The Legibility of Typefaces for Readers with Low Vision: A Research Review

Elizabeth Russell-Minda, Jeffrey W. Jutai, J. Graham Strong, Kent A. Campbell, Deborah Gold, Lisa Pretty, and Lesley Wilmot

Abstract: This article presents a systematic review of the research evidence on the effects of the characteristics of typefaces on the legibility of text for adult readers with low vision. The review revealed that research has not produced consistent findings and thus that there is a need to develop standards and guidelines that are informed by evidence.

Reading is critical to full participation in modern society, and as the population ages, the concern for the print accessibility of public documents will rise. For the many individuals with vision loss, reading print presents a major challenge when planning and performing everyday tasks. In Canada, the 2001 Participation and Activity Limitation Survey (PALS) reported that of the approximately 600,000 people with "seeing disabilities," most have low vision, and that roughly 500,000 people aged 15 and older require accommodations to read newsprint, such as special lighting, large print, or magnification (Statistics Canada, 2001). According to demographic information from the 2000 U.S. census, an estimated 937,000 Americans aged 40 and older were blind (U.S. definition) and 2.4 million had low vision in 2000. The leading causes of blindness and low vision in the United States in adults aged 40 and older were age-related macular degeneration (AMD), cataract, and glaucoma (Eye Diseases Prevalence Research Group, 2004).

The International Council of Ophthalmology's report, *Visual Standards: Aspects and Ranges of Vision Loss* (Colenbrander, 2002), recommended that the global vision community use the term *low vision* for degrees of vision loss less than blindness when individuals can be helped significantly by vision-enhancement aids and devices and that when detailed reporting on the ranges of vision loss are not feasible, the range for low vision should be less than 6/18 (0.3) (20/60) and greater than or equal to 3/60 (.05) (20/400). *Low vision* has also been described as the inability to read a newspaper or recognize faces from a conventional reading distance (40 centimeters, or about 16 inches) while wearing the best refractive correction (Chung, Mansfield, & Legge,

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1998). Many older people have difficulty reading standard print, including medication labels, even with appropriate magnification and illumination. High levels of magnification can reduce the size of the usable field for many individuals with low vision, and the manipulation of the characteristics of typefaces can reduce or eliminate the need for additional magnification (Arditi, 2004).

Previous research on the legibility of typefaces and psychophysical variables related to it has suggested that certain characteristics can affect legibility and reading acuity for both sighted readers and those with low vision (Arditi, 1996; Arditi, Knoblauch, and Grunwald, 1990; Legge, Rubin, and Luebker, 1987; Tinker, 1963). These characteristics include the presence or absence of serifs (Arditi & Cho, 2000, 2005); the width of strokes (Arditi, Cagnello, & Jacobs, 1995b; Berger, 1944a, 1944b); kerning or interletter spacing (Arditi et al., 1995a; Arditi, Liu, & Lynn, 1997; Moriarty & Scheiner, 1984; Whittaker, Rohrkaste, & Higgins, 1989); leading (the space between lines of text) (Tinker, 1963); point size (Legge, Rubin, Pelli, & Schleske, 1985); the height of letters (*x*-height, defined as the vertical measure of the lowercase "x" in any given font, and *t*-height, defined as the height of the bottom of the crossbar of the letter "t" in any given font) (Arditi, 2005); contrast (Rubin & Legge, 1989); and color (Legge & Rubin, 1986).

The legibility and readability of fonts have been studied by examining the individual characteristics of a font or differences among whole or unmodified fonts (Arditi et al., 1990; Mansfield, Legge, & Bane, 1996; Morris, Berry, Hargreaves, & Liarokapis, 1991). Research on the specific characteristics of fonts, such as stroke width or the use of serifs, requires the manipulation of individual parameters while keeping others constant. Alternatively, researching whole fonts may be easily done in practical application, but limits the generalizability to specific characteristics. When the characteristics of fonts are evaluated, the outcome may be contaminated because of the difficulty in knowing whether the reported differences in legibility are related to the size of the type, to different lighting conditions, or to fundamental differences in design.

