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Reading with peripheral vision: A comparison of reading dynamic scrolling and static text with a simulated central scotoma

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ABSTRACT

Horizontally scrolling text is, in theory, ideally suited to enhance viewing strategies recommended to improve reading performance under conditions of central vision loss such as macular disease, although it is largely unproven in this regard. This study investigated if the use of scrolling text produced an observable improvement in reading performed under conditions of eccentric viewing in an artificial scotoma paradigm. Participants ($n = 17$) read scrolling and static text with a central artificial scotoma controlled by an eye-tracker. There was an improvement in measures of reading accuracy, and adherence to eccentric viewing strategies with scrolling, compared to static, text. These findings illustrate the potential benefits of scrolling text as a potential reading aid for those with central vision loss.

1. Introduction

Conditions such as age-related macular degeneration can lead to a central scotoma – an at least partial functional loss of the highest acuity region of the retina for processing of visual input. The ability to perceive objects falling within this area (as is crucial for tasks such as reading) is therefore lost or seriously compromised, resulting in reading difficulties being one of the most commonly reported problems for those with macular degeneration (Hazel et al., 2000). The central scotoma can force individuals to adopt a strategy of employing the relatively more preserved peripheral areas of their retina, where acuity is reduced. One viewing strategy in particular thought to be able to increase gaze stability and thus reduce reading difficulty (e.g. Nilsson & Nilsson, 1986; Palmer, 2009; Palmer et al., 2009) is the eccentric viewing technique. Eccentric viewing (EV) is a technique used to look at targets using the peripheral retina (Timberlake et al., 1987). This strategy also capitalises on what appears to be a relatively natural adaptation in viewing strategy of people who experience central vision loss, to adopt a 'preferred retinal locus' (or loci; PRL); an area to which they may automatically redirect saccades so that information that would normally be fixated by the fovea is fixated by some more peripheral part of the retina (Whittaker, Budd, & Cummings, 1988).

Improving eye movement control has been shown to be beneficial for reading with macular degeneration (Seiple et al., 2005). However, an obstacle to reading with a central scotoma is that the strong natural tendency to foveate words by means of saccadic eye movements is counterproductive, and may be detrimental to the effectiveness of the eccentric viewing strategy (Crossland, Culham, & Rubin, 2004), making this a difficult strategy to maintain in practice. A related approach called the 'steady-eye' technique involves holding an eccentric viewing location whilst moving the text itself (Watson & Berg, 1983). However, although the popularity of aids such as stand magnifiers and CCTV devices (particularly with individuals who experience complete central vision loss; Ahn & Legge, 1995) may anecdotally support the use of this strategy (as these devices provide not only the obvious benefit of magnification of text but also require text either to be moved manually beneath the fixed lens [for stand magnifiers] or be projected onto a screen by moving a camera over it in such a way that it presents as scrolling on the screen [for CCTV devices], allowing a steady eye strategy to be employed), such devices have recognised issues with navigation between lines of text and with the limitation to viewing a very small window of characters at any one time (Beckmann & Legge, 1996; Bowers, Cheong, & Lovie-Kitchin, 2007).

An alternative method which would provide the benefits of stand magnifiers and CCTV devices whilst eliminating these problems would be to use dynamic, horizontally scrolling text: combined with eccentric viewing and the steady eye strategy this could potentially reduce the number of counterproductive fixations made onto the text itself. Any scrolling text device would ideally present the text as a single line (e.g. Walker, 2013),

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simplifying complex strategies adopted by those with central vision loss to navigate reading normal blocks of text, including the combination of multiple PRLs to view different parts of a paragraph and a complex multi-step pattern to move onto the beginning of new lines (Déruaz et al., 2002). Its presentation would also necessarily be digital, and therefore (as with CCTV devices; Ahn & Legge, 1995) may take advantage of the apparent benefits of reading from electronic devices over normal printed text (via enhanced contrast; Kretzschmar et al., 2013 – addressing findings that suggest low contrast sensitivity is a contributor to reading difficulty in low vision conditions; Rubin & Legge, 1989). Scrolling text may therefore have potential as a useful aid to improve reading with central scotomas, circumventing the need for the eye to actively seek out the text and thus possibly reducing the likelihood of making counterproductive eye movement.

