

Reading scrolled text in three window conditions

by Michael F Riley

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Psychology
Montana State University
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Abstract:
Twelve good readers and 12 poor readers read scrolled, computer generated text in each of three window sizes of two, five, and ten double-spaced lines and were tested for comprehension. Good readers were expected to show no effects of windowing on reading comprehension. Poor readers were expected to score lowest in the 2-line condition, best in the 5-line condition, and score somewhere in between in the 10-line condition. However, there were no significant effects or interactions. The subjects reported their reactions to the reading tasks in a post-experimental interview. Only one subject found the 5-line condition to be the most difficult for reading. The 5-line condition was considered to be the easiest and was also preferred by a majority of subjects. Related research and prospects for computer reading are discussed.

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A thesis submitted in partial fulfillment
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of

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in

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APPROVAL

of a thesis submitted by

Michael F. Riley

This thesis has been read by each member of the thesis committee and has been found to be satisfactory regarding content, English usage, format, citations, bibliographic style, and consistency, and is ready for submission to the College of Graduate Studies.

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ABSTRACT

Twelve good readers and 12 poor readers read scrolled, computer generated text in each of three window sizes of two, five, and ten double-spaced lines and were tested for comprehension. Good readers were expected to show no effects of windowing on reading comprehension. Poor readers were expected to score lowest in the 2-line condition, best in the 5-line condition, and score somewhere in between in the 10-line condition. However, there were no significant effects or interactions. The subjects reported their reactions to the reading tasks in a post-experimental interview. Only one subject found the 5-line condition to be the most difficult for reading. The 5-line condition was considered to be the easiest and was also preferred by a majority of subjects. Related research and prospects for computer reading are discussed.

INTRODUCTION

The use of computers for the storage and presentation of textual information seems assured. The Visual Display Unit (VDU) as an electronic "page" may even replace books as the standard medium for visible language. One author has stated that "as semiconductor chip technology continues to grow, a copy of a book, then a copy of an encyclopedia, then a copy of a big library will be stored on a chip costing less than $.20 as compared with a single paperback costing $2.00" (Berkely, 1981, p. 6). Two prototype information systems in Great Britain, Telidon and Viewdata, allow subscribers to access daily newspapers and weekly magazines, as well as complete novels for reading on a home television screen. Users' reactions to this new form of "book" have been favorable (Jackson, 1979). This use of the VDU as a medium for reading has created a need for recommendations on the design and layout of the electronic page (Bouma, 1979; Kolers, Duchnicky, & Ferguson, 1981; McCormick, 1982).

Prior human factors research into VDU design has been concerned primarily with hardware parameters such as levels of flicker, contrast, and resolution, and alphanumeric design (Bouma, 1979). Computer manufacturers could ignore human/machine interfacing problems as long as their users were small, highly skilled groups working with relatively simple machines (Brandscomb, 1981). As a result, design engineers dealt with the information needs of the user on a largely intuitive basis (Bouma, 1979). In contrast, the users of today are

more likely to be nontechnical personnel who require comprehensible, "user-friendly" displays (Schneiderman, 1981).

The need for research into VDU design is crucial because the searching and scanning techniques used in normal reading may not apply to VDUs (Jackson, 1979). For instance, the VDU is illuminous (i.e., it is its own light source) and therefore presents a display with properties quite different from the luminous static page. Whereas the book reader is at the mercy of the publisher's print style, the VDU user can usually decide on various aspects of format. The user is free to adjust the contrast and with little or no difficulty choose single or double-spacing, as well as regulate line length. For these reasons, many researchers discourage direct comparisons between the printed and the electronic page. In comparing the two mediums, Kolers et al. (1981) cautioned against adapting VDU design features uncritically from the print medium. Rosenthal (1979) has pointed out that even simple layout features such as keeping the long side vertical, as in standard book format, should be empirically examined.

One problem inherent in computer displays, though, is how to access new information. The VDU can be thought of as a "window" that allows access to a small portion of computer memory. Information beyond the bounds of this window can be accessed in either of two ways. One method is referred to as "paging". With paging, once the displayed text has been read, the user blanks the screen and waits for new lines of text to fill in. The second method available with most computer VDUs is the scroll function. With scrolling, lines of text appear at the bottom of the screen and flow upwards, finally disappearing at the

upper limits of the screen. With scrolling, the user selects a preferred rate of presentation and can then view large sections of text without interacting with the computer.