One concept of the legibility of print specifies that the test material should be performed under "threshold seeing conditions," a psychophysical acuity measurement that defines a threshold value at which a majority of subject responses are accurate. Another concept is related to the performance of various typeface designs when they are presented at sizes that are well above the reader's threshold. One aspect to be considered may be simply which font design is the most appealing or comfortable to the reader, often described as "readability" (Arditi, 2005; Kitchel, 2002). A significant problem arises when one font design "A" is found to be more legible than another font design "B," but font "B" is found to be more readable than "A." The apparent contradiction may be explainable by the inconsistent use of terms. Other criteria that are used to determine the legibility of typefaces are reading speed and critical print size (Chung et al., 1998; Mansfield et al., 1996). The critical print size is the smallest print size at which individuals can read with their maximum reading speed. This is an important measure because it indicates the minimum magnification that is required for effortless reading.

With this overview of research and performance measures in mind, the primary objectives of this review were to locate any research related to the effective characteristics of typefaces for readers with low vision, to determine the existence of any standards or guidelines that are related to such legibility, and to address the characteristics of French-language typefaces for readers with low vision. The latter was considered because French uses a number of accent marks that are not used in English, and the typeface that is used may make these marks more distinct or less distinct, and Canada, the country in which this research was conducted, is officially a bilingual country. In addition, research related to the legibility of medication labels was considered.

By incorporating methods that are frequently used in systematic reviews, we rated and synthesized the selected literature to formulate conclusions and make recommendations. Although this review is not typical of other evidence-based reviews that have been used in clinical-trials research environments, we incorporated methods that have been used in systematic reviews by integrating specific protocols when searching for studies, developing targeted criteria for inclusion and exclusion, and using systematic methods for rating the quality of studies. The methods used in this review were consistent with previous work related to the Vision Rehabilitation Evidence-Based Review project; see the web site <www.piads.ca/112/vrebr.htm> for details on the parent project of this article.

Methods

Selection of studies

Literature searches were conducted on the following primary databases: the Cumulative Index to Nursing and Allied Health Literature; Evidence-Based Medicine Reviews, which includes the Cochrane Database of Systematic Reviews and the Cochrane Controlled Trials Register; EMBASE; MEDLINE-OVID; and PubMed. Searches of secondary databases and the "gray" literature were also conducted. Typically, *gray literature* is any type of unpublished research and may include governmental, business, or academic theses, bibliographies, conference papers or abstracts, technical reports, and standards or best-practice documents. The specific sources of gray literature that we searched for this review included unpublished and published governmental, business, technical, or academic reports, as well as standards or best-practices documents. To locate standards or guidelines on the legibility of text, we searched all potential sources. The keywords used were specific to visual impairment and the legibility and characteristics of typefaces. No limits were set on the year of publication.

The primary inclusion criterion for the selection of research was that the study should address issues related to the legibility and characteristics of typefaces for readers with low vision using any type of medium (printed materials or electronically displayed text). All types of low vision conditions were considered, including the most prevalent age-related ocular conditions that pose difficulties when reading print, such as AMD, cataract, diabetic retinopathy, and glaucoma. All types of study designs were considered: controlled and uncontrolled; experimental and nonexperimental; randomized controlled trials and nonrandomized controlled trials; meta-analyses of randomized controlled trials, published or unpublished; and systematic or standard literature reviews. Secondary inclusion criteria included any international guidelines or standards that have been established for the legibility of typefaces for those who are print disabled and considerations of French typefaces. Although extremely important for users with low vision, research related to factors that are associated with computer accessibility issues was excluded. The search parameters were limited to the following criteria: English language, with no specific limits on participants' ages or years of publication. The search was limited to literature in English and studies related to the characteristics of French-language type, and was search concluded in March 2006.

Abstracts were independently reviewed by two of the authors and rated by the study designs, based primarily on the organizational model proposed by the Canadian Task Force on the Periodic Health Examination (1979) and the Oxford Centre for Evidence-Based Medicine <www.cebm.net>: (I) randomized controlled trials, systematic reviews, or meta-analyses; (II) cohort and nonrandomized experimental studies; (III) case control studies; (IV) case series and descriptive studies; (V) experts' opinions without critical appraisal or based on physiology, bench results, or "first principles"; and (VI) "gray literature." We decided to include an additional level of evidence to accommodate gray literature sources. The studies we selected were primarily nonrandomized or experimental designs or unpublished reports (with or without controls), and further ratings with an instrument for assessing the quality of the studies were not performed. Meta-analyses or comparisons of effect sizes on the selected studies were not conducted because of the heterogeneity of interventions, outcomes, and study designs.

