpose of accurately reporting data for this study. Furthermore, I also understand that results of this work may be published in academic journals and other methods of publication, and presented at education meetings and lectures. My understanding is that in all publications, complete anonymity will be maintained and that the publications will not mention my real name.

I understand that I may ask questions at any time during the observation. For questions relating to the specific design and management of the study, I may contact Gloria Reece (phone: (901) 388–3453 or via e–mail: g–reece@memphis.edu). For additional questions about the project, I may also contact Dr. Deborah L. Lowther of The University of Memphis, Memphis, TN 38152 (e–mail: lowther.deborah@coe.memphis.edu). For an explanation of or answers to questions regarding the research and the research subjects' rights, I may contact the University's Chair of the Committee for the Protection of Human Research Participants at (901) 678–2533. In the unlikely event of any injury as a result of this research effort, no reimbursement, compensation, or free medical care is offered by Gloria A. Reece, The University of Memphis, or The Charles Retina Institute.

_____ _____

Signature of Participant Date

Signature of Witness	Date
Signature of Principal Investigator	Date

SOUTHERN COLLEGE OF OPTOMETRY

INSTITUTIONAL REVIEW BOARD
HUMAN SUBJECTS (PARTICIPANT) APPROVAL

Name of Principal Investigator: Gloria A. Reece

Title of Project: "Text legibility for web documents and low vision"

The chair of the IRB of Southern College of Optometry has reviewed the human subjects protocol for the above mentioned research and determined that the project qualifies for approval. The time period for this approval expires one year form the date listed below. You must notify the IRB in advance of any proposed major changes in your approved protocol, such as additional research sites or research instruments.

You must file an annual **"Requestor Confirmation of Human Subject Protocol"** report with the IRB in advance if anticipate your research project going beyond one year.

Any subject consent forms must be signed in duplicate and a copy provided to the subject. The principal investigator must retain the other copy of the signed consent form for at least three years following the completion of the research activity, any they must be available for inspection if there is an official review of the Southern College of Optometry IRB by the United States Department of Health and Human Service or its successors for protection from Research Risks.

This action is officially recorded in the minutes of the committee.

IRB Chair Signature: _____

Date: _____

Southern College of Optometry

Request for Review of a Protocol for Research on Human Subjects

Cover Page (Please Type)

Project: WebText

Title: "Text legibility for web documents and low vision"

Principle Investigator (PI): Gloria A. Reece	**Title of PI:** Doctoral Candidate The University of Memphis College of Education Memphis, TN 38152
Department of PI: The University of Memphis College of Education Instructional Design and Technology Memphis, TN 38152	**Signature of PI:**[a] _____ **Date:** _____
PI Home Address: 3505 Patricia Ellen Dr. Bartlett, TN 38133	**PI Home Phone:** (901) 388–3453 **PI Business Phone:** None
Faculty Sponsor (Required for Student Projects): Dr. Deborah L. Lowther	**Title of Sponsor:** Assistant Professor
Proposed Start Date: May 5, 1999	**Proposed Stop Date:** June 18, 2000
Co–Principal Investigator: Dr. Tressa Eubank	**Title of Co–PI:** Chief, Low Vision Clinic
Department of Co–PI: Low Vision	**Signature of Co–PI and Date:** _____ Date: _____
Funding Source (Grant or contract, title, departmental funds, etc., or none): This project is funded soley by Gloria A. Reece.	

a. Signature permits viewing of Assurance in departmental office.
All necessary signatures must be obtained before presenting to the Institutional Review Board.

To be completed by the IRB:

__ Project qualifies for exemption under __ CRF __ Date: _____

__ Project qualifies for expedited review under __ CRF __ Date: _____

__ Project reviewed by Institutional Review Board _____ Date: _____

__ Project approved by Institutional Review Board __ Date: _____

__ Signature of IRB Chair: _____ Date: _____

Request for Review of a Protocol for Research on Human Subjects

Note: This form is Federally auditable. Attach additional pages if needed. All pages in the protocol and consent forms should be numbered. (Please type.)

1. **Project Title:** "Text legibility for web documents and low vision"

2. **Principal Investigator (PI):** Gloria A. Reece, Doctoral Candidate, The University of Memphis, College of Education, Memphis. TN 38152

   If a student, name and signature of faculty advisor approving research: Deborah L. Lowther, Ph.D.

   _____

3. **Department of PI (or faculty advisor):**

   The University of Memphis

   College of Education

   Department of Instruction and Curriculum Leadership

   Instructional Design and Technology

   Memphis, TN 38152

4. **Business phone of PI (or faculty advisor):** (901) 678–5645

5. **Co–Investigator(s):**

The University of Memphis	Department	Southern College of Optometry	Department
Marshall G. Jones, Ed.D.	ID&T	Tressa Eubank, O.D.	Low Vision
Linda Bol, Ph.D.	EDPR		
Emily Thrush, Ph.D.	English		

6. This research protocol has __x__/has not _____ been reviewed by the SCO Institutional Review Board or **another university** human subjects review board. If so, complete the following:

   a) It was last reviewed on May 4, 1999 (date) at SCO.

   b) It was reviewed at **The University of Memphis** (institution) on **October 7, 1998** (date).

   c) It **was** __x__/was not _____ approved. If it was not approved, explain.

   d) It has __x__ /has not _____ been modified since it was approved. If modified, describe all modifications.

   e) The completion date for this project **has _____ has not** __x__ been changed since the project was approved. If it has been changed, what is the new completion date?

   f) In submitting a request for re–review, the Principal Investigator should include a page on status thus far of the research indicating the following:

      (i) The number of subjects initially enrolled in the study and what number remained in the study. Are these the same subjects? If any subjects did not complete the study, state the reasons for withdrawal.

      PI Responds: The anticipated number of participants for this study is 320. They are the initial volunteers and may decline participation at any time during the study.

      (ii) A description of any adverse effects of unanticipated problems involving risks to subjects or others, or any of the subjects' complaints.

      PI Responds: This study is a non–invasive study and no harm is anticipated.

      (iii) A summary of any recent literature, findings, or other relevant information about risks associated with the research.

      PI Responds: There are no anticipated risks associated with this research as it is a non–invasive study.

(iv) If approved previously by another institution, a copy of the former application for human subject approval.

PI Responds: A copy of the application for human subject approval from The University of Memphis is given in the last section of this document.

Note: For re–review of a project which was approved less than 12 months ago by the Southern College of Optometry IRB, for the remaining items in this form fill in any changes compared to the protocol approved last year as well as explanations for the changes. If there are no changes to last year's protocol, writ in "no change" or "NC" across all items that have not changed.

Note: Review by the SCO Institutional Review Board (IRB) is conducted under an Assurance submitted to the Department of Health and Human Services. A copy of this Assurance is available to the Principal Investigator upon request.

7. Proposed project start date: May 5, 1999

8. Proposed completion date: May 5, 2000

9. Is this research to be supported in whole or in part by funds from any organization?

   ____ Yes __x__ No

   If so, which organization?

   If not a federal organization, please attach the organization's guidelines for institutional review of the human subjects protocol.

10. Does this project involve drugs or medical devices?

    ____ Yes __x__ No

    If so, please specify.

Note: If this project does involve drugs or medical devices, there must be a statement in the informed consent for that the records are open for inspection by the FDA.

11. **Attach:** (1) an abstract of the research plan in non–technical language, (2) a description of the research procedure, and (3) a detailed description of any experimental manipulation of the subjects.

    PI Responds: This study does not employ any experimental manipulation of the participants. An abstract of the research plan and a description of the procedure are given below. Example screens of the electronic test are given as an attachment to this document.

Consent to Act as a Research Subject

Note: This form should be used to construct a written informed consent form for human subjects for your research project. Include all topics in your customized informed consent form. Wording of your form should be in complete sentences and should not be self–contradictory (such as saying there is no risk and minimal risk) and should be easily understood by the layperson. Please type your informed consent form.

Project Title:

"Text legibility for web documents and low vision"

1. I agree to be included as a subject in a research study being conducted by: Gloria A. Reece. The following procedures will be performed: (list of procedures).

   a) Obtain informed consent and basic demographic information (see attached data collection instrument in Appendix B).

   b) Obtain near visual acuity scores from the optometrist or optometrist designee (see data collection instrument in Appendix C).

   c) Obtain a near reading distance measure (16 inches) as the participant is seated at the computer. Ask the participant if she or he can read the screen at 16 inches. If not, ask the participant to move in closer until it is both visible and readable. Then, the recorder will take a near distance measure at that point. Ask the participant to remain at the chosen distance for the remainder of the test.

   d) Train the participant on how to respond to the sample screens using the WebText "Contrast Preference Test" (see Appendix B). This test provides training for the participants. Here, they choose the background and text color and type size for their customized "Typeface Preference Test."

   e) Repeat the reading distance measure.

   f) Conduct the WebText "Typeface Preference Test" (see one sample set of test materials (24 screens) in Appendix D).

g) Repeat the reading distance measure.

h) Thank the participant for her or his participation.

2. The purpose of the study is to obtain opinions about the legibility of text for low vision readers. This study will specifically test for two typeface legibility clarity elements: (a) serif quality (serif versus sans serif) and (b) Roman versus italic.

3. I have been told that the procedures described above involve the following possible risks and/or discomforts or inconveniences, both immediate and long term: list of risks, etc. (list of risks, etc.)

   No risks are anticipated.

4. And that they might have the following possible benefits:

   a) Directly to me: (list benefits or state "none.")

      Provide opinions about text legibility that may improve the readability of text on computer screens.

   b) To others: (list benefits, for example, "a better understanding of …")

      Provide opinions about text legibility that may influence how designers create materials for the web. The results from this study may also provide information for the development of new universal design guidelines for web (includes electronic) documents for all users.

5. (Where applicable in experimental therapy projects) I have been told that there are alternative procedures that are available should I refuse to be in the study. These are: (list alternative procedures)

   None.

6. This information was discussed with me by [designated optometry student at SCO and/or Gloria A. Reece]. She or he will answer any further questions I may have concerning this study or procedures. I can reach her or him at (901) 388–3453 (8:00 p.m. to 10:00 p.m. daily) (If procedures are invasive, this number must be available 24 hours each day.)

7. I have been advised that Southern College of Optometry has no special program by which it provides compensation or medical treatment if injury occurs during biomedical or behavioral research.

8. My records will be kept confidential according to standard medical/optometric practice. (Where applicable) I understand that this project involves the testing of a new drug/device and therefore give my consent to allow my medical records to be reviewed by representatives of the drug/device company and (name of federal agency).

   Second statement is not applicable to the WebText study.

9. I recognize that my participation in this study is voluntary. Without prejudice to my future medical treatment, I am free to take part in, or withdraw from the study at any time.

10. (Include where applicable) My compensation for being in this study is $0.00. If I do not finish the procedures, I will receive a minimum of $0.00 or (describe arrangements).

    No arrangements.

11. I have received a copy of the Experimental Subjects' Bill of Rights and a copy of this consent form for my own use.

12. Include subjects' signature or signature of parent or legal guardian in under 18 years of age. Also, document the date the informed consent was signed. Example:

_____

Participant's signature (or signature of parent or legal guardian if under 18)

Date: _____

13. Should I have any questions about my rights as a subject, I may call the Institutional Review Board between 9:00 a.m. and 5:00 p.m. Monday through Friday at (901) 722–3362 (phone).

Experimental Subjects' Bill of Rights

The Institutional REview Board at Southern College of Optometry wishes you to know:

Any person who is requested to consent to participate as a subject in a research study involving drugs or medical devices or is requested to consent on behalf of another has the right to:

1. Be informed of the nature and purpose of the experiment.
2. Be given an explanation of any procedures to be followed in the study and of any drug from the experiment.
3. Be given a description of any attendant discomforts and risks reasonable to be expected from the experiment, if applicable.
4. Be given an explanation of any benefits to the subject and risks reasonably expected from the experiment, if applicable.
5. Be given disclosure of any appropriate alternative procedures, drugs, or devices that might be advantageous to me subject, and their relative risks and benefits.
6. Be informed of the avenues of optometric or medical treatment, if any, available to the subject after the experiment if complications should arise.
7. Be given an opportunity to ask any questions concerning the experiment without the intervention of any element of force, fraud, deceit, duress, coercion, or undue influence on the subject's decision.
8. Be given the opportunity to withdraw consent to an experiment any time without any adverse effects on medical or optometric treatments in the clinic. If an SCO student, withdrawal will not effect grades on any course or academic standing.

If you have any questions regarding a research study, the researcher or his/her assistant will be glad to answer them. You may seek information from the Institutional Review Board established for the protection of volunteers in research projects by calling (901) 722–3362 Monday through Friday, between 9:00 a.m. and 5:00 p.m.

IRB for the WebText Study at the University of Tennessee–Memphis

FORM 1

UT MEMPHIS IRB APPLICATION FOR REVIEW

Text Legibility for Web Documents and Low Vision

Principle Investigator: Gloria A. Reece, Doctoral Candidate

The University of Memphis

1. Purpose of the Study

The purpose of this study (WebText Study) is to identify preferences for specific text legibility characteristics that facilitate text contrast when viewing text on a computer screen (e.g., web pages) by individuals with partial sight (low vision) who also have resolution–related eye problems.[1] (Individuals with partial sight may have difficulty reading newsprint with ordinary eyeglasses or contact lenses.) It is expected that the responses from the participants will help researchers address gaps in text legibility and vision literature and provide information to software designers regarding preferences for text legibility qualities.