VDUs that feature a scrolling mode typically use one of two types. One, a smooth scroll, resembles movie credits in that lines are continually displayed and seem to float upward toward the top of the screen. Smooth scrolling is accomplished by moving the information in each raster line upward one line at a time. The second type is a jump scroll. Jump scroll is created by freezing the entire page for a predetermined amount of time before an instantaneous shift or "jump" moves the text one line upward, with the top line disappearing and a new one added at the bottom. Jump scroll terminals have no control over individual raster lines. Instead, the whole page of text moves upward in an instantaneous, blinking jump, stopping at the next higher line.

The few studies that have investigated scrolling reported that subjects could effectively read scrolled, computer-generated text. For example, Oleron and Tardeau (1978) measured the effects of scrolling on the recall of sentences that varied in levels of organization and abstraction. Their data indicated that scrolling did not disrupt or impoverish recall when compared with the static page. They also found a significant interaction between presentation mode (static vs. scrolled) and the level of text organization. Apparently the subjects found it easier to form relationships with organized material in the static condition. Oleron and Tardeau concluded that scrolling facilitated recall if the text was narrative.

Kolers et al. (1981) had subjects read computer text at four different scrolling rates: at their preferred rate, at 10% slower, and at 10% and 20% faster than the preferred rate. They recorded subjects' eye movements as a measure of cognitive efficiency. The data indicated that subjects' ocular efficiency improved as the speed of scrolling increased. That is, subjects' reading speed, when adjusted for the change in display time, increased with no apparent loss in comprehension. The number of words per fixation also increased by 25% from the slowest to the fastest rate.

Kolers et al. (1981) found no differences in reading comprehension between the scrolling conditions and the static page condition. They did report that the static page was read more efficiently than was the text scrolled at the subject's preferred rate, but the efficiency was about the same as the 10% faster condition. Apparently the subjects were underestimating their reading speed with scrolled text by about 10%. The researchers also reported that 60% of the subjects indicated a preference for scrolled versus static page reading. Based on these data, Kolers et al. concluded that scrolling can induce people to read more efficiently.

One suggestion made by Kolers et al. (1981) was that VDU users might find scrolled text easier to read if only a few lines are displayed at a time, although they offered no recommendations on the subject. A small window, for example, would unclutter the visual array by removing previously read lines from the screen. Readers would be expected to experience fewer line-finding problems as the window decreased in size. The obvious problem with a small window,

however, is that readers would have little or no time to recheck portions of the text. A larger window would give readers some leeway in rechecking the text, but this advantage could be offset by increases in line-finding problems.

Window size is not standardized in the computer industry, nor has it been a controlled variable in scrolling research prior to this study. For example, the subjects in the Kolers et al. (1981) experiment read from a VDU with a 20-line display area. The Oleron and Tardeau (1978) study used a 24-line display. Telidon and Viewdata systems likewise employ a 24-line display. Most microprocessors feature a 16-line display (Rao, 1982), whereas Hewlett/Packard has opted for the 20-line format in their VDUs. The optimal window size for reading scrolled text has not been empirically determined. The purpose of this experiment was to test the effects of different window sizes on reading comprehension, as a function of reading ability.

Good and poor readers read computer-generated text in each of three window sizes of 2, 5, and 10 double-spaced lines. Subjects were tested for comprehension following each window size condition. The dependent variable was the number of items correct on the comprehension test. Differences in reading style between good and poor readers suggested that subjects would be affected differently by window size, depending upon their level of reading proficiency.

Good readers have the ability to recognize words automatically and rapidly, and are adaptable and flexible in both eye movements and comprehension strategies, when told to read for either detail or

general information (Golinkoff, 1976; Stanovich, 1980; Stern, 1978). Downing and Leong (1982) cite flexibility of reading speed as a noteworthy feature of the skilled reader. Good readers show less dependence on prior context or expectancies in word recognition tasks (Stanovich, 1980). This ability apparently frees more of their attentional capacity for the comprehension process. They can read in larger thought units, or chunks of text, as opposed to a word-by-word approach to reading (Golinkoff, 1976). In studying selective attention, Willows (1974) reported that "increasing the complexity of the visual array interferes with the mechanics of scanning and decoding the symbols on the page" (p. 214). Good readers can apparently deal with these basic reading skills automatically, which allows them to concentrate more closely on the extraction of meaning from the text. Based upon this evidence, it was hypothesized that the number of lines of text would not have a significant effect on good readers' comprehension, and they would therefore score consistently across the three window conditions.