Results

Search results

We selected and reviewed 18 studies from a total of 184 that met the inclusion criteria and represent a wide array of research designs and methodologies (see Table 1). Comprehensive tables of the studies' attributes were created by extracting data from each study (this data is available by request from us). No randomized controlled trials were located. The excluded 166 studies failed to meet the primary and secondary inclusion criteria outlined in the Methods section. No evidence regarding the legibility of French typefaces was found. We located no definitive, evidence-informed literature on font-legibility standards or guidelines for low vision reading materials.

Choice of typeface and font size

In one of the few quantitative studies on the legibility of fonts and the reading performance of persons with low vision, Mansfield et al. (1996), using whole fonts printed on high-contrast charts, found a small, but significant, advantage of Courier over Times Roman in reading acuity, critical print size, and reading speed. Gains in reading speed were modest, and it is possible that for print sizes that are close to the acuity limit, the choice of typeface could make a significant difference in the reading performance of persons with low vision. Arditi (2004) found that modified fonts using prototype font-adjustment software (Font Tailor) enhanced legibility, on average, by more than 75%. The study did not demonstrate any advantage over standard fonts, such as Times New Roman.

Table 1
Selected studies.

Study	*N*	Methods	Results
(II) Arditi & Cho (2005)	4	■ 9 lower-case custom fonts varying in serif size (0%, 5%, and 10%). ■ RSVP and MNREAD corpus (computer monitor and paper). ■ Viewing distances at 788.4 centimeters (sighted), 106 and 58.4 centimeters (low vision).	The presence or absence of serifs made no difference in the reading speed of all the participants (sighted and low vision). A small observed effect of serif size was found in Experiment 1, using an acuity criterion of legibility. Because of the small effect size, there was no difference in legibility between serif or sans serif typefaces.
(II) Arditi (2004)	40	■ Font Tailor (prototype font adjustment software) and Times New Roman, 18 to 72 points. ■ Text viewed from 7 to 40 inches.	The participants produced a variety of distinct fonts with Font Tailor, resulting in enhanced legibility (the gain in legibility averaged 75%). No increases in legibility over and above standard fonts like Times New Roman were demonstrated.
(II) Arditi et al. (1990)	4	■ Times New Roman (modified, nominally 18 point). ■ Character size varied by altering the viewing distance, range 0.165 degrees to 1.3 degrees. ■ The participants had 20/20 or better visual acuity in both eyes (some with lens correction).	For small characters, fixed width (FW) produced the fastest reading, with modified variable width (MVW) yielding better performance than variable width (VW) spacing, indicating crowding effects. For medium and large characters (~0.25 degrees to 6 degrees height), the performance was best with VW, slowest with MVW, and intermediate with FW spacing. RSVP showed that higher text density was responsible for superiority at medium and large character sizes.
(II) Chung (2002)	6	■ Five modified letter spacings. ■ RSVP method. ■ Testing at the fovea, 5 degrees and 10 degrees in the inferior visual field. ■ Critical print size (CPS) measured for four print sizes using standard letter spacing. ■ Two print sizes tested at 0.8 and 1.5 times the CPS. ■ Viewing at 200, 40, and 30 centimeters. ■ Times Roman (unmodified; monitor). ■ RSVP method.	Increased letter spacing beyond the standard size, which presumably decreases the adverse effect of crowding, does not lead to an increase in reading speed in central or peripheral vision.
(II) Chung et al. (1998)	6	■ Eight print sizes in central vision and retinal eccentricities of 2.5, 5, 10, 15, and 20 degrees in the lower visual field. ■ Viewing at 200 centimeters and 120 centimeters for testing at the fovea and 2.5 degrees eccentricity, respectively.	Print size is not the limiting factor for maximum reading speed in peripheral vision. The participants were all sighted; the authors suggested extending the findings regarding the effects of print size on reading speed to people with low vision.
(II) Drummond et al. (2004)	180	■ The box for eyedrops in Arial font (unmodified), without magnification. ■ Near vision assessed with the usual reading prescription (eyeglasses).	The participants with best-corrected VA $\leq$ 6/24 showed a significantly diminished ability to read the instructions on eyedrops bottles ($p < .001$ for each comparison). The preferred Arial font point sizes were 16 for the 6/24 group, 18 for the 6/36 group, and 22 for the 6/60 group.

