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Reading of Dynamically Displayed Text by Low Vision Observers

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Introduction

When compared to the time required to read a normally displayed page of text, low vision observers read faster from a scroll display, in which the text is continuously panned across a computer screen (Legge et al., 1989). They also read faster from a rapid serial visual presentation (RSVP) display in which each word is presented to the same place on a computer screen (Rubin & Turano, 1994). The views seen from the scroll display are similar to what would be seen when a magnifier or other low vision aid is scanned across a page of text. Readers with low vision are reported to read text displayed in this manner about 15% faster than a static page of text (Legge et al., 1989). As Legge et al. point out, this advantage may be due, in part, to the time saved because no return sweeps are needed to reposition the eyes at the beginning of the next line of text. This return sweep is time consuming for normally sighted observers (Rayner, 1978), and even more so for low vision observers who are known to have difficulty with eye movement control (cf. Peli, 1986; Whittaker et al., 1991). This advantage for scroll displays was not seen for normally sighted observers in Legge et al.'s study. In fact, they read 44% slower on average.

Rubin and Turano (1994) compared reading rates for static and RSVP displays. Low vision readers read about 80% faster from the RSVP display. This was primarily due to the over 200% increase in reading rate for low vision observers without central field loss (CFL). Low vision observers with CFL read RSVP text about 50% faster than statically displayed text. This is much less than the four-fold increase in reading they found for normally sighted observers.

Data from normally sighted observers imply that reading will be faster for text displayed with RSVP than with the scroll technique. In addition, the need for eye movements is eliminated when reading from an RSVP display (Potter, 1984). Although low vision observers with CFL do make eye movements when reading from an RSVP display (Rubin & Turano, 1994), they are made less frequently than when reading from a standard text display because interword saccades and return sweeps are not necessary. Based on these observations, we hypothesized that low vision observers, especially those with central field loss, would read significantly faster from an RSVP than a scroll display.

Methods

Subjects: Adults 55 years of age or older who's first language is English were recruited for this study. Based on their acuity (see procedures for details), they were divided into three subject groups: normal vision (n = 14), middle vision (n = 8), and low vision (n = 13). Normal vision was defined as acuity of 20/40 or better in the better eye; those with middle vision had acuity between 20/50 and 20/80 in their better eye; low vision subjects had acuity of 20/100 or worse in their better eye. We further categorized our subjects based on the status of their central field. All of our normal vision subjects had intact central fields. Four middle vision subjects had CFL, three had no CFL, and the status of the central field is unknown for one subject. Of the 13 low vision subjects, 11 had CFL. The average age across the three groups was 72 years.

Apparatus: Acuity was tested monocularly using a Mentor B-VAT II. Using this system, acuity targets (letters) are displayed individually. A modified Horizon Low Vision Magnifier was used for text presentation and data collection. The text was displayed as white characters on a black background on a 27 in Sony color television monitor. The dimensions of the screen allow for the

simultaneous display of up to ten characters at the magnification used. A Bitstream san serif, proportionally-spaced bold font was used for character generation. A lower-case 'e' measured 5.6 x 4.1 cm at the magnification used.

Materials & Design: One hundred sixteen of the MNRead sentences developed by Legge et al. (1989) were used. They each have 55 characters and no internal punctuation. Each subject read sentences out loud from both the scroll and RSVP displays. The order of presentation was counter balanced across subjects, and no subject saw a given sentence more than once.

Subjects were seated at varying distances from the screen so that the maximum velocity of the characters would not exceed 40 deg/sec in the scroll condition for reading rates well in excess of those found in pilot experiments for each subject group. Seating distance was based on acuity, and retinal character size was at least 4x the acuity threshold for each subject.

Procedure: For both acuity measurement and reading assessment the room lights were turned off. A 60 watt bulb that provided light for the experimenter was positioned such that neither the bulb nor its reflection was in the line of sight of the observers.