This non–invasive study extends current research on text legibility and contrast for individuals with visual challenges resulting from resolution problems by examining issues in scientific studies from each of these areas. The primary purpose of this study is to determine if there are text legibility preferences for low vision readers for electronic documents. Specifically it identifies typographical quality elements and obtains preferences for four: (a) typeface (serif versus sans serif) (b) tone or weight qualities (Regular (no emphasis) or italic), (c) typesize, (d) text and background color. The experimental study will use a procedural test for assessing preferences regarding contrast and will test for the remaining qualities.

Previous studies examining the effects of text legibility and contrast for individuals with partial sight have concentrated primarily on print media; this study is the first to investigate

1. When referring to individuals who have subnormal visual acuity or abnormal visual field, the following terms are commonly used: (a) partial sight or partially–sighted, (b) low vision readers, (c) subnormal readers, (d) visually impaired, and (e) visually–challenged.

   When referring to individuals who have normal visual acuity or normal visual field, the following terms will be used: (a) normally–sighted, (b) normal readers, and (c) fully–sighted.

by direct observation the text legibility preferences as they relate to eye resolution problems for dynamically displayed (display on demand) information on the web in a normal reading situation. It builds on the scientific studies on text legibility, contrast, and perceptual training and figure–ground performance from several perspectives: (a) typography or the process of printing with types, (b) visibility or perceptibility at a near reading distance, (c) direct observation, and (d) clinical testing of near visual acuity for low vision.

In an attempt to identify effective design principles for text legibility for individuals with visual challenges, this work will examine two key research questions:

- What kinds of typeface contrast (e.g., style of typeface—serif versus sans serif) do readers with resolution problems find easiest to read for web documents?

- What font emphasis (weight or tone) qualities (e.g., italic or Regular (no emphasis)) do readers with resolution problems find easiest to read for web documents?

This study tests two hypotheses:

> **Hypothesis 1:** Low vision readers with functional vision loss resulting from resolution problems will have varied preferences in typeface contrast (serif or sans serif) when reading familiar words in web documents (a readability task) at typesizes near their visual threshold than participants without functional vision loss.

Predictions for Hypothesis 1:

Given the scant availability of information in the literature, preferences for serif or sans serif typefaces vary among low vision readers for printed materials and lack of information on this topic for electronic documents, it is hypothesized that low vision readers with resolution problems will vary among themselves and across comparisons with the control group in their preferences for typeface contrast (serif or sans serif) (Prince, 1967; Shaw, 1969) when reading on–screen text. Therefore, these readers may prefer smooth, clean typefaces in the Oldstyle or Slab Serif categories of type, which are always fonts with serifs, when reading familiar words (picture image), sentences, and lengthy textual material (readability tasks) (Prince, 1967) in typesizes that are close to their visibility threshold (Shaw, 1969). These same low vision readers may also prefer typefaces in the sans serif family when reading short bursts of text (legibility tasks)—individual letters and syllables (Prince, 1967) and for navigational elements such as headlines, button information, and signs as these items may contain text in sizes above or below their visibility threshold. Similarly, low vision readers may have consistent preferences for typefaces in the sans serif family when reading small text below their visibility threshold.

These predictions are less than clear–cut and pinpoint the issues in the serif versus sans serif paradox for on–screen and on–paper text. In more general terms, design researchers for print media, Turnbull and Baird (1980) contend that standard Roman faces (serif typefaces) provide maximum legibility and greater contrast for normal readers and that Gothic faces (sans serif typefaces) are better suited for display text because the monotonous tone of the face impairs reading. Experimental studies by Tannenbaum (1964) demonstrate that one sans serif typeface attracts more attention than two serif faces. This finding supports the argument for using sans serif typefaces for legibility tasks as they assist in way–finding, a critical need for those with low vision.

Therefore, we can use information obtained from experimental studies in print media for normal readers and current design practice as a basis for these predictions. In doing so, low vision readers may find that fonts (serif and sans serif) in common use are equally legible. From both legibility and readability perspectives, this hypothesis would be consistent with findings for normal readers (Tinker, 1932) in that typefaces that are familiar (serif and sans serif) are equally legible, which is also consistent with some current web design practice (Lemay, 1997). It would also be consistent with current design practice (on–screen and on–paper) for normal (Williams & Tollett) and subnormal readers (The Lighthouse, 1995). Furthermore, these findings are also consistent with those of Reece (1992, 1994), Reece and Scheiber (1993a, b) in that effective multimodal documents (on–screen and on–paper) require compromises in design based upon audience, purpose or aim of the document, hardware and software constraints, and mode of delivery.

> **Hypothesis 2:** Participants will prefer Roman forms of typefaces (serif and sans serif) and have no differences in their preferences for italic typefaces when reading familiar words (a readability task) in web documents at typesizes near their visual threshold.

Predictions for Hypothesis 2:

In a speed of reading study, Tinker and Paterson (1942) and Tinker (1966) found that use of italics and capital letters retarded reading for normally–sighted readers. Similarly, Morrison (1986) also suggests that italic typefaces actively engage normal readers when reading printed materials. While studies are scant and possibly non–existent in the literature for partial sight, it is expected that low vision readers will have strong preferences for the Roman form of typefaces (serif and sans serif) and that there will be no differences in their preferences for italic typefaces as compared to those without vision loss.

2. Background and Current Status of Work in the Field

The rapid proliferation of on–screen documents using renaissance designs that are breaking monotonous tones of documents on the world wide web (www), the availability of thousands of typefaces (over 30,000 commercial typefaces (Strizver, 1999), and the use of new and bigger fonts with more variety in texture and trendy collections of swash (fancy letters) and alternate characters, custom ligatures, logotypes, and a variety of other characters (Haley, 1999) raise concern for the effectiveness of text legibility for individuals who are visually challenged.

In printed materials, discrepancies exist in the application of typographical guidelines and actual printed product (by genre), indicating that conventional wisdom also serves as a strong guide in the design of documents for normal readers (Van Der Waarde, 1999). Contrastingly, little attention has been given to empirical studies on typographical design principles for on–screen documents for a universal audience that includes those with visual challenges. Thus, we have the paradox of text legibility design principles: Design principles for printed materials for normal readers may be applied to on–screen designs; however, designers must make judicious decisions (and possibly compromises) about text legibility principles based upon their design experiences, conventional wisdom, empirical knowledge, purpose of the document, audience, and mode of delivery (Reece, 1992, 1993–1994; Reece & Scheiber, 1993).

As of this writing, little, if any, research has been done on the influence of backlit materials for low vision readers. Between 1937 and 1964, only one experimental study on the readability of letters and numbers using backlighting was conducted for normal readers (Wright, 1958). One recent study suggests that text for visually challenged readers can be improved by increased luminance (Fine and Peli, 1995).

The focus of this research is to develop effective design principles for text legibility for web documents that are effective for low vision readers who have a **resolution** eye problem. Of key interest is how font–based legibility can relate to the legibility of text and application of contrast (e.g., serif faces—contain lines (“feet”) that cross the main stroke of a character) versus sans serif faces, text color (black or white), and background color (white, grey, or black)). Moreover, “What types of contrast are preferred on direct observation in fonts by adults with these low vision characteristics?”

3. Characteristics of Participant Population

This study requires 320 participants (640 eyes) who have resolution–related eye problems affecting the anterior and posterior segments. We anticipate UT–Memphis enrollment of 112 participants for the anterior segment categories (See Table 1.) and 88 participants for the posterior categories[1]. Additionally, approximately half of the control group (32 partic-

ipants) will come from both clinics. Inclusion criteria is given in the footnotes of Table 1. (See also the footnote regarding data collection in the table.)

The WebText study uses a normal reading situation whereby web–based text will be remotely[1] displayed on–screen to 320 volunteers who have subnormal vision that can be classified as a resolution problem (see Table 1 below). All participants shall be 18 years of age and older, binocular in their corrected visual acuity, classified by a code in the ICD 9–CM codebook (Codes for Optometry, Part Two: Diagnostic Codes (Abridged for Eye Care. 1998 edition), a functional literacy level as determined by the optometrist, and capable of viewing and responding to a 10 to 20–minute electronic test containing 24 screen displays of word pairs (See attached screen samples.).

1. Please consult the data collection notes in Table 1. These numbers may change slightly for the posterior segment categories as feedback from doctors at CRI and SCO is pending a discussion this week.

1. The web pages will use a remote display of on–screen text for the sole purpose of maintaining control of the rate at which the pages are viewed and to control internet connectivity factors.

Table 1. Participant Grouping and Characteristics[a]

Vision Classifications:		**Normal Vision[b]** **Visual Acuity (Distance) Print Size (Meters)**	**Low Vision[c]** **Visual Acuity (Distance) Print Size (Meters)**			**Row Totals[d]**
Categories of Visual Impairment:		**No Loss**	**Mild**	**Moderate**	**Severe**	
World Health Organization Levels:		20/25 or Better	20/30 to 20/60	20/70 to 20/160	20/200 to 20/400	
The Lighthouse Near Acuity Test Range:		(.5M or Better)	(.6 to 1.2M)	(1.4 to 3.2M)	(4 to 8M)	
Grouping:	**Characteristics:[e]**					
CONTROL (48)	Best Corrected[f] (48)	48 of 80				48 of 80
ANTERIOR SEGMENT[g] (8)	Resolution (Primary) (3)		0 of 20	3 of 20	0 of 20	3 of 60
	Resolution (Secondary) (5)		3 of 20	2 of 20	0 of 20	5 of 60
POSTERIOR SEGMENT (ADULT ONSET)[H] (32)[I]	Resolution (Primary) (25)		12 of 20	10 of 20	3 of 20	25 of 60
	Resolution (Secondary) (7)		5 of 20	1 of 20	1 of 20	7 of 60
Total Participants		48 of 80	20 of 80	16 of 80	4 of 80	88 of 320

a. Numbers given in terms of number of “people” needed for viewing a test with binocular vision.

b. Control group participants shall have 20/25 or better corrected (aids worn) visual acuity as defined by the World Health Organization (WHO) and have a visual acuity on The Lighthouse Near Acuity Chart ranging from .5M or better (20/20 to 20/25). These participants shall come from all supporting clinics.

c. Low vision participants shall have a resolution eye problem (anterior or posterior segment disorder); a mild, moderate, or severe visual acuity as defined by WHO; a functional vision loss of 20/60 or worse while being rehabilitative in near visual acuity; and a visual acuity on The Lighthouse Near Acuity Chart ranging from 1M (20/50) to 4M (20/200). These participants shall come from all supporting clinics. Participants with macular disease shall have a central field loss of not greater than five degrees (scotoma).

d. Data collection notes (considers all **152** participants who have successfully completed all aspects of the WebText study since May, 1999):

Thirty–five people have multiple eye problems that have not been classified into any segment; although, most of these participants appear to have posterior segment eye problems. Doctors in the supporting clinics for these participants are currently being contacted for assistance in the detailed classification of these cases.

Sixteen participants are being excluded from the study as they are over 65 years of age (see item “b” above). If these participants shall be included in the study at a later date, the grouping breakdown will be as follows: (a) mild = 7, (b) moderate = 8, and (c) severe = 1. It is also expected that these participants could be added to the Resolution (primary) categories.

Five people may be excluded from the study as they have dominant monocular vision characteristics are expected to be classified as posterior segment participants. If these individuals shall be excluded from the study at a later date, the grouping breakdown will be as follows: (a) mild decreases by 1, (b) moderate decreases by 3, and (c) severe decreases by 1.

One participant is being excluded due to her or his close connection with the development of the study. If this participant shall be included in the study at a later date, this change would be an addition to the control group.

Two participants remain unclassified due to impending information on clinical diagnosis.

Ten participants have successfully participated in the study and have mismatches with the eye problems under investigation.

e. All participants shall be 18 years of age and older, volunteers for the study, binocular in their corrected visual acuity, classified by a code in the ICD–9–CM codebook (Codes for Optometry, Part Two: Diagnostic Codes (Abridged for Eye Care, 1998 edition), a functional literacy level as determined by the optometrist, and capable of viewing and responding to a 10 to 20–minute electronic test.

f. In general ophthalmology practice, uncorrected visual acuity is measured without aids (e.g., glasses, contact lenses, etc.). However, Vaughan et al., (1995) note that poor uncorrected distance acuity may also be due to refractive (i.e., focusing) errors and indicates that corrected visual acuity is a better assessment of eye health.

g. **Resolution groups** for the **anterior segment** shall have two subcategories: (a) Resolution—Primary and (b) Resolution—Secondary. Within the primary resolution group, participants with the following eye problems will be considered: cornea, anterior chamber, iris, lens, hereditary corneal dystrophy, aniridia, and cataract. Within the secondary resolution group, participants with congenital or acquired problems will be considered: amblyopia (non–pathological) due to strabismus or adverse refractive error), nystagmus (primary etiology), pathological myopia, and traumatic changes.

h. **Resolution groups** for the **posterior segment** shall have two subcategories: (a) Resolution —Primary and (b) Resolution—Secondary. Within the primary resolution group, participants with retinal problems will be considered: central scotomas, cone dystrophies, diabetic retinopathy, macular diseases (includes macular degeneration), and retinal edema. Within the secondary resolution group, participants with congenital or acquired problems will be considered: albinism, color deficiencies, glaucoma, retinitis pigmentosa, retinal edema, and traumatic changes.

i. See data collection notes under item “b” above.