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Table 1
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Study	N	Methods	Results
(II) Estey et al. (1990)	52	■ Hospital pamphlets in 12- and 14-point Universe medium (a sans serif font) or 14-point Century Schoolbook (a serif font) typeface (unmodified fonts). ■ Blue, green, and black text.	65% of the patients admitted for cataract surgery found the Universe (sans serif) 14-point typeface the most legible, when reading samples of literature for patients. Black print on a white background was the preferred combination.
(II) Liu & Arditi (2001)	4	■ METAFONT. ■ Five-letter strings randomly drawn (Sloan letters, a color monitor, and high contrast). ■ Viewed at an optical distance of 10 meters. The letter height ranged from 3.44 to 4.23 arc minutes. ■ Letter confusions compared at wide (1.0 letter height) and narrow (0.1 letter height) interletter spacings. ■ Distance corrections worn ($n = 2$).	Increased random guessing and lateral interactions between features of neighboring letters can account for most of the deterioration in acuity observed under narrow-spacing conditions (using randomly drawn five-letter strings from the alphabet).
(II) Liu & Arditi (2000)	3	■ METAFONT. ■ Four- and five-letter strings (uppercase letters). ■ Letter height ranging from 1.0 to 1.44 centimeters, viewed at 10 meters. ■ Distance corrections worn.	When information about the length of letter strings was uncertain, there was a tendency to underestimate the lengths of small, closely packed letter strings. The participants tended to omit one of the interior letters or to combine two neighboring letters under such conditions.
(II) MacKeben (2000)	6	■ Arial bold (modified), frequently confused letter pairs. ■ Single letters (Sloan) displayed 8 degrees to the right of the fovea; 36 arc minutes letter height. ■ Target duration adjusted (66–133 minutes) for tasks near the threshold. ■ Binocular viewing at 91 centimeters. ■ The participants had correctable refractive errors.	O↔D and H↔N among the three most frequently confused letter pairs for five of the six participants. The most frequently confused letter pairs varied among the participants. The results indicated the possibility of enhancing eccentric viewing conditions by optimizing the design characteristics of the typeface.
(II) Mansfield et al. (1996)	92	■ Adobe Times Roman and Courier bold (unmodified). ■ High-contrast MNREAD acuity charts. ■ Print sizes, defined as x-height, ranged from 1.3 to 0.5 logMAR (at a viewing distance of 40 centimeters). ■ The participants wore their usual optical correction for reading.	Small, but significant, advantages for Courier over Times Roman in reading acuity, CPS, and reading speed for the participants with low vision. For the sighted participants, the differences are slighter, with an advantage in reading speed for Times. For print sizes close to the acuity limit, the choice of font could make a significant difference in reading performance.