Poor readers, on the other hand, do read in a word-by-word manner, and are generally inflexible to task demands (Golinkoff, 1976). Golinkoff stated that "inadequate reading comprehension seems to imply being somewhat of a slave to the actual word" (p. 656). Poor readers seem compelled to pay closer attention to subskills such as decoding, to the extent that they compromise the main purpose of reading, that of comprehending the text (Downing & Leong, 1982). Willows (1974) reported the poor reader's dependence on the visual aspects of reading made them very susceptible to any adverse reading conditions. Based

upon the reading style implied by these researchers, it was hypothesized that the poor readers' comprehension would be affected by the number of lines of text displayed on the VDU.

The 2-line window should present the most difficult condition for the poor readers. Unlike the more competent readers, they are unable effectively to skim or to process larger chunks of text when they fall behind. Eye movements studies have indicated that poor readers' attempts at chunking only lead to regressive saccades (Stern, 1978), because the information content of the material cannot be extracted with one fixation. Regressions in the 2-line condition will likely result in lost information as lines scroll off the screen before being read. Hence, poor readers are expected to perform worst in the 2-line condition.

Poor readers' scores are expected to be highest in the 5-line condition, which seems to offer reading advantages over the 2- and 10-line windows. For one thing, the three additional display lines should allow readers the luxury of some limited rechecking not available in the 2-line size. Poor readers should lose less information in the 5-line size because of this factor. Poor readers may experience some line-finding problems in the 5-line condition, but not nearly the amount that will occur in the 10-line condition. Target errors in return sweeps, eye movements from the end of one line to the beginning of the next, slow reading speed because extra fixations are needed to correct errors (Leisman, 1978). The potential for line-finding errors should be greater in the full screen 10-line condition then the 5-line window condition. The flexibility in reading speed exhibited by good

readers should enable them to overcome any line-finding problems, and as a result keep pace with the text. The poor readers, however, lack this ability. Any increase in return-sweep errors should disrupt their reading process to the point that comprehension is reduced in the 10-line window when compared to the 5-line window.

In summary, the purpose of this experiment was to test the effects of different window sizes on the comprehension of good and poor readers who read scrolled, computer-generated text. Overt reading behavior differences between the two groups lead to different predictions about the effects of the windowing on their reading performance. Good readers have developed a reading style that should enable them to overcome any adverse conditions due to windowing, and should score consistently across the window conditions. Poor readers lack the skills necessary for this and should be affected by window size. They should score lowest in the 2-line condition, greater in the 5-line condition, and show no improvement or possibly do worse in the 10-line condition in comparison to the 5-line condition. Confirmation of this hypothesis would indicate that standard size displays of 16 to 24 lines will not benefit all readers and may adversely affect comprehension in many readers.

METHOD

Subjects

The subjects were 24 students enrolled in an introductory psychology class who were preselected for reading ability. A total of 12 students made up the good reading group and 12 made up the poor reading group. The selection process was as follows. The experimenter obtained permission from about 200 students to examine their reading ability scores kept on file in the campus testing center. A good reader was someone who placed in the upper quartile, and a poor reader was someone who placed in the lower quartile of the Montana State University Placement Test and Indices Report. The students were then screened for reading ability and those who qualified were placed into a pool of good and poor readers. The first 12 readers from each group who agreed to participate were used as subjects. Participants were awarded extra credit toward their course grade.

Materials and Apparatus

The reading materials were three distinct texts from the American College Testing Program (Steinberg, 1981), a primer for college entrance tests. Such practice exams are structured to closely parallel the testing format of the real exams (Carris & Crystal, 1982). Each passage was approximately 600 words long, and each had eight four-alternative forced-choice questions. The paragraphs were thus selected as being representative of a college freshman reading assignment.