Control group participants (80 volunteers with no vision loss) shall have 20/25 or better corrected (aids worn)[1] visual acuity as defined by the World Health Organization (WHO) and have a visual acuity on The Lighthouse Near Acuity Chart ranging from .5 M (20/25) or better to .8 M (20/40). The participants shall come from ophthalmology and optometry clinics in a large southern metropolitan area.

Low vision participants (240 volunteers with mild, moderate, and severe vision loss) shall have a resolution eye problem (anterior or posterior segment disorder); a mild, moderate, or severe visual acuity as defined by WHO; a functional vision loss of 20/60 or worse while being rehabilitative in near visual acuity; and a visual acuity on The Lighthouse Near Acuity Test ranging from 1 M (20/50) to 4 M (20/200). These participants shall come from ophthalmology and optometry clinics in a large southern metropolitan area. Participants with scotomas shall have a central field loss of not greater than five degrees (scotoma).

The number of participants for each category in the statistical design model will be based upon the number of dependent variables in the study. Experiential work denotes that one should estimate five people per dependent variable. The five dependent variables for the WebText study are the following: (a) text color, (b) background color, (c) size, (d) serif quality (serif or sans serif), (e) typeface quality (Roman or italic).

The low vision groups will be divided into two major categories: (a) anterior segment and (b) posterior segment, adult onset). These groups can then be further divided into two smaller categories each (See detailed footnotes in Table 1).

4. Method of Participant Selection:

Participants will be recruited from Drs. Stephen Scoper's and Peter Netland's clinics during their regularly–scheduled clinic appointments.

5. Study Sites:

The following clinics will be used as study sites:

- The University of Tennessee, Memphis, Dr. Stephen Scoper, M.D.
  756 Ridge Lake Blvd.
  Ste. 206
  Memphis, TN 38120

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1. In general ophthalmology practice, uncorrected visual acuity is measured without aids (e.g., glasses, contact lenses, etc.). However, Vaughan et al. (1995) note that poor, uncorrected distance acuity may also be due to refractive (i.e., focusing) errors and indicates that corrected visual acuity is a better assessment of eye health.

- The University of Tennessee, Memphis, Dr. Peter Netland, M.D.
  756 Ridge Lake Blvd.
  Ste. 206
  Memphis, TN 38120

- Charles Retina Institute, Dr. Mohammed Rafieetary
  6401 Poplar Ave.
  Memphis, TN 38119
  (901) 767–4499

- Southern College of Optometry, Dr. Tressa Eubank, Chief of Low Vision Clinic
  1245 Madison Ave.
  Memphis, TN 38104–2222
  (901) 722–3276

6. Methods and Procedures Applied to Human Subjects:

The WebText Study will be implemented in conjunction with the participant's regular ophthalmology office visit, allowing a data collection duration of four weeks for both clinics in **September and October, 1999**.

Participants will come from four large clinics that serve a large metropolitan community as described on pages 11 and 12. Initially, participants will be given informed consent forms for voluntary human subject release for each participating clinic. They will be informed that the study will last 10 to 20 minutes. Next, authentic Lighthouse Near Acuity Test scores of the participants will be gathered by a designated recorder under the supervision of an ophthalmology professional. The WebText study will be implemented after the Lighthouse Near Acuity Test (see attachments).

Individuals will receive a "thank–you" token (e.g., coffee mug, 20/20 pens, acetate overlays, or bold line paper) for their participation. Participants will receive no direct benefit from their involvement in this research; however, they may have some satisfaction in that they will have stated some opinion about text preferences for the study, which may be used by product developers to address universal access issues relating to display of on–screen text for web delivery. Others will benefit by having guidelines available regarding text legibility for on–screen materials.

Participant Training and Testing

Initially, participants will be given an introduction to the WebText study in which they will learn about the study's purpose, provide their informed consent for participation. Each indi-

vidual will agree to participate in both the in–clinic procedures and the WebText evaluations.

Procedure for the Clinical Evaluations

The first step in the clinical evaluation procedure will be to collect the participant demographic information and informed consent. On the day of the study, information will be gathered for the following: (a) visual acuity information at 40 cm for best corrected near and distance Snellen and Jaegar standard scores, (b) binocular acuity scores, (c) anterior and posterior segment classifications, (d) central vision loss: no loss, mild, moderate, and severe, and (e) The Lighthouse Near Acuity Test score in print size in meters (m) at 40 cm.

The clinical evaluations for each low vision case will be conducted by ophthalmology professionals specializing in resolution eye problems relating to either the anterior or posterior segment. Visual acuity testing will be done in conjunction with an appointment that the individual has with the eye specialist and will use The Lighthouse Near Acuity Test as recommended in the vision literature (Mehr & Freid, 1976). Levels of visual impairment will be mapped to World Health Organization Levels of Visual Impairment as it is a published standard used by the American Optometric Association (1998).

Procedure for the WebText Evaluations

Two procedural questions will provide guidance for the testing structure of this study:

- What kinds of background (e.g., white, Netscape neutral grey, or black) and text color (e.g., black on white (standard video), black on grey (neutral video), white on black (reverse video) contrast do low vision readers with resolution problems prefer for web documents?
- What font size (e.g., 8–point, 12–point, 16–point, 24–point or 36–point) is easiest to read for low vision readers with resolution problems for web documents?

These questions are based upon empirical studies provided in the literature. (See Works Cited for more information.)

Environmental Conditions and Platform

Illumination. This study uses a normal reading situation and standard illumination as provided by the clinics. Before the study begins, seven illumination measurements (in footcandles) will be made for each clinic test room as they pertain to standard and custom lighting needs.

Computer Set–up. Participants will be seated at a distance of 16 inches from a 19–inch color Trinitron monitor (1024 by 768 pixels with 18–inch viewable area) using True Color (24–bit) display and running Microsoft Windows NT Workstation 4.0 operating system on a standard Dell personal computer (450 mHz Pentium II processor with 128 mBytes RAM). On–screen displays for the tests will run remotely under Netscape Communicator™ version 4.5. The computer monitor will be set at a common brightness and contrast setting for all participants as there are no universally–accepted standards for contrast and glare sensitivity testing and glare disability testing (Physician's Desk Reference, 1999).

Near Reading Task and Visibility Definition. On the day of the study, the recorder will make four computer screen measurements for the near distance task at 16 inches: (a) start–up (before evaluations begin), (b) before the typesize test, (c) before the typeface test, (d) end of the typeface test. Exceptions in the 16–inch measure will be granted to those expressing a visibility problem at 16 inches. A visibility problem will be defined as "a need to move closer or farther from the screen to comfortably read the text." In these custom cases, measures will be taken at those custom, preferred reading distances. These measurements are essential if one is to report meaningful information about the study (Physician's Desk Reference, 1999; Williams, 1998).

7. Potential Risks to the Participant

There are no forseeable risks to participants as this work is a non–invasive study. The WebText Study does not employ any experimental manipulation of the participants. An abstract of the research plan and a description of the procedure are given herein. Example screens of the electronic test are given as an attachment to this document.

8. Protection Against Risks

The exclusion criteria in this investigational plan is based upon the ophthalmology professional's knowledge of the individual case as determined by the case history. Strict adherence to the protocol will minimize any risks associated with this study. Investigators are professionally and clinically trained to conduct this work. Legal procedures such as Institutional Review Board processes are being followed for the protection of participants and researchers involved in this work.

9. Potential Benefits to the Participant

Participants receive no direct benefit from their involvement in this research; however, they may have some satisfaction in that they will have stated some opinion about their text preferences for the study, which may be used by product developers to address universal access issues relating to display of on–screen text for web delivery.

10. Potential Benefits to Society

There may be an overall benefit to society if better electronic text can be developed for all readers.

11. Risk/Benefit Assessment

There are no forseeable risks associated with this work; there are potential benefits to both participants and society as described in items 9 and 10 above.

12. Therapeutic Alternatives

There are no therapeutic alternatives associated with this work.

13. Confidentiality

All research records will be maintained and secured by the instructional design researcher off–site. Data with participant identifiers will be released to the investigators of this work upon request:

- Gloria A. Reece, Doctoral Candidate, The University of Memphis
  3505 Patricia Ellen Dr.
  Bartlett, TN 38133
  (901) 325–0139 (Pager)
  (901) 388–3453 (Home and Messages)

- Dr. Stephen Scoper, The University of Tennessee, Memphis
  756 Ridge Lake Blvd.
  Ste. 206
  Memphis, TN 38120

- Dr. Peter Netland, The University of Tennessee, Memphis
  756 Ridge Lake Blvd.
  Ste. 206
  Memphis, TN 38120

- Dr. Mohammed Rafieetary, The Charles Retina Institute
  6401 Poplar Ave.
  Memphis, TN 38119
  (901) 767–4499

- Dr. Tressa Eubank, Southern College of Optometry
  1245 Madison Ave.
  Memphis, TN 38104–2222
  (901) 722–3276

- The University of Memphis Institutional Review Board
  The University of Memphis
  Dr. Herbert Gould, IRB Chairman
  Memphis, TN 38152

- The Southern College of Optometry Institutional Review Board
  Southern College of Optometry
  Dr. Scott Steinman, IRB Chairman
  Memphis, TN 38104–2222

- The University of Tennessee, Memphis Institutional Review Board
  Dr. Clair E. Cox, IRB Chairman
  (901) 448–4824

The results of this research may be published in society journals and conferences; however, the published documents will not include the participant's name or any other identifying information.

14. Payment for Participation

There will be no payment for participation in this study.

15. Financial Obligations

There will be no additional costs incurred by the participant. The WebText study will be provided by the instructional design researcher at no cost to the patient.

16. Research Injuries

Any research–related injury will be treated by Dr. Steven Scoper. Study participants will have access to a 24–hour phone number to contact Dr. Scoper: (901) 761–4557

17. Informed Consent

Proper informed consent will be obtained by the primary investigator, Gloria A. Reece.

Informed Consent for The WebText Study at the University of Tennesee–Memphis

Principal Investigator: Gloria A. Reece, Doctoral Candidate
Secondary Investigator: Stephen V. Scoper, M.D.
Institution: The University of Tennessee, Memphis
Department of Ophthalmology
956 Court Avenue, Suite D–228
Memphis, TN 38163

Instructional Design Sponsor: The University of Memphis
College of Education (COE)
Department of Instruction Curriculum Leadership
Instructional Design and Technology Group
Memphis, TN 38152

Introduction

You're being asked to take part in a research study about text contrast for display on computers. The purpose of this study is to identify types of print for computer screens that are easier to read for persons with vision problems. (Individuals with partial sight may have difficulty reading newsprint with ordinary eyeglasses or contact lenses.) It is expected that your responses will help researchers address gaps in text legibility and vision literature and provide information to software designers regarding preferences for text legibility qualities that this work examines. This study will obtain your opinions about how easily text can be read on the computer.

The total number of participants to be enrolled from UT–Memphis is **188** of 320 total study participants. Of these 188, **158** will be reduced vision participants. Additionally, **30** people with **no vision loss** will also be needed. The clinics are located at this address: 756 Ridge Lake Blvd., Ste. 206, Memphis, TN 38120.

The study will last about 10 to 20 minutes and be held during an appointment that you have with Gloria Reece at The University of Tennessee Medical Group during **September and October, 1999.**

Procedure

The first task that you'll complete before the study begins is to give the recorder your permission to conduct the study. You'll be asked to sign an informed consent document that is required by the clinics and academic institutions that are associated with this work.

During the WebText study, you'll be sitting in front of a computer. Initially, your near vision will be checked; you'll need to wear your vision aids for all of the near reading tasks

during the study. Additional acuity data (ocular history and Snellen distant acuity scores for right and left eyes) that will be needed for the study will be obtained from the routine clinic information in your medical chart.

Next, you'll be trained on how to respond to the typeface samples using two sample screens. You'll be shown how the questions will be stated, the types of responses that you'll be making, and the types of data that will be recorded. Your participation is voluntary and you'll be given an opportunity to decline further participation before the word pairs are displayed to you on–screen.

Last, you'll view 24 pairs of words, and identify the one that is easiest to read. You'll respond, "top" or "bottom" for each screen that you view.

Risks Associated with Participation

There are no foreseeable risks or discomforts anticipated in this research.

Benefits Associated with Participation

You may enjoy stating your preferences regarding types of print which may be used by product developers to address universal access issues relating to display of on–screen text for web delivery. Your opinions will provide information about how more effective choices can be made for displaying text on–screen, which may benefit society.

Confidentiality

All participant records will be confidential. Although the results of this work may be published in academic journals and other methods of publication, and presented at education meetings and lectures, you'll not be identified as a participant. In all publications, complete anonymity will be maintained and the publications will not mention your real name.