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Study	*N*	Methods	Results
(II) Moriarty & Scheiner (1984)	260	■ Sales brochure text set in 11-point type with 1-point leading on a 25-pica line width, using Times Roman and Helvetica (unmodified).	Difference in mean words read between close-set type and mean words read set in regular type was significant for the effect of the close-set type. No difference in reading speed was found between the serif and sans serif typefaces. No significant effect was found on reading speed as a result of the interaction of letter spacing and typeface.
(II) Morris et al. (2002)	27	■ Modified Lucida (serif and sans serif). ■ RSVP method (monitor). ■ Text had x-heights of 40 and 160 pixels. ■ Viewed at 4 meters, retinal x-heights were about 4 and 16 points.	From the resulting confidence intervals, there was a performance advantage with the sans serif font. Results also suggest rendering serifs at small sizes may be counterproductive, and provide nothing toward sentence-based recognition with RSVP reading.
(II) Morris et al. (1991)	4	■ Modified 12- and 24-point fonts: "Times Pseudo Fixed Width," "Times No Side Bearings," Lucida Sans, Lucida Typewriter, and METAFONT (6 and 12 point; on a monitor).	Most typographic variation has little or no effect on reading rates for characters at typical reading sizes. Crowding effects due to inadequate spacing are significantly worse for poorly rasterized fonts than for well-rasterized ones.
(II) Smither & Braun (1994)	39 (Experiment 1) 34 (Experiment 2)	■ Courier, Century Schoolbook, and Helvetica (unmodified), bold and Roman weights, and 9, 12, and 14 points. ■ 18 medication bottles, and 18 hospital pharmacy labels (on a flat surface). ■ Corrective lenses worn.	When reading bottle labels, the older participants found Century Schoolbook in 12-point bold or Roman the most legible. For flat surfaces, Century Schoolbook and Helvetica, 12 or 14 point bold, were best. Courier 9 point was the most difficult to read.
(II) Yager et al. (1998)	46	■ Unmodified Dutch and Swiss at fixed x-height; two different luminance conditions. ■ RSVP (monitor); high contrast. ■ Reading distance 1 m: lowercase x-height, 8 micromilimeters, 2.75 arc minutes, ~5.5 times letter acuity with ETDRS chart.	Swiss letters were, on average, 3.3% wider than the Dutch. 16 out of 20 participants read the sans serif font Swiss more rapidly than the Dutch (serif font). RSVP reading speed affected in the low luminance condition for the two fonts.
(VI) Campbell et al. (2005)	398 (over two experiments)	■ Adsans (sans serif), Arial, Clearview (sans serif), Lucida, Times Roman, and Verdana (all unmodified). ■ The participants could use their optical devices (magnifiers). ■ 16-point font printed on paper and over-the-counter drug inserts printed in 7-point.	The results from Phase 1 indicated that Adsans was the most preferred font and Times Roman the least preferred. For Phase 2, Adsans was also the most preferred font.

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Study	*N*	Methods	Results
(VI) Perera (2001)	308 (total over 5 experiments)	■ Tiresias, Times, and Arial, 16 point (whole and modified). ■ Text samples from a large-print book on paper.	The participants found Tiresias more legible than Times or Arial and preferred the sans serif typeface. Most preferred enlarged spacing, and legibility increased as the weight (bold) increased. A "rounded" punctuation shape and normal (versus enlarged) spacing were preferred.

I = randomized controlled trials, systematic reviews, or meta-analyses; II = cohort studies or non-randomized studies with a control; III = case control studies; IV = case series and descriptive studies; V = expert opinion without critical appraisal or based on physiology, bench results, or "first principles"; and VI = unpublished gray literature.

Yager, Aquilante, and Plass (1998) found that 16 out of 20 sighted participants could read an unmodified Swiss (sans serif) font more rapidly than an unmodified serifed Dutch typeface, displayed on a monitor with high contrast. The lower-case *x*-height of the fonts was approximately 5.5 times as large as the letter acuity, and the acuity reserve for Swiss was higher than for Dutch viewed in low luminance conditions, which may have accounted for the difference in reading speeds. The study also found that letters with a uniform stroke width appear to be more legible.

Chung et al. (1998) measured the effect of print size on the reading speed of persons with typical peripheral vision using unmodified fonts, displayed in high contrast, on a monitor. The results showed that a larger print size was required to achieve the maximum reading speed in peripheral than in central vision. Research has shown that readers with low vision require larger print (of at least 16- to 18-point type), although there is no consensus on the optimum character size for large-print publications. For sighted readers, at a usual reading distance of 40 centimeters or about 16 inches, type sizes ranging from of 9 to 14 points are best (Legg, Rubin, Pelli, & Schleske, 1985). The range of visual ability is highly variable from one individual to the next, and reading thresholds are individualized.

