# Is there a preview benefit when reading scrolled text?

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## Introduction

When we read, our eyes move systematically across the page. On average, we fixate on an area of text for about 250 msec, then move our eyes about seven letters to the right (Rayner, 1978). On a given fixation, about 17 letters, primarily to the right for readers of English, provide information important to reading. The letters surrounding the fovea (about 4 on each side of the fixated letter) are sufficiently visible for identification and for use in word access. Beyond this region, only letters to the right of fixation influence reading and eye movement behavior (Binder et al., 1999) and readers are able to identify letter shapes (to about nine letters from fixation) and gather word length information out to about 13 letters from fixation.

When reading from a continually scrolling display, the letters available to the right of fixation are constantly changing. Buettner et al. (1986) reported that normally-sighted observers read about 15% slower from this display than from a standard page display. However, we have shown reading rates for single sentences that are faster than 350 words per minute (wpm) from a scroll display (Fine & Peli, 1995), similar to what one would expect when reading similar stimuli from a page of text (Rayner, 1978).

Rayner and his colleagues (Rayner et al., 1981) have shown that reducing the size of the visible window reduces reading rates. Fixation durations increase and saccade size decreases as the number of letters available on each fixation is reduced. Legge et al. (1985a,b) reported that four to five letters were sufficient for both normally-sighted and visually impaired readers to reach their maximal reading rates from a scroll display. However, we (Fine & Peli, 1996) found that normally-sighted readers required a window of about eight letters, and visually-impaired readers required about nine letters. We used different criteria and the letter size we used was smaller than the letter size used in Legge et al., which could account for at least some of the difference in our findings.

The eight-letter window we found is larger than the window size necessary for word identification (the average word was about 5 letters), but smaller than one would need to navigate across a page of text. Unpublished data from our lab indicate that most observers who read text scrolling from right to left make saccades that land near the right edge of the screen and then track the letter across the screen until a new saccade is made (similar to reports from Legge et al., 1985). These data, combined with our observation that maximal reading rates weren't attained until the window was much larger than the average word length, led us to hypothesize that the additional letters in the scroll display provide motion information and help guide eye movements.

To test this hypothesis, we asked subjects to read sentences from the scroll display with windows of different widths. In one block of trials, the windows were created using an opaque occluder, similar to what we had used in our previous study. In the other block of trials, the windows were created using occluders created from a light diffusing paper, providing word length and letter shape information, but not enough information to identify specific letters.

**Methods**

Sixteen elderly (mean age 68 yrs; range 59–75), normally-sighted (mean logMAR –0.04±0.08; range –0.26 to +0.08; Snellen equivalent 20/18; range 20/11 to 20/24) subjects participated in this experiment. None reported any known ocular disease, and all were native English speakers.

MNRead sentences (Legge et al., 1989) were displayed using a modified Horizon Low Vision Magnifier. A description of the system can be found in Fine and Peli (1995). White letters on a black background were continuously scrolled from right to left across a 27 in. monitor. Letters were 0.66 deg (capital X height; ~8x single letter acuity threshold for VA 20/20) at the 2.8 m seating distance used for all subjects.

Window size (number of letters visible) was controlled by attaching either opaque or diffuse occluders to the right and left edges of the television monitor. Both occluder types spanned the full height of the monitor. The opaque occluders were made from black posterboard. The diffuse occluders were created by mounting two sheets of “4 mil clear inkjet film” (Azon Color, Inc.) to pieces of 6 mm thick, clear plastic, and were mounted 5 mm from the face of the monitor. To assure that letters could not be identified through the diffuse occluders, a small pilot study was conducted. The subject (EF) was presented with a random list of slowly scrolled, widely-spaced letters. The spacing between the monitor and the occluder was varied until a 50% correct criterion was reached. This distance (11 mm; spacer plus plastic) was then used for the reading experiments.

Window type (opaque and diffusive) was blocked, and window size randomized for each subject. The same random order was used for both window types. Subjects maximum reading rate was determined using a staircase procedure similar to that used in our previous study (Fine & Peli, 1996) for window sizes of 3, 5, 7, 9, and 11 letters visible. We also included a 13 letter window in the opaque condition. This represents the widest possible window for the larger letters we are using in a replication of this experiment with low-vision observers (not reported here).

**Results**

Presentation rates were corrected to account for the number of letters masked for each window size (Fine & Peli, 1996). Figure 1 shows reading rates for each window size by occluder condition averaged across the 16 subjects. A two (occluder type) by five (window size) repeated measures ANOVA showed main effects of both occluder type [$F(1, 15) = 12.02$, $p = .004$] and window size [$F(4, 60) = 46.16$, $p < .001$]; the variables did not interact.

The data were fit with an exponential function that predicted reading rate, *RR*, from the window width, *w*:

$$RR = RR_{\max}\left(1 - e^{-\frac{w}{w_0}}\right)$$

where $RR_{max}$ was the maximum reading rate and $w_0$ was the width constant. Thus, when the window width was three times $w_0$, the reading rate was 95% of $RR_{max}$. The window width that results in 95% $RR_{max}$. was defined as the required window size. As shown in Table 1, the