Each subject's acuity was measured using the Mentor B-VAT II. They were asked to name each letter presented. The character size for which they were able to correctly name four of five target letters was recorded as the acuity in each eye. This was then converted to logMAR for further analyses. Subjects were then seated and told that sentences would be presented on the screen and that they should read them out loud. The display format was described and a sample sentence shown. Testing began at 200 words per minute (wpm) for normal vision subjects, 100 wpm for middle vision subjects, and 10 wpm for low vision subjects. The rate was increased in steps of 10 wpm for low vision subjects and 20 wpm for all other subjects until two or more errors were made on a single sentence. The step size was then halved, and the rate decreased by one step. After the first reversal, the rate at which each subject could read a sentence with fewer than two errors was recorded as the maximum reading rate for that condition. This procedure was repeated with the second display format, except that starting rate was based on the maximum rate attained for the previous condition.

Results & Discussion

Table 1 shows the average maximum reading rates for each group by display condition. The ratio of RSVP rate to scroll rate is also given. This metric, called RSVP-gain (after Rubin & Turano, 1994) was used in the following analyses. There was no effect of vision group on RSVP-gain [$F(2,32) = 2.09$, $p = .14$]. However, when the low and middle vision subjects are combined, the same analysis yields a significant effect of vision group [$F(1,33) = 4.29$, $p = .05$]. As can be seen in Table 1, only the normal vision group read faster with the RSVP than the scroll display. The increase in reading rate with RSVP for normally sighted readers was expected based on previous findings. However, the lack of increase for the visually impaired (low and middle vision) group was surprising. As discussed in the Introduction, low vision readers were found to be about 15% faster for scrolled text (Legge et al., 1989) and 80% faster for RSVP (Rubin & Turano, 1994) when compared to reading a full page of text. (The specifics of the subject population are not available from Legge et al.'s study. Rubin and Turano classified patients with acuity worse than 20/50 as low vision. Thus, all our middle vision subjects would have been classified as low vision in their study.) Therefore, visually impaired subjects should have been faster reading from the RSVP display in this comparison.

A comparison of RSVP-gain based on status of the central field revealed no difference in performance between those subjects with and without CFL [$F < 1$]. A comparison of reading rate for scroll and RSVP displays for those subjects with and without CFL (the normally sighted subjects were removed from this analysis) showed that those subjects with no CFL read significantly faster from both display formats [both t's > 5.0, $p < .0001$]. As before, there was no difference in RSVP-gain across these two groups when the normal vision subjects were removed from the analysis. This result is also surprising based on previous research. Rubin and Turano (1994) reported an almost 200% increase in reading rate for RSVP presentations for their low vision subjects with no CFL. Their subjects with CFL improved by only about 50%. Thus, we

Table 1. Average Maximum Reading Rates in WPM for RSVP and Scroll Text Displays by Subject Group

Subject Group	N	RSVP Rate	Scroll Rate	RSVP/Scroll
All Subjects†	35	273.0	234.7	1.13
CFL	14	96.0	108.0	0.98
no CFL	20	406.0	333.4	1.24*
Normal Vision	14	438.1	334.6	1.33**
Middle Vision	8	254.8	250.0	0.99
CFL	3	178.2	210.0	0.82
no CFL	4	308.5	300.0	1.03
Low Vision‡	13	106.4	117.7	1.00
CFL	11	66.1	70.9	1.03
no CFL	2	327.9	375.0	0.87

† The status of the central field was unavailable for one middle vision subject.

‡ When the outlier is removed from this analysis (see Fig. 1), the RSVP-gain for the low vision group is 0.87, which is not significantly different from 1.0.

* $p < .05$; ** $p < .01$ by t-test. No other effects were significantly different from 1.0.

should have seen a difference in RSVP-gain between our CFL and no CFL readers in the visually impaired group.