Investigators

The investigators, instructional design sponsor, and doctoral committee members for this work for the UT–Memphis clinics are the following:

Gloria A. Reece, Doctoral Candidate and Principle Investigator (all clinics)
The University of Memphis
College of Education
Memphis, TN 38152
(901) 325–0139 (Pager)

Stephen V. Scoper, M.D.
Secondary Investigator at The University of Tennessee, Memphis

Peter Netland, M.D., Ph.D.
The University of Tennessee, Memphis

Mohammed Rafieetary, OD, Charles Retina Institute

Tressa Eubank, OD
Secondary Investigator at Southern College of Optometry

Deborah L. Lowther, Ph.D.
Instructional Design Sponsor and Committee Chair
The University of Memphis
College of Education
Memphis, TN 38125

Doctoral Committee for Gloria A. Reece

The University of Memphis:

Marshall Jones, Ed.D.
Instructional Design and Technology

Linda Bol, Ph.D.
College of Education
Educational Psychology Research

Emily Thrush, Ph.D.
English Department

Each of the above–named investigators, the institutional review boards at The University of Memphis and The University of Tennessee, Memphis, the instructional design sponsor of the research (includes dissertation committee for Gloria A. Reece) will have access to confidential data which identifies the participant by name.

Compensation and Treatment for Injury

You understand that you are not waiving any legal rights or releasing The University of Tennessee, The University of Memphis, or their agents from liability or negligence. You understand that, in the event of physical injury resulting from research procedures, the University of Tennessee or The University of Memphis does not have funds budgeted for compensation either for lost wages or for medical treatment. Therefore, these universities do not provide for treatment or reimbursement of such injuries.

In the unlikely event of any injury as a result of this research effort, no reimbursement, compensation, or free medical care is offered by Gloria A. Reece, The University of Memphis, or The University of Tennessee, Memphis.

Questions

You understand that you may ask questions at any time during the observation. For questions relating to the specific design and management of the study, I may contact Gloria Reece (phone: (901) 388–3453 or via e–mail: g–reece@memphis.edu). For additional questions about the project, I may also contact Dr. Deborah L. Lowther of The University of Memphis, Memphis, TN 38152 (e–mail: lowther.deborah@coe.memphis.edu). For an explanation of or answers to questions regarding the research and the research subjects' rights, you may contact: Dr. Clair E. Cox, IRB Chairman, The University of Tennessee, Memphis. She may be reached at (901) 448–4824 during regular business hours.

In the event of a research–related injury, you may contact Dr. Stephen Scoper at his 24–hour number: (901) 761–4555.

Payment for Participation

There will be no payment for participation in this study.

Cost of Participation

There will be no additional costs incurred by your participation in this study. The WebText study will be provided by the instructional design researcher.

Voluntary Participation

Your decision to participate in the WebText study is completely voluntary. You're free to choose either to enter the research study or not to enter the study. There will not be any penalty or loss of benefits for you if you decide not to participate. You'll always be treated with the best level of medicare care available from your doctor.

Even after agreeing to take part in this research, you may withdraw from the study at any time. If you decide to withdraw from the study, there will be no penalty or loss of benefits for you.

Consent of Participant

I have read or have had read to me the description of the research study as outlined above. Gloria Reece has explained the study to me and has answered all of the questions that I have at this time. I have been told of the potential risks as well as possible benefits of the study.

I freely volunteer to participate in this study. I understand that I do not have to take part in this study and that my refusal to participate will involve no penalty or loss of rights to which I am entitled. I further understand that I am free to later withdraw my consent and discontinue participation in this study at any time. I understand that refusing to participate or later withdrawing from the study will not have an adverse affect on my medical care.

_____	_____
Signature of Participant	Date
_____	_____
Signature of Witness	Date
_____	_____
Signature of Principal Investigator	Date

APPENDIX C

Clinical Workup Sheet for WebText Study Participants

Vision Grouping Classification Record

Table C–1. Clinical Workup Sheet for WebText Participants

WebText ID No.:			
Date of Office Visit:			
Clinic: **UT–Memphis**	Chart No.:		
Participant Name:			
Address:			
City/State:			
Zip +4:			
Phone:	Day:		
	Evening:		
	Mobile/Pager:		
Internet:			
Date of Birth (mm/dd/yy):	Age in 1999:	Age at WT Study:	**Gender:** M F
Ocular History (OHX): (Omit clinical procedures/ surgeries.)	Ocular History (ICD–9 Code Description/Number)		
Both Eyes (OU)			
Right Eye (OD)			
Left Eye (OS)			

Table C–1. Clinical Workup Sheet for WebText Participants

Snellen Monocular Acuity on Day of Office Visit (Technician Data):	CC	SC	
Right Eye (OD)			
Left Eye (OS)			
Snellen Monocular Acuity on Day of Office Visit (Technician Data):	CC	SC	
Right Eye (OD)			
Left Eye (OS)			
Lighthouse Near Acuity on Day of Office Visit (Technician Data)	Right Eye (OD)	Left Eye (OS)	Both Eyes (OU)

Table C–2. Vision Grouping Classification
(Binocular Lighthouse Near Acuity Test Score Print Size in Meters (M notation) at 40 cm)

Group	Print Size in Meters (M Notation)	Snellen Distant Equivalent
Control Group (Acuity at 40 cm in cm):		
40/50	.5M	20/25
Low Vision Groups (Acuity at 40 cm in cm):		
40/80	.8M	20/40
40/100	1M	20/50
40/120	1.2M	20/60
40/160	1.6M	20/80
40/200	2M	20/100
40/250	2.5M	20/125
40/300	3M	20/150
40/400	4M	20/200
More than 40/400	More than 4M	Disregard

APPENDIX D

Scoring Matrix for WebText Test

Table D–1. First Computer Screen Measurement at 40 cm (16 inches) or Less

Observation Item **Observation Context:** "Does the individual have a natural tendency to move forward to improve focusing?"	Observation Score	
1. Is the individual able to read the screen at a distance of 40 cm? (If the observation is negative, go to item 2.)	❑ Yes	❑ No
2. If no, ask the person to lean forward until the text is readable. Make a custom measure and write it in the space on the right. (Go to step 3.)	Custom measure: Distance read in meters _____	
3. Ask the person to remain at their chosen distance for the remainder of the test.		

Table D–2. Scoring Matrix for Contrast Preference Test

Item (Please check one item for each of the two categories.)	Choice **Script:** "What color of background do you prefer for the text that you'll read on–screen?"	Observer Comments
Background and Text Color	❑ White background with black text	
	❑ Grey background with black text	
	❑ Black background with white text	
	❑ No response	

Table D–3. Second Computer Screen Measurement at 40 cm (16 inches) or Less

Observation Item **Observation Context:** "Does the individual have a natural tendency to move forward to improve focusing?"	Observation Score	
1. Is the individual able to read the screen at a distance of 40 cm? (If the observation is negative, go to item 2.)	❑ Yes	❑ No
2. If no, ask the person to lean forward until the text is readable. Make a custom measure and write it in the space on the right. (Go to step 3.)	Custom measure: Distance read in meters _____	
3. Ask the person to remain at their chosen distance for the remainder of the test.		

Table D–4. Scoring Matrix for Contrast Preference Test

Item (Please check one item for each of the two categories.)	Choice **Script:** "What is the smallest size that you can most comfortably read without eye strain?"	Observer Comments
Text Size	❑ 8 pt. (Row 1)	
	❑ 12 pt. (Row 2)	
	❑ 16 pt. (Row 3)	
	❑ 24 pt. (Row 4)	
	❑ 36 pt. (Row 5)	
	❑ No Response	

Table D–5. Third Computer Screen Measurement at 40 cm (16 inches) or Less

Observation Item **Observation Context:** "Does the individual have a natural tendency to move forward to improve focusing?"	Observation Score	
1. Is the individual able to read the screen at a distance of 40 cm? (If the observation is negative, go to item 2.)	❑ Yes	❑ No
2. If no, ask the person to lean forward until the text is readable. Make a custom measure and write it in the space on the right. (Go to step 3.)	Custom measure: Distance read in meters _____	
3. Ask the person to remain at their chosen distance for the remainder of the test.		

Table D–6. Scoring Matrix for Typeface Preference Test (Sheet 1 of 3)

Screen No.	Word Pair and Instruction **Script:** "Which word is easiest for you to read—the one on the top or the bottom?"	Observer Comments
1.	hero hero	
2.	glitter glitter	
3.	receive receive	
4.	island island	
5.	treasure treasure	
6.	journey journey	
7.	language language	
8.	apple apple	
9.	beyond beyond	

Table D–6. Scoring Matrix for Typeface Preference Test (Continued) (Sheet 2 of 3)

Screen No.	Word Pair and Instruction **Script:** "Which word is easiest for you to read—the one on the top or the bottom?"	Observer Comments
10.	because because	
11.	teacher teacher	
12.	over over	
13.	nervous nervous	
14.	above above	
15.	silence silence	
16.	prairie prairie	
17.	after after	
18.	sister sister	

Table D–6. Scoring Matrix for Typeface Preference Test (Continued) (Sheet 3 of 3)

Screen No.	Word Pair and Instruction **Script:** "Which word is easiest for you to read—the one on the top or the bottom?"	Observer Comments
19.	about about	
20.	around around	
21.	winter winter	
22.	cabin cabin	
23.	open open	
24.	rooster rooster	

Table D–7. Fourth Computer Screen Measurement at 40 cm (16 inches) or Less

Observation Item **Observation Context:** "Does the individual have a natural tendency to move forward to improve focusing?"	Observation Score	
1. Is the individual able to read the screen at a distance of 40 cm? (If the observation is negative, go to item 2.)	❑ Yes	❑ No
2. If no, ask the person to lean forward until the text is readable. Make a custom measure and write it in the space on the right. (Go to step 3.)	Custom measure: Distance read in meters _____	