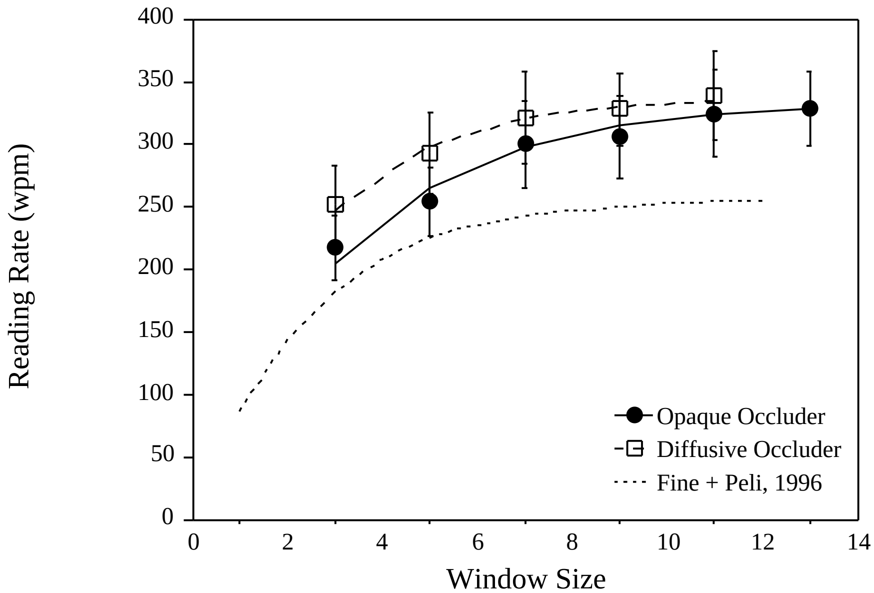


Figure 1. The data points show the average reading rate (±95% CI) at each window size. The curves show the exponential fits to the data of the current study and from our previous study (Fine & Peli, 1996).

required edge size was greater (9.0 characters) for the opaque edge condition than the diffusive edge condition (6.8 characters).

These fits suggest that reading rates with the diffusive occluders are similar to reading rates of slightly bigger windows with opaque occluders. Figure 2 shows the same reading rate data, shifted one window size (two letters) in the diffusive condition. As can be seen there, the two data curves are almost identical, supporting our conclusions.

Eleven of the 16 subjects tested also read with no occluders attached to the monitor. The maximum possible screen width on our monitor was about 23 letters. The average reading rate for these subjects reading with a 23 letter window was 351±77 wpm, only slightly faster than the 11 letter window conditions (Table 1). If we are correct in our assumption that reading with diffusive occluders is equivalent to reading with two additional letter shapes visible, then the window size necessary to attain 95% of maximum reading rates under the conditions used in this experiment is about 9.

**Discussion**

The window sizes necessary to attain 95% of maximum reading speeds were larger in this experiment (~9 letters) than in our previous study (~7 letters) (Fine & Peli, 1996). The angular size of the letters in our previous study was 3x larger than those used in the current study. This could account for the difference in findings, since, as shown in Fig. 1 the maximum reading

| | $RR_{max}$ (wpm) | $w_0$ (characters) | required window size (characters) |
|---|---|---|---|
| Opaque | 329 | 3.0 | 9.0 |
| Diffusive | 337 | 2.3 | 6.8 |
| Fine & Peli, 1996 | 257 | 2.4 | 7.2 |

Table 1. Results of the exponential fit to the data of the current study and our previous study (Fine & Peli, 1996). Note that using this analysis makes the required window size slightly smaller than the eight characters described in the Introduction.

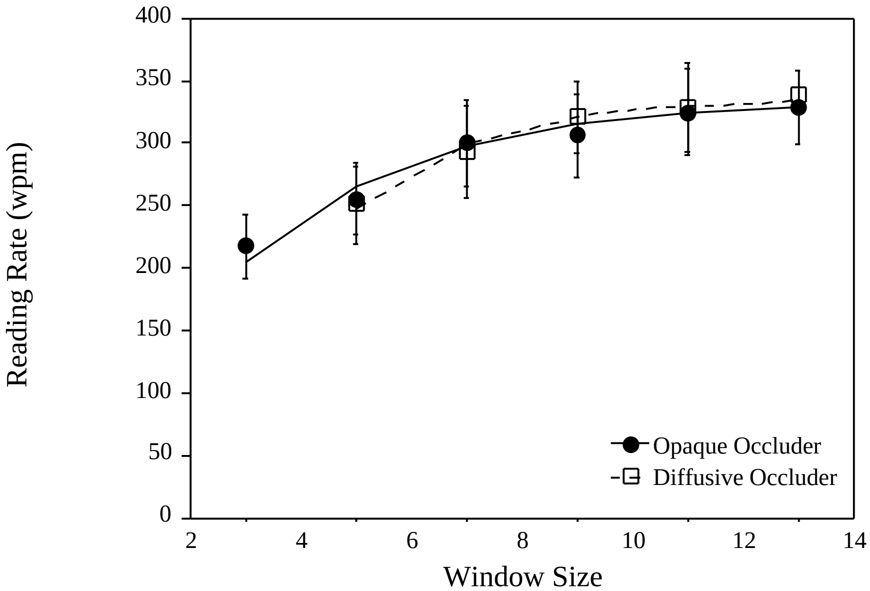


Figure 2. The data from Fig.1 with the diffusive occluder condition shifted 2-letter spaces to the right.

speed was also much slower in that study (284 vs. 332 wpm for the 11 letter opaque condition in this study).

The data from this study lead us to believe that normally-sighted readers benefit from a preview that is equivalent to two to three extra letter, beyond what is available for word identification. These extra letters may provide a preview of letter and word shape and help guide eye movements. Experiments are underway to determine if these additional two letters are sufficient, or if additional diffused letters would benefit readers more. We are also collecting data from persons with low vision to determine if they too are able to benefit from the letter shape and motion stimulus provided by the diffuse occluders.

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