We also examined the relationship between RSVP-gain and logMAR. Figures 1 and 2 show these data for the analysis by vision group and status of the central field, respectively. For the low vision group there was a significant relationship between logMAR and RSVP-gain [$r = .57$, $p = .04$]. However, if the one outlier is removed from the analysis, there is no relationship between these variables [$r = -.08$, $p = .81$]. There was also no relationship found for either the middle or normal vision groups. When the subjects were divided based on status of the central field, there was no relationship between logMAR and RSVP-gain for those subjects with CFL. For those subjects with no CFL, there was a significant relationship between logMAR and RSVP-gain [$r = -.47$, $p = .04$]. Those with normal vision (none of whom had CFL) showed a significant change in reading rate between the two display conditions, while those with visual impairment did not (see Table 1). The correlation between logMAR and RSVP-gain for the no CFL subjects reflects this difference.

Figure 1. Relationship Between RSVP-gain and logMAR by Vision Group

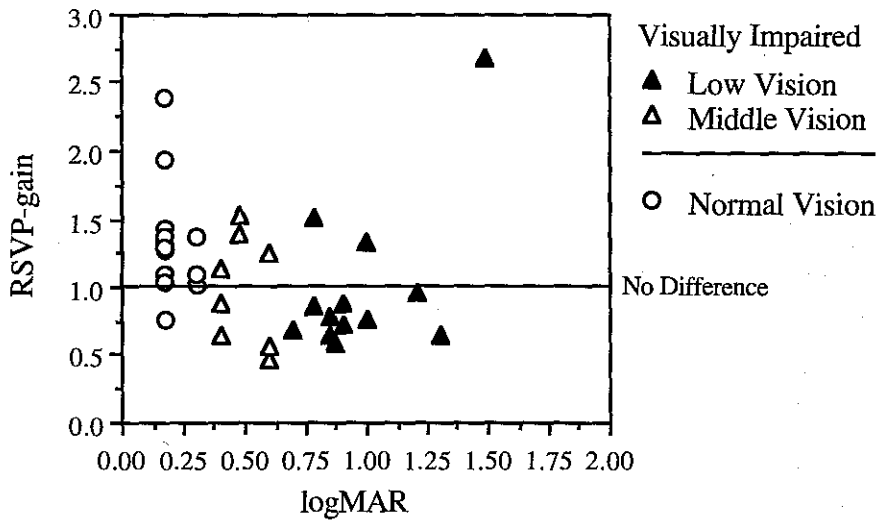
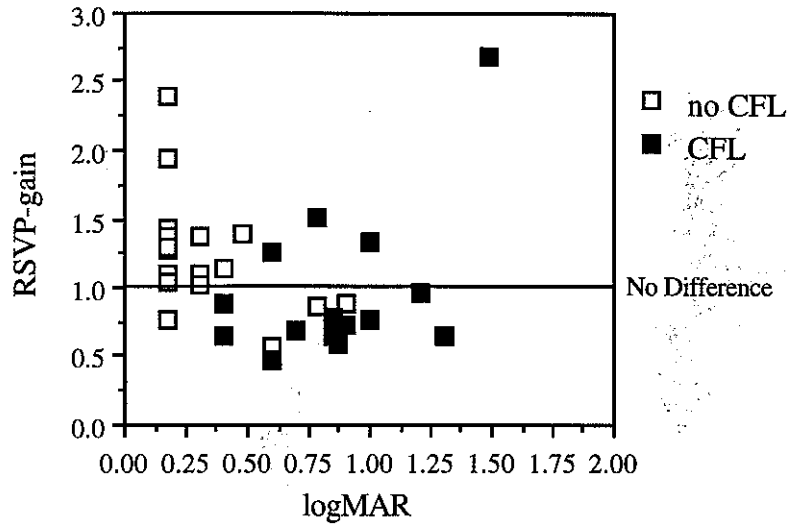


Figure 2. Relationship Between RSVP-gain and logMAR by Status of the Central Field



Conclusions

A direct comparison of reading rates for scroll and RSVP displays revealed no difference in performance for subjects with visual impairment (acuity 20/50 or worse). The only subjects who were able to read faster from the RSVP display were those with normal vision (better than 20/40). The lack of increase in reading rate for visually impaired subjects in the RSVP condition is surprising when compared with previous research. We are currently investigating the possible causes of this result.

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