READING WITH A STAND MAGNIFIER
Effect Of Number Of Letters On Reading Rate

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INTRODUCTION

Increasing letter magnification leads to increased reading rates for most visually impaired observers (Legge et al., 1985a) . However in most cases, increasing magnification reduces the number of letters simultaneously visible (often called the field of view or window size). When reading horizontally scrolled magnified text, four to five letters were needed to attain maximal reading rates (Legge et al., 1985b) . We have recently replicated this finding for this passive reading condition. Whittaker and Lovie-Kitchen (1993) have reported that the number of letters needed for self-navigated reading is substantially larger. However, Beckmann and Legge (1991; Beckman et al., 1993) reported that for self-navigated reading with a CCTV, only 5 letters were needed to achieve maximal reading rates.

For stand magnifiers, many more letters are presumably needed for optimal reading, possibly because of the help larger fields afford for text navigation (i.e., finding the next line) (Cohen & Waiss, 1991) . The number of letters needed is not known. Neve (1989) measured reading rates as a function of field of view for low power hand held magnifiers and found that reading rates increased when the field of view was increased from 40 to 80 characters. Smaller fields of view that are more common in stand magnifiers (Cohen & Waiss, 1991) were not evaluated in that study

One possible reason there are no definitive data regarding the effect of field of view on reading rates with stand magnifiers is the difficulty defining and measuring this parameter. The monocular and binocular fields of view are different (Blommaert & Neve, 1987) and not easily measured because they vary with eye-to-lens distance. Katz and Zikos (1994) demonstrated that the curvature of a typical magnifier requires a change in accommodation from the center of the lens to the periphery. The required change can be large in commonly used stand magnifiers (0.75-2.4 D). This effect can be even larger when attempts are made to increase the lens size and the field of view by aspheric design because this usually increases the optical distortions.

Fiber optic taper magnifiers (Peli & Siegmund, 1995) provide an ideal tool for measuring the effect of field of view on reading rates. These magnifiers, which provide a real, enlarged image with minimal distortions on the top face, have a clearly defined field of view that is not affected by binocular parallax. Covering the top face of the taper with an annular occluder results only in a change in the number of letters visible, while all other parameters—magnification, weight, brightness, contrast, illumination, etc.—remain unchanged.

Using this method we found that increasing the number of characters visible through a magnifier increases reading rates. Rates continue to increase with as many as 13 characters visible, well beyond the 5 characters need to read text scrolled passively or through a CCTV. As previously suggested, these additional characters may be needed for navigation.

METHODS

Subjects: English speaking adults with and without visual impairments participated in this study. Two groups of normally sighted volunteers were recruited. Fourteen were between the ages of 16 and 30 years (Mean age: 18; Median acuity: 20/15) (YN); eighteen were aged 55 years or older (Mean age: 68; Median acuity: 20/20) (ON). Normal vision was defined as visual acuity of 20/40 or better in the subject's better eye, with habitual correction. Sixteen visually impaired subjects (acuity worse than 20/40 in their better eye) (VI) also participated (Mean age: 75; Median acuity: 20/70). Eight of these subjects had documented central field loss (CFL) in their better eye; thirteen had CFL in at least one eye.

Apparatus: A 5.3 cm top face, 2.5× taper was used for the reading task. When placed over text printed using a Times 10 pt font, the 2.1 cm (5.3/2.5) bottom face allowed for 13 adjacent 'e's to be viewed simultaneously. The contrast transfer through this taper was 79% of the contrast of the printed materials, which was 83% (Peli & Siegmund, 1995) . The height of the taper was 4.7 cm, and it weighed 9.5 oz.

The number of letters visible on the upper face of the magnifier was limited using a white adhesive vinyl cut into doughnut-shaped occluders using a laser plotter. In addition to reading using the taper with no occluder (13 characters visible), subjects also read with occluders that left 11, 9, 7, 5, 3, 2, and 1 characters visible.

Passages were printed with a laser printer on white paper using a Times 10 pt font, and then mounted on poster board measuring 14.9 cm × 21.6 cm. The passages were printed in a 2 in. (5.1 cm) column, with 3.8 cm margins on the left and right. The top margin was 6.1 cm. This layout was chosen to mimic the layout of a newspaper column. Passages were backed with hook-and-loop tape, which allowed them to be positioned in the same place on the reading surface, flush with the front edge of the table. The passage was surrounded by additional poster board affixed to the table in order to provide a smooth surface over which to navigate with the magnifier. Passages were placed on a reading surface 81 cm high. Subjects were seated in a height-adjustable chair and encouraged to find a comfortable reading position. Fluorescent ceiling lights and a 60W incandescent goose-neck lamp lit the reading area. The lamp was positioned over the reader's left shoulder so that no reflection of the bulb was seen in the magnifier (Peli & Siegmund, 1995).

Design and Procedure: Subjects read using their habitual reading correction. All subjects silently read at least 12 passages selected from elementary level reading primers: three with an unoccluded taper (13 characters) and three with each of three occluder sizes (9, 5, and 3 characters visible). Normally sighted younger and older subjects, and those visually impaired subjects who were able, also read three passages without the taper. In addition, the younger subjects read with 11, 7, and 1 characters visible. The seven and eleven character conditions were omitted for the remaining readers because there was no difference in reading rate between the 7 and 5 character conditions and between the 11 and 9 character conditions. A 2 character condition was used for the normally sighted older readers because pilot subjects found the task too difficult with only one character visible. Visually impaired readers were unable to read with either of these occluder sizes. After each passage, the subject was read four multiple-choice questions, which were responded to orally.