APPENDIX E

Screen Captures of Web Pages for the WebText Test

Figure E–1. Splash screen for WebText test

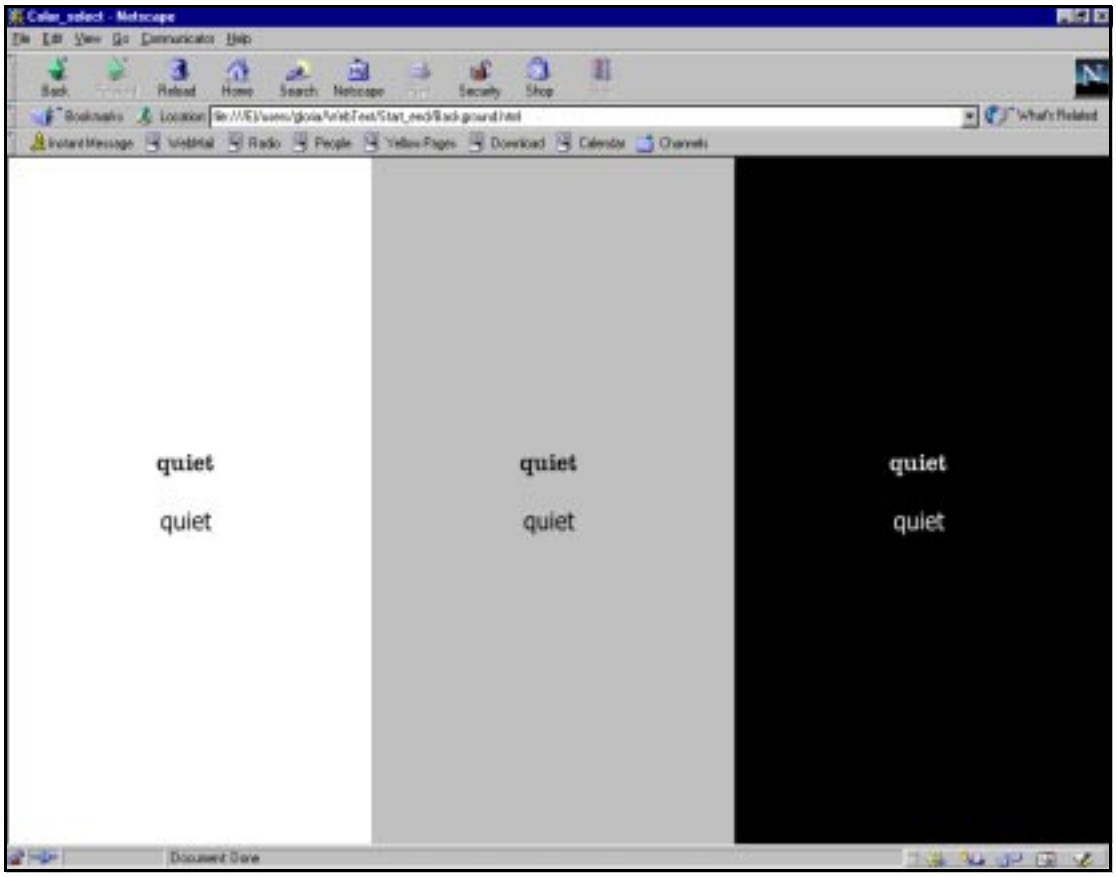

Figure E–2. Background color selection screen for WebText test

Figure E–3. Typesize selection screen on white background for WebText test

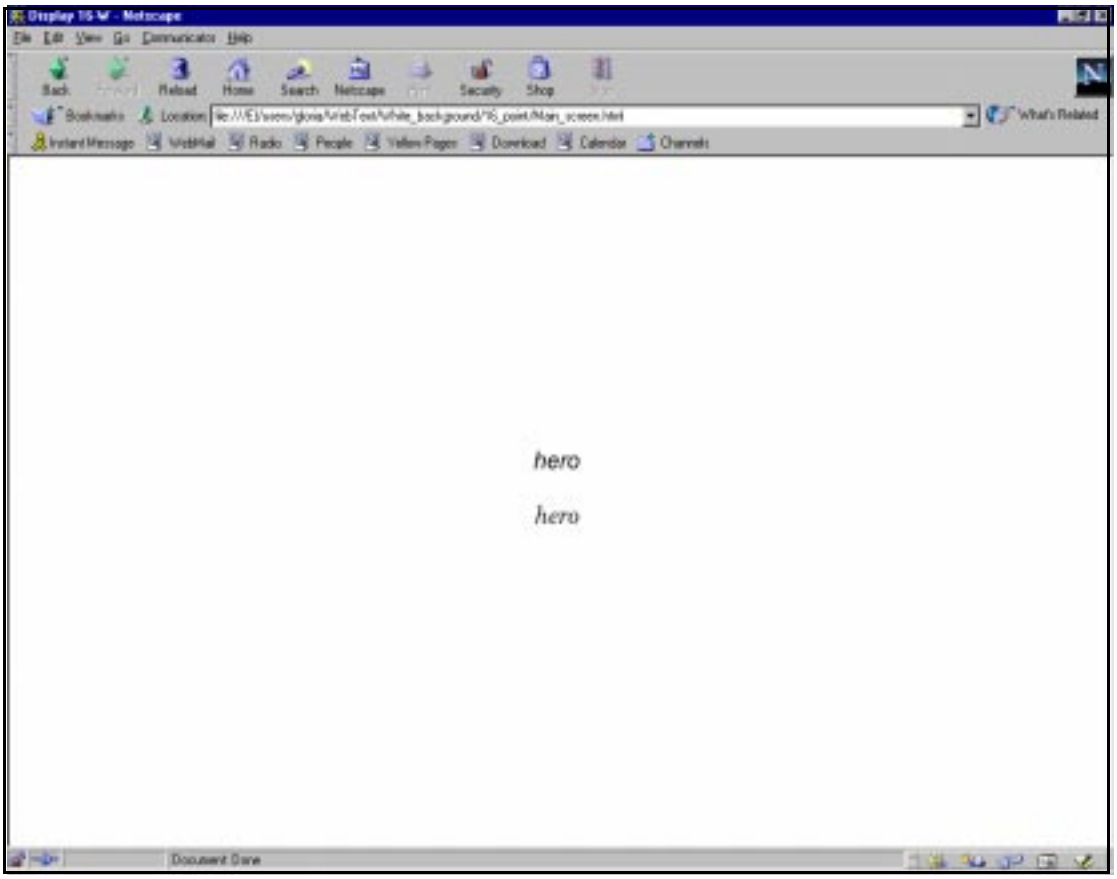

Figure E–4. Example screen using black text on white background

Figure E–5. Example screen for WebText test using white text on black background

Figure E–6. Example screen for WebText test using black text on grey background

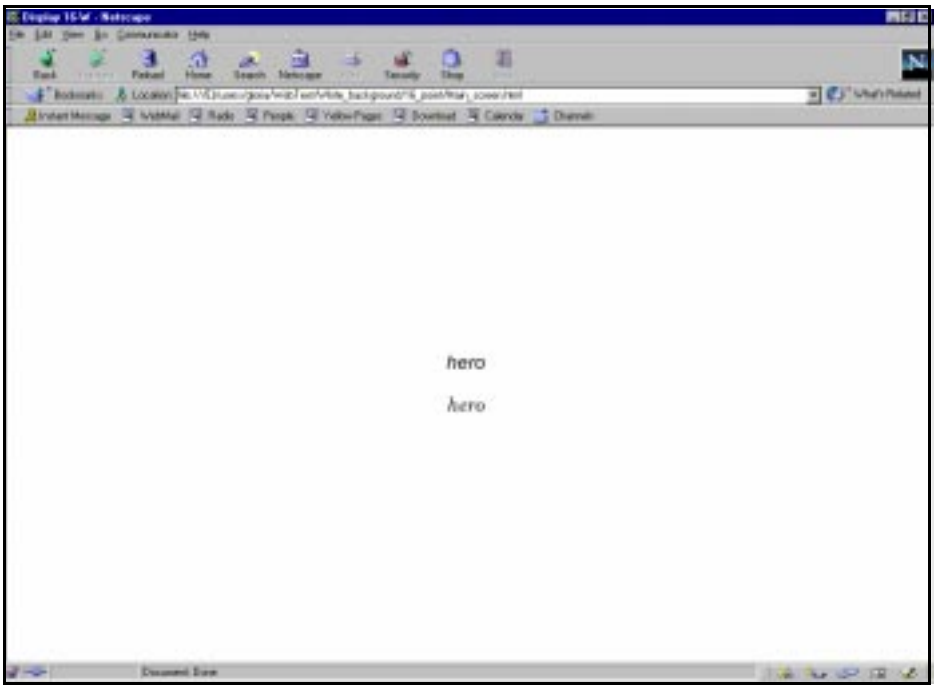

Figure E–7. Screens 1–2 for WebText test using black text on white background

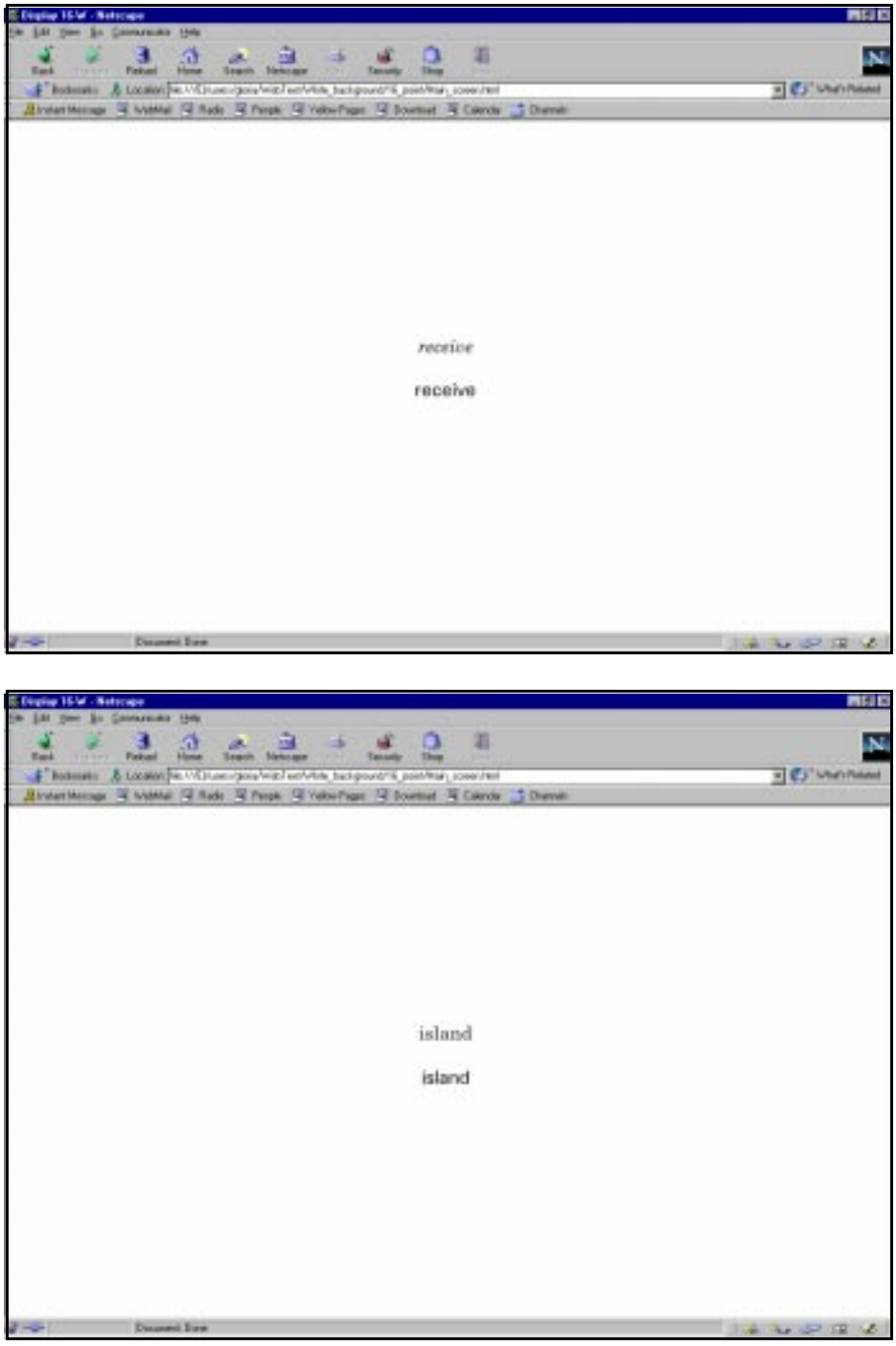

Figure E–8. Screens 3–4 for WebText test using black text on white background

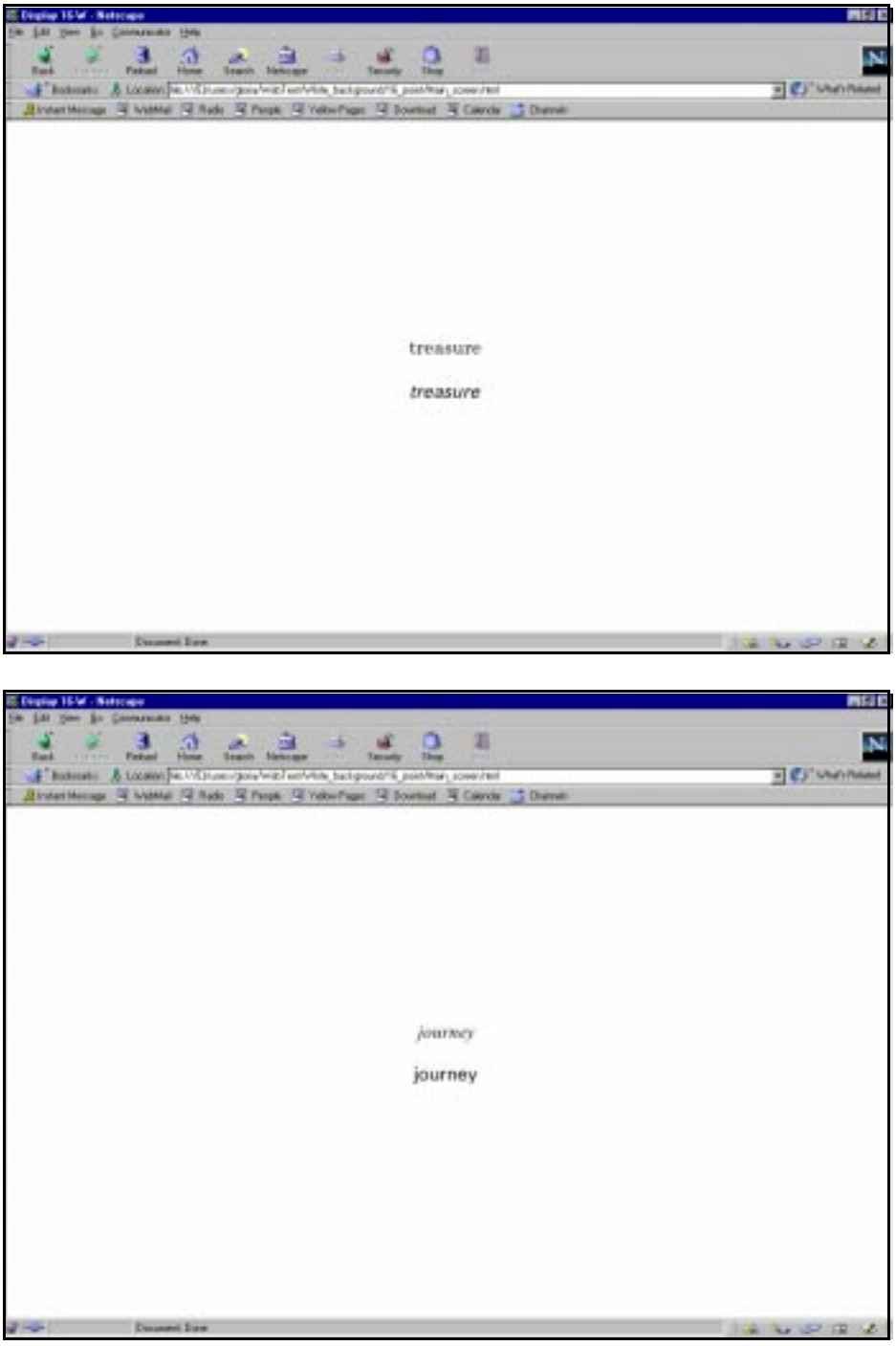

Figure E–9. Screens 5–6 for WebText test using black text on white background