The VDU was controlled by a Hewlett-Packard 9845B desktop computer, which recorded all data. The VDU had a 20-line display area with an 80-character line length and displayed standard alphanumerics. The scroll type on the 9845B is a jump scroll. For this experiment, the text was double-spaced because Kolers et al. (1981) reported a slight increase in reading speed when subjects read double-spaced instead of single-spaced text. The lines were limited to 60 characters and centered on the screen to avoid the curved margins of the VDU. The computer keyboard was covered by a sheet of cardboard during the experiment, and only those keys necessary for making a response were exposed. Lighting was held constant for all subjects, and they were free to adjust their posture during the experiment.

Windowing was achieved by programming the computer to limit the display area to either 2, 5, or 10 double-spaced lines, depending upon the treatment condition. Because a repeated-measures design was used, window order was counterbalanced across subjects to control any effects due to practice. The method of counterbalancing yielded six possible orderings for the window size variable, so both reading groups utilized each counterbalanced order twice to accomodate the 12 subjects in the group. The stimulus paragraphs were also completely counterbalanced and were combined with window order so that each paragraph was read an equal number of times in each window condition.

Procedure

The experimenter greeted the subjects at the beginning of each session. A session began with a familiarization period under computer

control, during which the subject was acquainted with the apparatus and the task. A session began with the introduction:

> YOU ARE ABOUT TO PARTICIPATE IN THE COMPUTER READING STUDY! IN THIS STUDY YOU WILL BE ASKED TO READ THREE PARAGRAPHS, AND ANSWER QUESTIONS BASED ON WHAT YOU HAVE READ. THE PARAGRAPHS WILL BE "SCROLLED" ACROSS THE SCREEN FROM THE BOTTOM TO THE TOP. PRESS "CONT" TO SEE WHAT THE SCROLLED PARAGRAPHS WILL LOOK LIKE.

This was followed by a sample scrolled paragraph. The three window sizes were also demonstrated so that the subject knew what to expect.

The experimenter then assisted the subject in finding his or her preferred scrolling rate. The scrolling rate is defined as the amount of time, expressed in milliseconds, that a line remains stationary before shifting to the next higher line. Subjects were told that their preferred rate was the speed at which "you can read a line without hurrying to catch up or waiting for a new line to appear." The subjects were told at this point to read for comprehension while choosing a preferred rate. The method of adjustment was as follows. Each subject was first shown a section of practice text with a 1500 ms/line duration and was asked to judge whether it seemed too fast or too slow. Depending upon the response, the scrolling rate was then either increased or decreased, and a second practice paragraph was presented. Subjects were given as many trials as were necessary to find a comfortable preferred rate.

Kolers et al. (1981) found that subjects tend to select a preferred rate which is about 10% slower than their normal reading speed. The computer was programmed to increase the subject's selected rate by 10% as recommended by Kolers. Subjects were also told that a

beep would sound when only five lines remained to be displayed before the screen was blanked. This insured that the subjects had no more time to read in the 5-line and 10-line conditions than in the 2-line window. Only when the experimenter was assured that the subject understood all instructions did a session begin. The computer then selected a paragraph, presented it in the first window size, and then presented the appropriate question set. The procedure was repeated three times for each subject, once for each paragraph/window pair assigned through counterbalancing for that subject.

Post-experimental Interview

Each subject was asked to respond to 11 questions about the reading task at the end of the experimental session. The experimenter read the questions to the subjects and recorded their answers. The question set and responses for each group are presented in Appendix B. The first four questions specifically concerned the subject's reactions to the different windows. The remaining questions were more concerned with general aspects of the subject's reading behavior and the experiment.

RESULTS

Comprehension Scores

The data are summarized by reading ability and window size in Table 1. The means and standard deviations are in terms of the percentage correct out of the eight multiple-choice questions that followed each paragraph presentation. Table 2 summarizes the results of the 2 x 3 (Reading Ability x Window Size) analysis of variance. The analysis revealed a significant effect of reading ability. Neither the main effect of window size nor the interaction of window size and reading ability was significant. Data transformations performed as a result of skewed response distributions did not affect the F-values.

Reading Speed

The good readers had a mean preferred reading rate of 1455 milliseconds/line, and the poor readers had a mean rate of 1726 milliseconds/line, an 18% difference in speed. The good readers' preferred rate was significantly faster than the poor readers', $t(22) = 2.87$, $p < .01$.