The order of occluder size (including no occluder) and passages was randomly determined for each subject. Normally sighted younger readers were presented with all of the conditions in random order (including reading without the taper and the 1 character condition). Normally sighted older subjects and visually impaired subjects read with 13, 9, 5, and 3 characters visible in random order, and then, if they were able, read three passages without the taper. Normally sighted older subjects then read with 2 characters visible. A short break was given after every six passages (2 occluder sizes), and more frequently if requested by the subject.

Before testing began, each subject read at least one passage using a different taper (7.0 cm top face; 2.75× magnification). The primary purpose of this practice passage was to train readers to navigate with the taper, and to familiarize them with the level of difficulty of the questions. Acuity was measured monocularly, with habitual correction, using a Mentor B-VAT II™ using the procedure described in Fine and Peli (1995) .

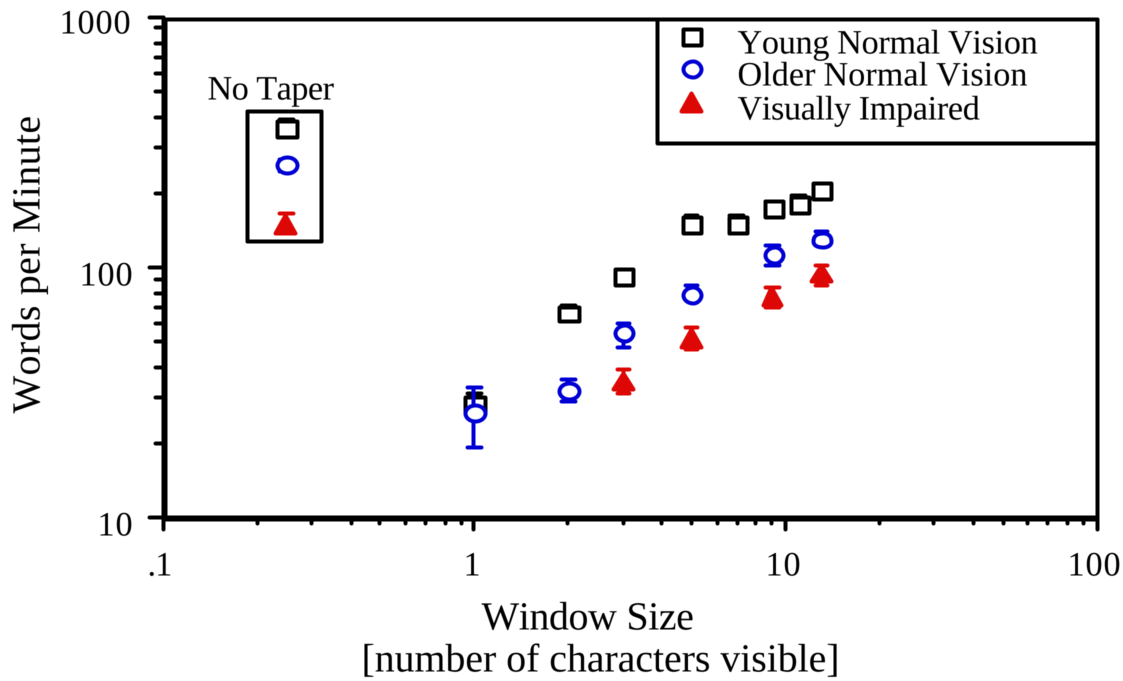

Figure 1. Reading rate in wpm by window size for the YN, ON, and VI groups. Reading rate continues to increase, even with the largest window size, and never reaches reading rates without the taper.

RESULTS

Figure 1 shows reading rates (in wpm) by window size for the three subject groups. The first thing to note is that, as expected, the YN group read faster than the ON group, who in turn read faster than the VI group. This was true both with and without the taper, and for all window size conditions except 1 character. In addition, reading rates continued to increase for all window sizes, and never reached the reading rates possible without the taper. For the YN group, the slope of the reading rate by window size function does tend to become more shallow with seven or more characters visible. For the ON and VI groups reading rates have not begun to level-off even with as many as 13 characters visible. Thus, unlike reading scrolled text or from a CCTV, more than 5 letter simultaneously visible is necessary to attain maximal reading rates.

DISCUSSION

Increasing the number of characters visible through a magnifier increases reading rates. Rates continue to increase with as many as 13 characters visible, well beyond the 5 characters needed to read scrolled text or to read with CCTV. As previously suggested, these additional characters may be needed for navigation. However, the reasons for the difference in results between self-navigation with a stand magnifier (this study) and CCTV (Beckman & Legge, 1991; Beckman et al., 1993) are not clear. As previously demonstrated, a substantial amount of time is lost finding the beginning of the next line of text. In our study, informal observation for some subjects indicated that as much as 50% of reading time is used for that task. The CCTV table, with its guided horizontal movement and beginning-of-the-line stop may reduce the amount of time required to find the next line, and thus reduce the needed field of view for this navigation task.

The continuing increase in reading rates with increasing field of view suggests that even faster rates could be achieved with further increases in taper size, although as we saw with the YN readers, this would be expected to level-off. However, increases in the size of a taper also result in increased weight and cost (the weight and cost increase as the cube of the increase in diameter). The increase in weight may rapidly reduce any further advantage provided by an increased field of view because of motor-control limitations.

Since much of the reading time is lost in locating the beginning of the next line of text, a magnifier that provides a full column field of view would be desirable. Such a magnifier will require only vertical movement down the column and should increase reading rates substantially. Lens optical magnifiers with such large fields of view, such as the mirror magnifier, are limited to low magnification. Although taper magnifiers of higher effective magnification can be made in this size (2 in. bottom face) they would be very large (a 2.5× magnifier would have a 5 in. upper face), heavy, and currently too expensive.

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