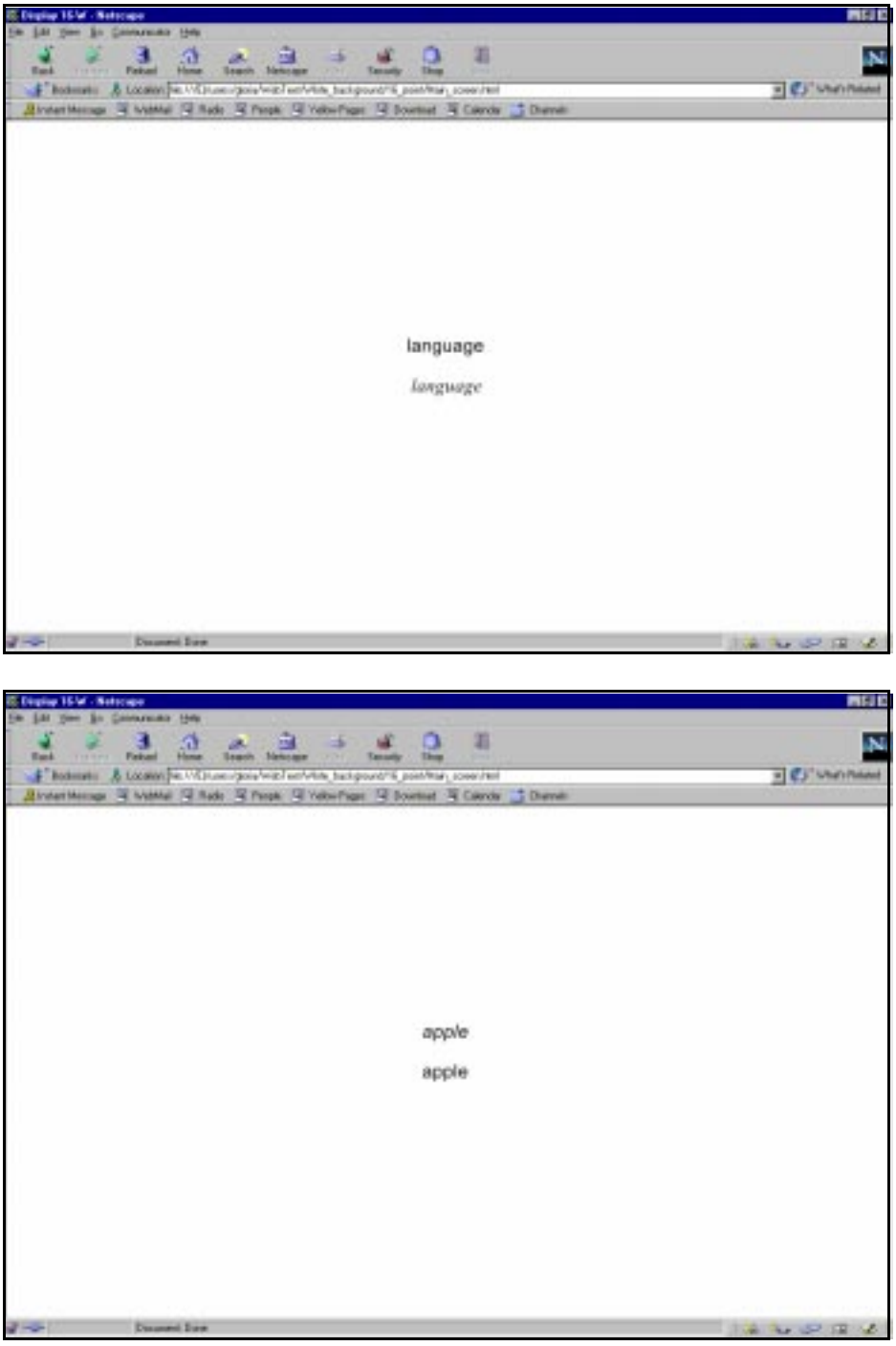

Figure E–10. Screens 6–7 for WebText test using black text on white background

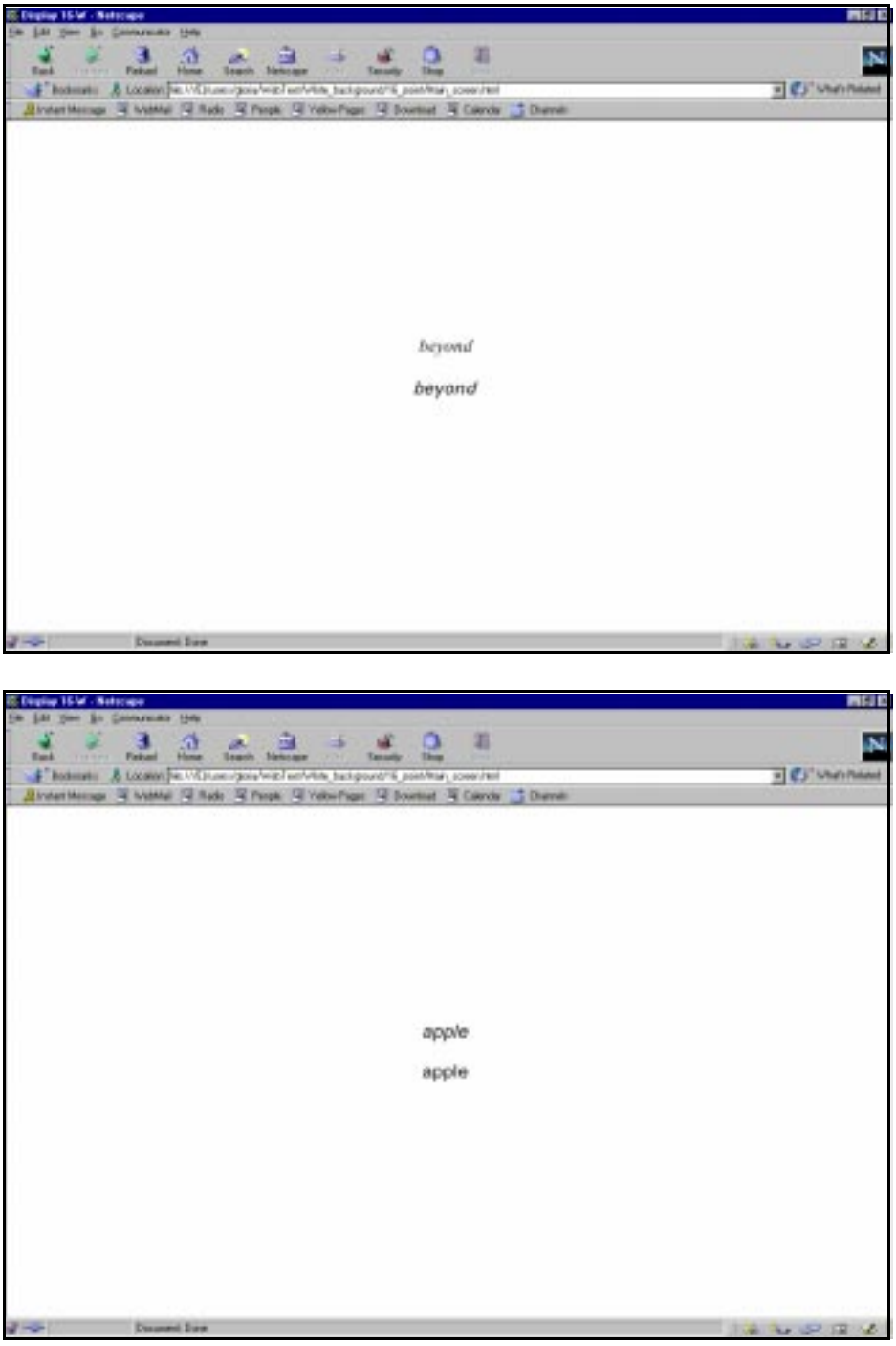

Figure E–11. Screens 7–8 for WebText test using black text on white background

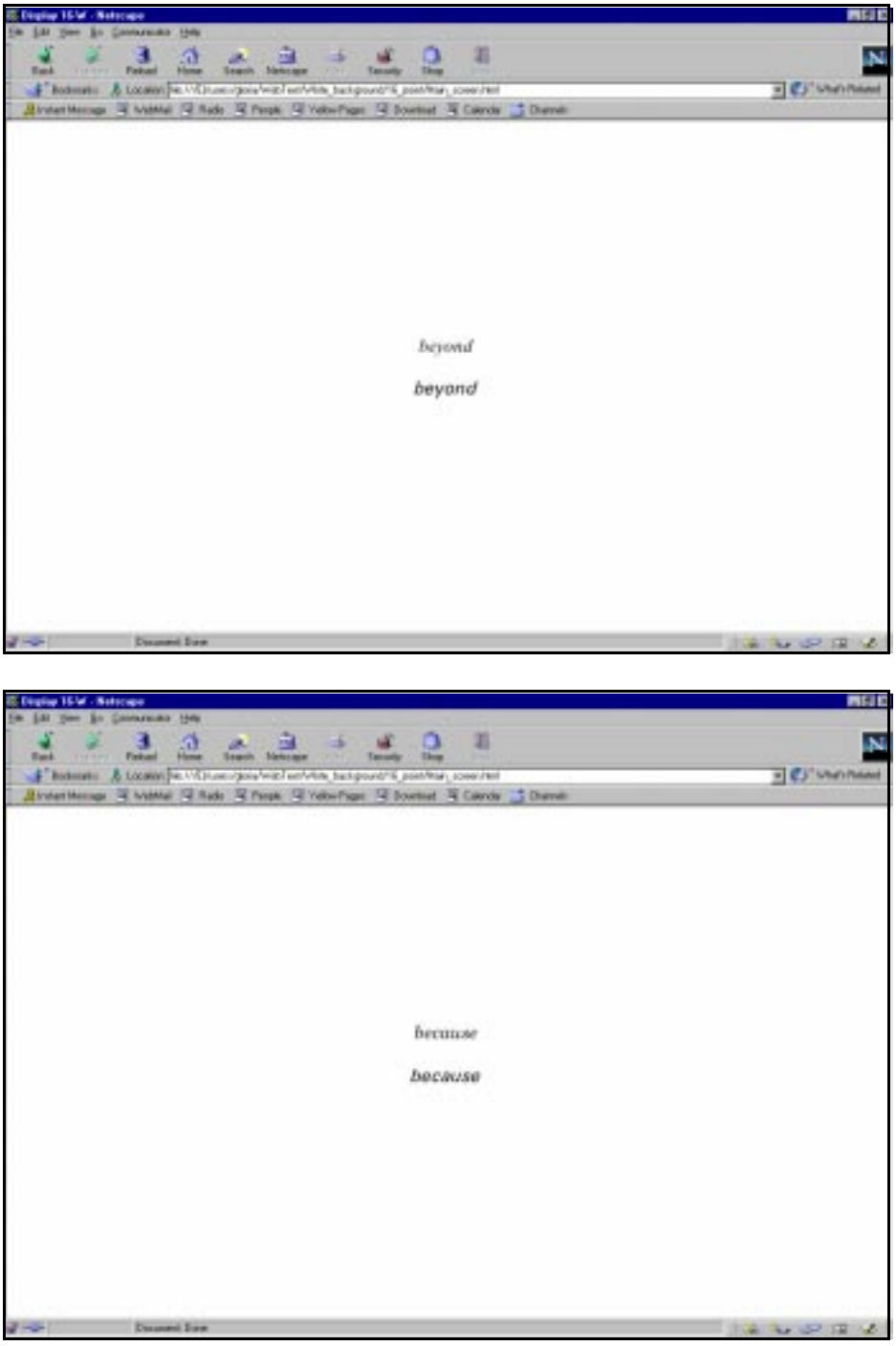

Figure E–12. Screens 9–10 for WebText test using black text on white background

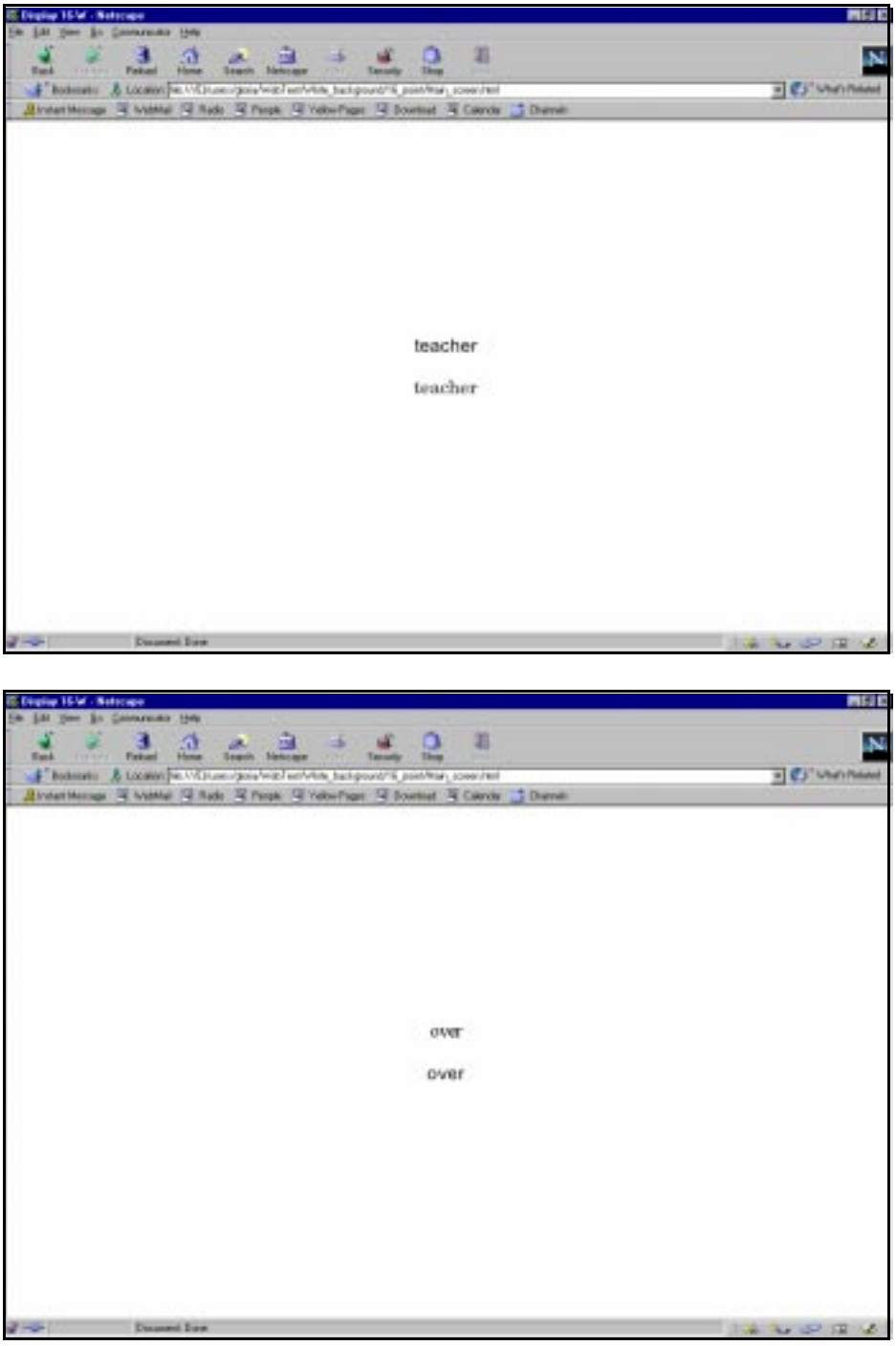

Figure E–13. Screens 11–12 for WebText test using black text on white background

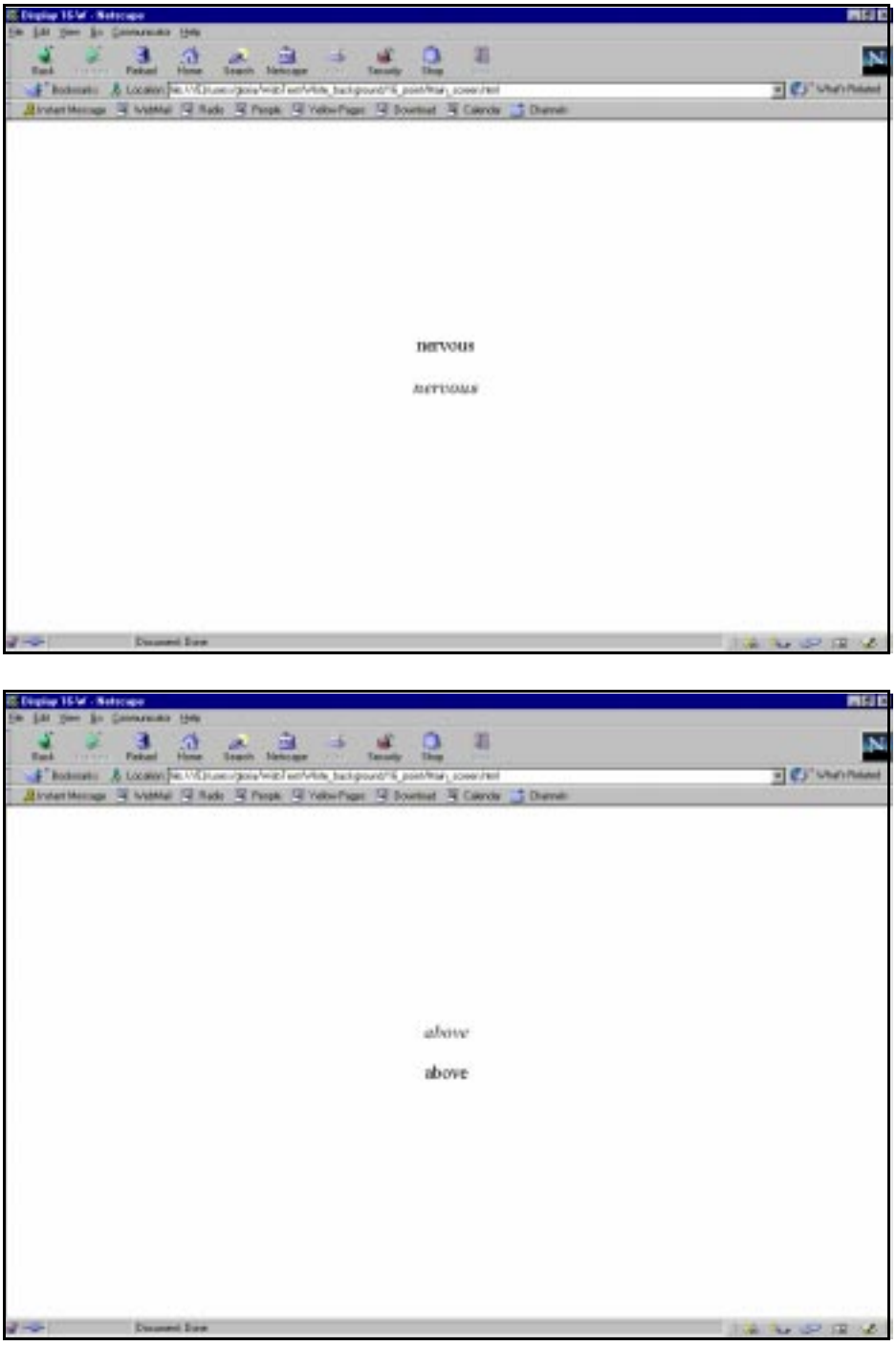

Figure E–14. Screens 13–14 for WebText test using black text on white background

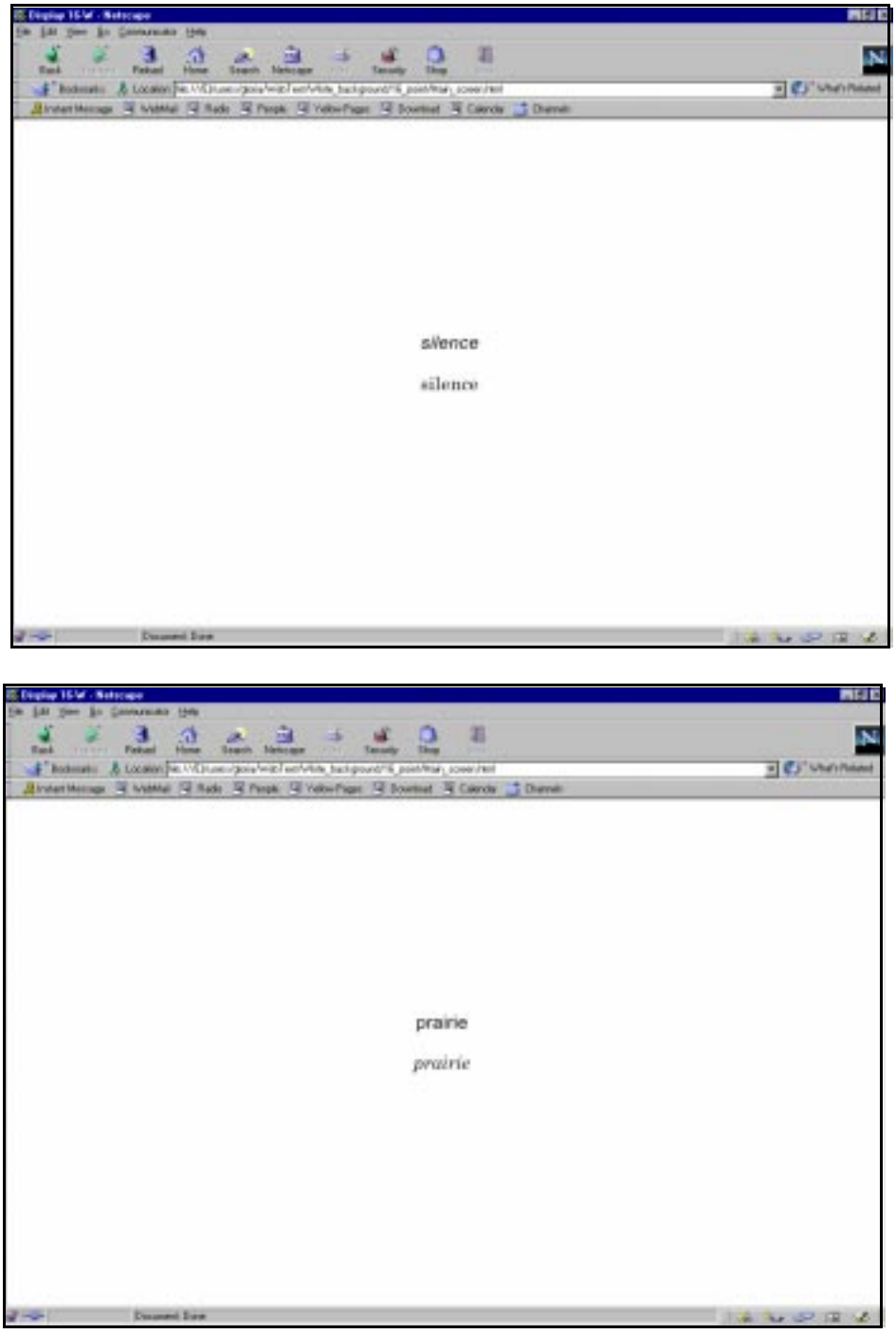

Figure E–15. Screens 15–16 for WebText test using black text on white background

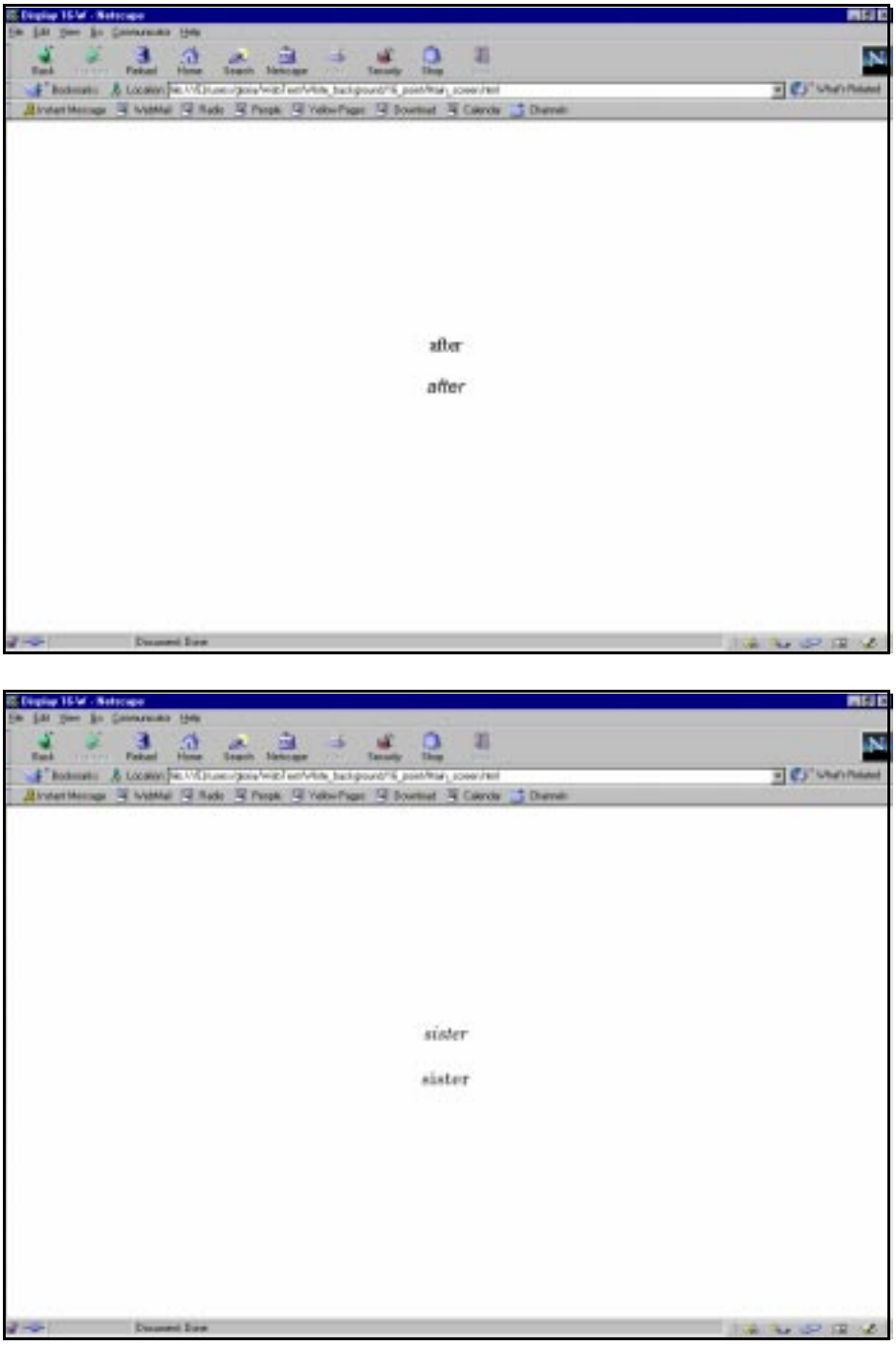

Figure E–16. Screens 17–18 for WebText test using black text on white background

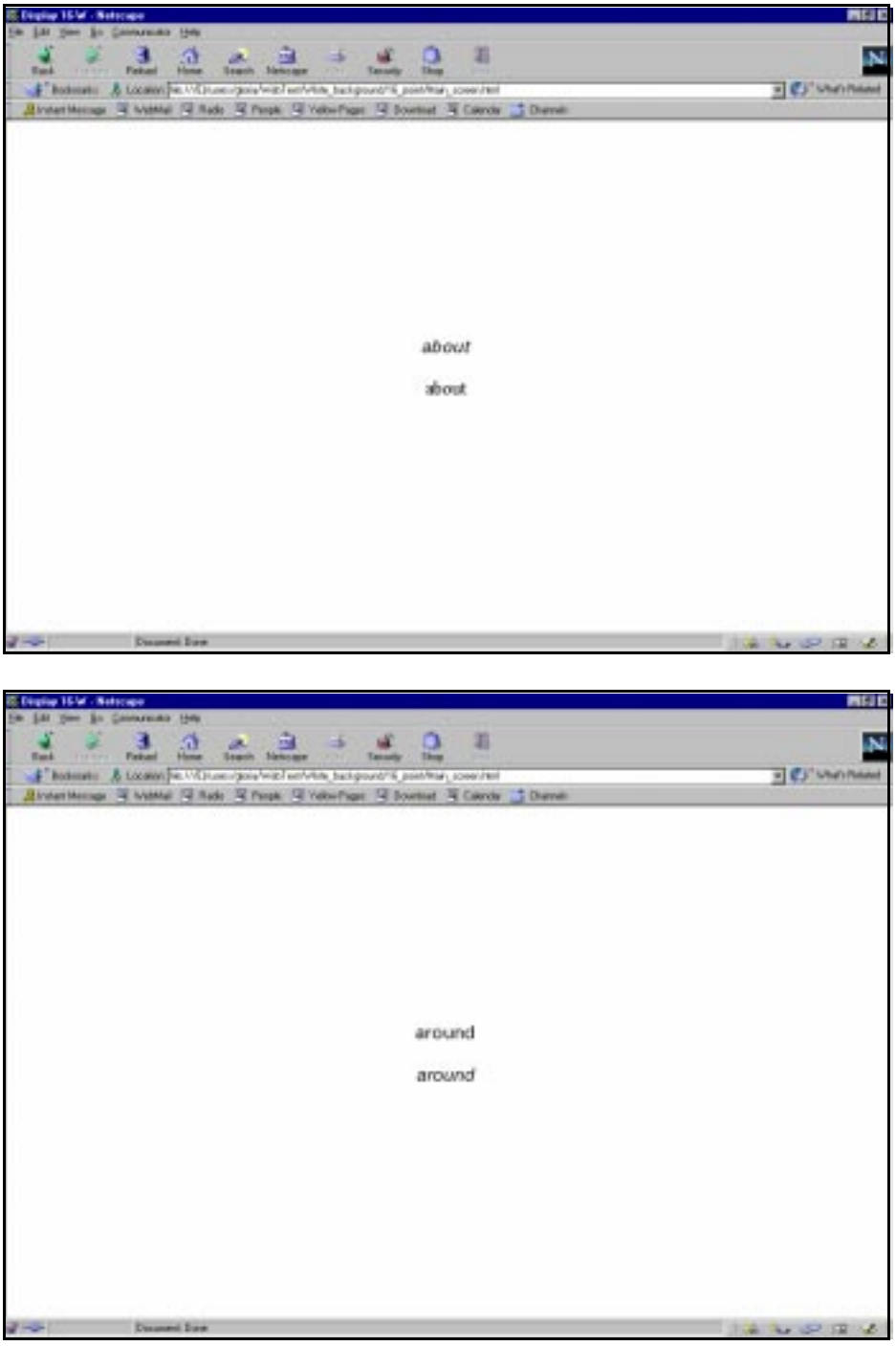