In a series of experiments comparing the customized Tiresias large-print typeface to Arial and Times Roman, Perera (2001) found that in nearly all the trials, the participants preferred the large-print typeface, Tiresias, over Arial or Times Roman. Most of the experiments used whole, unmodified fonts, with the exception of the serif, space and weight, and punctuation exercises. All text was printed on paper. The participants with poor reading vision preferred Tiresias more than did those with good vision in experiments comparing the legibility (serif and typeface), space, and weight of typefaces and punctuation. In addition, Campbell et al. (2005) reported that across a total of 398 participants, a 16-point, unmodified sans serif font, called "Adsans," was found to be more readable than Times Roman, indicating that familiarity with a popular typeface did not correlate with a preference for legibility or readability. All text in the experiment was on paper or on medication bottles and labels.

The American Printing House for the Blind (APH) recommends the use of its APHont font when creating large-print materials for individuals with low vision because of its usability characteristics: even spacing between letters, no serifs, wider letters, rounder letters, and larger punctuation marks. We did not locate any experimental, published studies on APHont but did inspect a brief report related to large-print guidelines and APHont found on the APH web site (Kitchel, 2004). In addition to specialized typefaces created for large-print materials, research has been conducted on the legibility of highway signs with consideration for night vision, high-brightness materials, and aging drivers. The Clearviewhwy typeface was created to decrease a phenomenon called irradiation by increasing the spacing between letters without decreasing the distance at which the characters are legible (Garvey, Pietrucha, & Meeker, 1997). Since highway signage was not part of our inclusion criteria for selecting studies, we did not assess the research literature on this subject. Overall, the best available evidence, based on experimental research and subjective preferences, suggests that typefaces such as Arial, Helvetica, Verdana, and Adsans are more readable than is Times New Roman, for example (as measured by reading performance and subjective preferences). It is also evident that readers with low vision require at least a 16- to 18-point type, although there appears to be no consensus on the optimum character size for large-print publications.

Serif or sans serif?

The results from research on the effects of the presence or absence of serifs on the legibility of print seem to be inconclusive. Frequently, the research had not held constant particular typeface characteristics, such as stroke width, size, or ornamentation (Woods, Davis, & Scharf, 2005). Both Arditi and Cho (2005) and Moriarty and Scheiner (1984) found no differences in reading speed with sans serif and serif fonts. Arditi and Cho (2000), using nine customized fonts printed in lowercase on paper and displayed on a monitor, found an extremely small effect of the size of serifs in one experiment. With small letter sizes, close to the acuity limit, serifs may actually interfere, although slightly, with legibility. However, there was no strong determination of a definite difference in legibility between serif and sans serif fonts. Moriarty and Scheiner used unmodified fonts, printed on a sales brochure, with regular and close letter spacings.

When Morris, Aquilante, Yager, and Bigelow (2002) compared 4- and 16-point modified Lucida fonts, they found that serifs appeared to interfere only at small sizes and did not contribute anything to sentence-based word recognition through Rapid Serial Visual Presentation (RSVP) reading software. The participants viewed the text on a computer display at 4 centimeters (about 2 inches), corresponding to approximately 4-point and 16-point type at a normal reading distance of 40 centimeters (about 16 inches). They concluded that serifs may slow RSVP reading at small retinal sizes and may be counterproductive. Yager et al. (1998) and Perera (2001) found that the participants' reading performance improved when they read text printed in the unmodified Swiss and Tiresias typefaces, respectively. The participants also preferred the sans serif fonts. Campbell et al. (2005) reported a preference for sans serif fonts (unmodified), as determined by the rating and ranking of readability tasks. Although the research evidence does not enable us to make strong conclusions about the readability or legibility of serif or sans serif fonts, there appears to be a subjective preference among readers with low vision for sans serif fonts.