Previous research has investigated scrolling text for this purpose, although little work has been carried out to date. For example, Legge and colleagues (1989b) found that reading rates for scrolling text were around 15% higher than for static text in a low vision population (although this sample did not all have conditions involving central vision loss). Another study comparing reading rate with scrolling text and rapid serial visual presentation (RSVP; in which words are presented sequentially in one spatial location, thus also allowing reading to be carried out at fixation) with a specific central vision loss group found a trend towards faster reading with scrolling text, and proposed that the lack of significance was likely due to low power rather than lack of effect (Fine & Peli, 1995). Most relevantly for the present study, Bowers, Woods, and Peli (2004) compared horizontally scrolling text with static, RSVP, and vertically scrolling text, finding no significant differences in reading speed between these formats. Bowers, Woods, and Peli (2004) reported that, of the four formats they tested, horizontally scrolling text was most often identified as the preferred format of their low vision sample (see also: Walker, 2013). This finding would likely indicate that, despite the lack of reading speed advantage, scrolling text may be advantageous over other measures (possibly due to an exploitation of the EV technique as discussed previously). Furthermore, reading speed is directly related to the rate of dynamic text presentation which presents a potential confound when making direct comparisons with reading static text. This study will therefore focus on a detailed examination of oculomotor measures of adherence to the eccentric viewing strategy and reading error rates.

The present study aims to investigate reading performance with eccentric viewing and horizontally scrolling text, using a gaze-contingent artificial scotoma paradigm (see e.g. Rayner & Beretra, 1979) in order to evaluate if reading performance and adherence to the EV strategy were improved with dynamic text presentation. Unlike in previous research looking similarly at different text presentation formats, which have tended to use reading speed as a main outcome measure, here the focus is instead on the adherence to the eccentric viewing strategy during reading under conditions of simulated central vision loss. Participants will be instructed to hold fixation at the eccentric location when reading scrolling text; this strategy in theory eliminating the need to make horizontal eye movements (as are crucial in reading of normal static text), and therefore possibly improving participants' ability to suppress fixations onto the text itself. This will be evaluated by analysis of eye movements falling in specified regions of interest around, above, and surrounding the text. A comfortable speed for reading scrolling text eccentrically was established prior to the study and a fixed scrolling speed used to reduce possible perceptual and oculomotor factors (such as blurring of moving text, and nystagmus eye movements) that can arise with faster scrolling rates. A region-of-interest analysis of eccentric fixation was performed along with measures of reading errors.

2. Methods

2.1. Participants

Participants were 17 students from Royal Holloway, University of London (mean age = 20.8 years, SD = 1.7; 15 female). All participants had self-reported normal or corrected-to-normal vision and spoke English as their first language (in order to try to ensure that errors made when reading were not due to misunderstanding of the text). Informed consent was collected from all participants prior to the study, as approved by departmental ethical review.

2.2. Apparatus and stimuli

Stimuli were displayed on a 1024×768 pixel CRT monitor (60 Hz refresh rate) at a distance of 68 cm (sustained with use of a table-mounted headrest).

The stimuli used in this study were 160 sentences; 96 from the MNRead compilation (Legge et al., 1989a) and a further 64 generated based on this compilation. These sentences each had an average of 59 characters (including spaces; MNRead compilation 58.8 SD 1.9; extra 59.3 SD 0.8), with an average of 12 words (MNRead compilation 11.9, 1.4; extra 10.9 SD 1.0). Letter size was taken from a lower case 'x' as 0.67°; larger than the minimum acuity limit of around 0.1° at the forced minimum text eccentricity of 2.5° (Anstis, 1974). The sentences were presented as black text (Times New Roman font) on a white background.

2.2.1. Eye-tracking

Pupil and corneal reflection were recorded monocularly (right eye, left patched) during reading by an SR Research EyeLink 1000 eye tracker at 500 Hz. This was used to produce a predefined gaze-contingent scotoma, appearing at fixation as a circle of matching colour and luminance to the background. This artificial scotoma was of 5.04° diameter (i.e. greater than the 5° area of the retina consisting of the macular; Drieghe, 2011) and was the same colour as the background.

2.3. Design

All participants completed both conditions of text presentation type investigated by this study (static and horizontally scrolling). Analyses were conducted for reading accuracy, calculated as percentage of sentences in which errors were made; and adherence to eccentric viewing strategy, calculated as the proportion of total fixation duration spent fixating in regions of interests around the text and eccentric viewing area (see Fig. 1). Counterbalancing of the order of conditions was applied, and analysis comparing the results of the counterbalancing groups showed no evidence of order effects.

2.4. Procedure

Prior to the experiment, the participants were informed about the two viewing strategies (EV and SES) and asked to adhere to the appropriate strategy (i.e. EV only for static and both for scrolling text) as much as possible. They were also reminded of the appropriate reading strategy or strategies to use prior to each block of sentences (i.e. when reading static sentences participants were asked to fixate above the line of text but otherwise to make horizontal saccades and fixations along this line as in normal reading, but when reading scrolling sentences they were asked to fixate the cross above the text and to refrain from making any eye movements as far as possible). The artificial scotoma paradigm (and its