Figure E–17. Screens 19–20 for WebText test using black text on white background

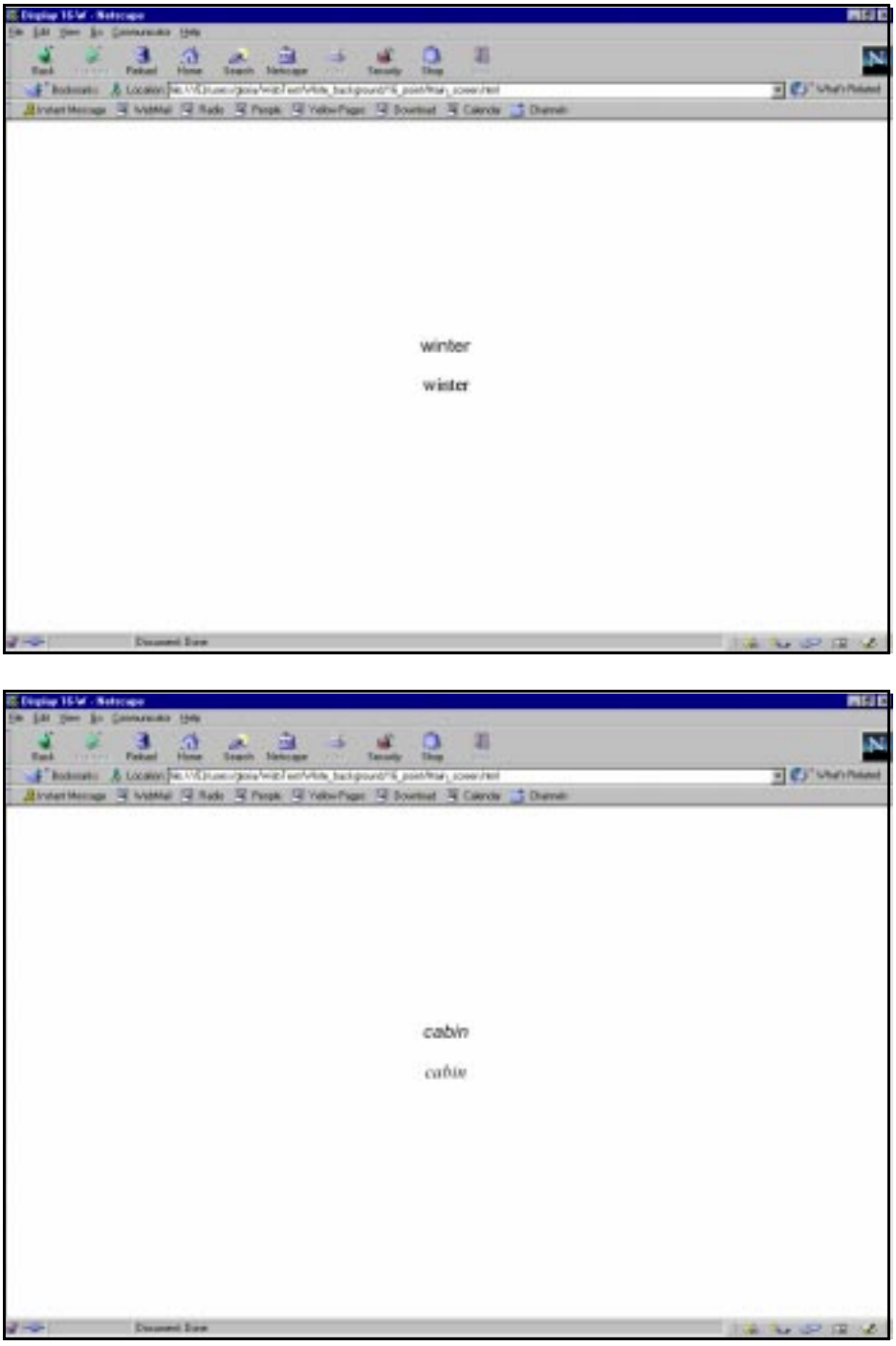

Figure E–18. Screens 21–22 for WebText test using black text on white background

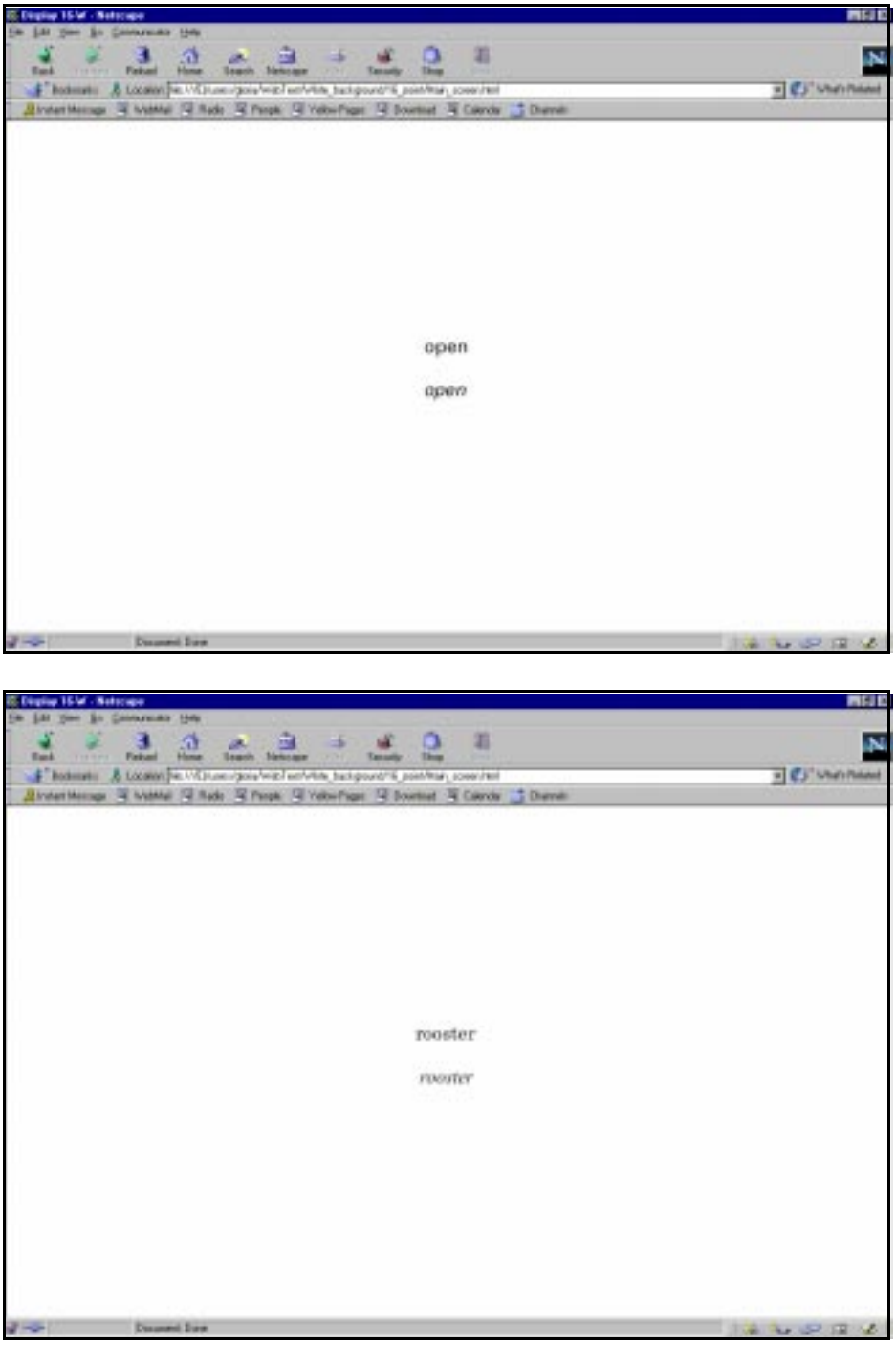

Figure E–19. Screens 23–24 for WebText test using black text on white background

Figure E–20. Closing screen for WebText test

Vita

Gloria Anne Reece was born in Dunn (Harnett County), NC and received her elementary and secondary education in Garner, NC. She received a Bachelor of Science degree in Business Communication from Florida Institute of Technology, Melbourne, FL in December, 1990; and a Master of Science degree in Technical and Professional Communication, also from Florida Institute of Technology, in December, 1994. She began work on the doctoral program in Instruction Curriculum Leadership, with a concentration in Instructional Design and Technology, at The University of Memphis, Memphis, TN in 1994. She served as an undergraduate and graduate laboratory assistant in The Department of Humanities at Florida Institute of Technology and as a graduate assistant in The College of Education and the Center for Academic Excellence (CAE) at The University of Memphis. After being admitted to doctoral candidacy, Gloria was awarded an Instructional Design and Technology Fellowship/Assistantship for 37 ICL 9000 research hours. Additionally, she has several years of professional experience in technical and professional communication positions at a variety of companies, including IBM Corporation, Research Triangle Park, NC; Northern Telecom, Inc. (later Nortel Inc.), Research Triangle Park, NC; Harris Corporation, Melbourne, FL; Federal Express Corporation, Memphis, TN; and Share One Inc., Memphis, TN. Most recently, she has provided consulting services in information systems to Kirby Optical, Memphis, TN.