Crowding and letter confusion

Individuals with central vision loss (caused by conditions such as AMD) read with peripheral vision or used eccentric viewing strategies. Some studies have shown that reading rates among those using the peripheral visual field are slower than those reading with central vision, possibly because of enhanced crowding in peripheral vision. *Crowding* refers to the decreased visibility of a visual target in the presence of nearby objects (Cline, Hofstetter, & Griffin, 1997). Some studies have suggested that increased letter spacing may reduce this "crowding effect" and increase reading speeds when peripheral vision is used (Chung, 2002). Most of the knowledge on the "crowding effect" has come from letter-identification experiments in which observers either knew which letter in the display was the target or knew how many letters they were supposed to report from a stimulus string (Liu & Arditi, 2000). Using five different letter spacings, Chung found that increased kerning beyond the standard for letter spacing did not lead to an increase in reading speed in central or peripheral vision in sighted participants when text was displayed on a computer monitor using the RSVP method. Using a color-monitor display, Liu and Arditi (2000, 2001) observed that under narrow-spacing conditions, random guessing and lateral interactions between features of neighboring letters accounted for most of the deterioration in acuity. When information about the length of letter strings was uncertain, the participants tended to underestimate the lengths of small, closely packed letter strings. Moriarty and Scheiner (1984) found that a higher overall average number of words were read when messages were set with close and regular spacing. However, they could not support their hypothesis that the interaction between letter spacing and typeface affects reading speed.

Eccentric viewing reading performance may be enhanced for people with central vision loss by optimizing letter-recognition conditions. Some studies have sought to investigate this concept by studying letter-recognition tasks and analyzing letter-recognition errors—or "confusions." In MacKeben's (2000) study, frequently confused letter pairs of the Sloan set of 10 (letters C, D, H, K, N, O, R, S, V, and Z) were displayed 8 degrees to the right of the fovea on a computer monitor, set in Arial Bold, and, for some experiments, modified using typeface creation software. Sloan "optotypes" refer to 10 letters (sans serif, on a 5″ × 5″ grid) originally selected for their similar levels of legibility for use in visual acuity charts. For unmodified Arial Bold, O↔D and H↔N were found to be among the most frequently confused letter pairs for the majority of subjects. Letters were then modified by doubling the width of the horizontal stem on the "H," to make it less likely to be confused with "N," and by adding serifs to the "D," to make it less likely to be confused with "O." By modifying the features of just these two letters in a set of 10, the mean recognizability was, on avearage, improved by 18.7%. Using interletter spacing variations and widths of letter strings with METAFONT, Liu and Arditi (2000) found that the participants made more mistakes in judging the number of letters in the stimulus strings as interletter spacing decreased. Liu and Arditi (2001) showed that there were particular common letter confusions for both narrow and wide letter spacings, as well as confusions that were unique to either narrow or wide spacings. According to the research evidence, it appears that for individuals with low vision, including those who use eccentric viewing strategies, there is an overall advantage in reading performance of including adequate spacing between letters. Although the results from the research assessed in this review are inconclusive, adequate spacing between letters may help reduce confusions among letters.

Medication labels and printed health materials

Smither and Braun (1994) investigated the reading speed and subjective preferences of participants who read labels on medication bottles in Century Schoolbook, Courier, and Helvetica (unmodified typefaces), with 9-, 12-, and 14-point type and two weights, bold and Roman. The results pointed to better performance and overall preference for 12-point Century Schoolbook in boldface. For the second experiment, which used flat surfaces, the results indicated a preference for both Century Schoolbook and Helvetica, 12- or 14-point type, in boldface. Drummond, Drummond, and Dutton (2004) observed that participants with a best-corrected visual acuity lower or equal to 6/24 (20/80) had a significantly diminished ability to read instructions on their eyedrop bottles. The participants preferred Arial font (unmodified) in sizes ranging from 16 to 22 points, according to various acuity levels.

In a study of the preferences of potential cataract patients for printed materials, Estey, Jeremy, and Jones (1990) found that 65% of the participants found 14-point Universe font to be the most legible, compared to Century Schoolbook. The participants preferred the high-contrast reading materials, with black text on a white background, on the printed materials. Campbell et al. (2005) showed that in comparing six different typefaces (unmodified) in 7-point type on sample over-the-counter medication inserts and labels, the participants preferred a sans serif typeface (Adsans). Evidence based primarily on individual preferences suggests the benefits of using sans serif typefaces, with no smaller than a 12-point type, in boldface, for both medication bottles and flat surfaces. However, it is difficult to make strong evidence-informed conclusions as to the most suitable typeface, point size, and weight for medication labels. We could not locate any established or evidence-informed guidelines or standards related to the characteristics of typefaces for medication labels or printed health information.

Discussion

In summary, historical evidence from typographical research has typically not taken people with low vision into account, and the results of the research cannot always be applied to readers with low vision. This review found that the strongest evidence available from the research literature was associated with the following statements about the choice of particular characteristics of typefaces that can affect legibility: sans serif typefaces, such as Arial, Helvetica, Verdana, or Adsans, are more readable than is Times New Roman, for example; readers with low vision require at least a 16- to 18-point type for maximum readability and legibility; on the basis of subjective preferences, sans serif typefaces tend to be more readable or legible than are serif typefaces; evidence points to an overall advantage in reading performance and a reduction in letter confusion with adequate letter spacing; and on the basis of individual preferences, the use of a sans serif typeface, in no smaller than a 12-point type font, in boldface, provides the most readable conditions for both medication bottles and flat-surface labels and health literature.

With respect to technological advances in research designs, it has been only within the past decade that computers have been able to provide researchers with better control over the design of typefaces. Modifications of fonts are a necessary element for experimental research, and they are made possible through the use of computerized fonts and software, but with obvious differences in legibility between printed text and displayed text, primarily because of display variables. If font size is the variable, then research conducted at typical reading distances is difficult because of inadequate screen resolution. Although significant improvements have been made in the research because of technological advances in the manipulation of typefaces, the amount of experimental literature in this area is still limited.

Clearly, the choice of typefaces and the characteristics of fonts can affect legibility and the reading performance of individuals with low vision. In terms of which ones are the best for reading performance, some information has been proved scientifically, and some is still open to debate. Some aspects of the legibility of print appear to be dependent on subjective preference and comfort. The presence or absence of serifs, contrast between the text and the page, the thickness of letters, interletter spacing, leading, and the medium on which text is printed can all affect the legibility of type. The purpose of this review was not to promote one reading method over another. It is important to note, however, that on the basis of current research and specific conditions (ophthalmologic or age), appropriate magnification—through the use of low vision devices and large print—can enhance the reading performance of individuals with low vision. With an ever-increasing aging population, printed materials will need to be universally accessible to all types of people and in all types of public documents. Current guidelines on good design for printed materials for people with low vision are extremely beneficial, and there is growing enlightenment among the sighted community and public and private organizations of the need to keep pace with these developments. It is perhaps only a matter of time before standardized concepts on the legibility of text for people with low vision are instituted on both the local and global scale.

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Elizabeth Russell-Minda, M.A., *research coordinator, Lawson Health Research Institute, Aging, Rehabilitation, and Geriatric Care Research Centre, Parkwood Hospital, 801 Commissioners Road East, Room B-3016, London, ON, Canada, N6C 5J1J. e-mail <erussel4@uwo.ca>.* ***Jeffrey W. Jutai, Ph.D.,*** *associate professor and senior scientist, Lawson Health Research Institute, Aging, Rehabilitation, and Geriatric Care Research Centre; e-mail: <jjutai@uwo.ca>.* ***J. Graham Strong, O.D., M.Sc.,*** *director, Centre for Sight Enhancement, School of Optometry, University of Waterloo, Waterloo, ON, Canada N2L 3G1; e-mail: <gstrong@sciborg.uwaterloo.ca>.* ***Kent A. Campbell, Ph.D.,*** *director, Research Support Unit, Bloorview Research Institute, Bloorview Kids Rehab, 150 Kilgour Road, Toronto, ON, Canada M4G 1R8, and assistant professor, Department of Occupational Therapy, University of Toronto, Toronto, Canada; e-mail: <kcampbell@bloorview.ca>.* ***Deborah Gold, Ph.D.,*** *associate director, Research Department, Canadian National Institute for the Blind (CNIB), 1929 Bayview Avenue, Toronto, ON Canada M4G 3E8; e-mail: <deborah.gold@cnib.ca>.* ***Lisa Pretty, B.A.,*** *manager, National Communications Department, CNIB; e-mail: <lisa.pretty@cnib.ca>.* ***Lesley Wilmot, B.A.,*** *director, National Communications Department, CNIB; e-mail <lesley.wilmot@cnib.ca>. Address all correspondence to Dr. Jutai.*