Post-experimental Interview

The responses to the questionnaire are presented in Appendix B. In response to Item 1, only one subject, or 4% of the sample, indicated that the 5-line window presented the most difficult display for reading. Of the remaining subjects, 50% indicated the 2-line and 42%

indicated the 10-line window to be most difficult for reading. The χ^2 analysis for goodness of fit revealed a significant difference between these responses, χ^2 (2, $\underline{N}$ = 23) = 8.95, $\underline{p}$ < .02. The responses to Item 2 revealed that 46% of the sample considered the 5-line window to be the easiest for reading. In contrast, only 25% reported that the 2-line window was the easiest condition, and 25% reported that the 10-line window was easiest for reading. These differences, however, were not significant, χ^2 (2, $\underline{N}$ = 23) = 2.17, $\underline{p}$ > .05. A total of 50% of the subjects expressed a preference for the 5-line condition. The remaining subjects were evenly divided between the 2-line and the 10-line conditions as to which was most preferred. These differences were also found to be nonsignificant, χ^2 (2, $\underline{N}$ = 24) = 3.0, $\underline{p}$ > .05.

Responses to other questions indicated that out of all subjects, (a) 83% reported loss of some information, (b) 67% indicated experiencing line finding problems, (c) 58% perceived the scroll rate as being too fast, (d) 46% reported experiencing eye fatigue, and (e) only 33% felt they could read from the VDU for an hour or more.

Table 1. Mean percentage comprehension scores by reading ability and window condition.

Reading Group	Window Condition			Overall
	2-Line	5-Line	10-Line	
Good	68.8 (17.3)	67.7 (27.9)	63.5 (20.1)	66.7 (22.0)
Poor	33.3 (19.5)	38.5 (17.2)	35.4 (23.7)	35.8 (19.7)
Overall	51.0	55.2	52.1	

Note. Standard deviations are shown in parenthesis.

Table 2. Analysis of variance.

Source	SS	DF	MS	F	P
Individuals (r/B)	15881.076	22	721.867		
Reading Ability (B)	17189.670	1	17189.670	23.813	< .0001
Window Size (C)	160.590	2	80.295	.245	.7841
BC Interaction	186.632	2	93.316	.284	.7539
Error (rC/B)	14444.444	44	328.282		
Total	47862.413	71			

DISCUSSION

This experiment was designed to test the hypothesis that reading comprehension could be significantly affected by the window size of the VDU, depending upon a subject's level of reading ability. Trends in the data for both the good and poor readers follow what was predicted, but the combination of small numbers of subjects, small mean differences, and large within groups variance resulted in nonsignificant effects of windowing. Thus, there is no evidence to support the hypothesis that one window size is better than another for reading scrolled text, at least when comprehension is measured.

The good readers performed as expected. Their scores were significantly higher, in all conditions, than the poor readers, and they read with a significantly faster rate of scroll. Only three of the 36 scores produced by the good readers were at or below the chance, or guessing, level (25% correct). As a group they averaged nearly 70% correct on the comprehension tests. This level of performance suggests that the good readers could actively read and comprehend the texts, even when presented on a completely novel medium.

The poor readers scored very low in all conditions. Whether their performance reflects a failure sufficiently to read the text or that the texts were too hard is not clear from the data. It is safe to assume, however, that the poor readers may have found the paragraphs too difficult. After all, texts similar to these were used to identify them as being in the lower quartile in reading achievement.

Any windowing advantages which would appear as an increase in comprehension would remain undetected if the paragraphs were too difficult even under ideal reading conditions.

It is equally likely that the medium, the mode of presentation, did not allow the poor readers to actually read parts of the text. While readers in both groups reported problems with line-finding and with lost information, it is the poor readers who are assumed to lack the reading skills to overcome these difficulties. Their dependence on the visual aspects of reading hinders the maintenance of prior information and its integration with new information (Just & Carpenter, 1980). The poor readers, unlike the good readers, are relatively unable to "fill in the blanks" to make up for lost information. Also, unlike the good reader, the poor reader is usually unsuccessful at skimming, or chunking, after falling behind in the reading. The poor reader may attempt to skim, but it is doubtful that they extract any meaningful information using this technique. That 10 of the 12 poor readers reported skimming during the experiment can be taken as evidence that the display disrupted their normal reading patterns. Although nine good readers also reported having to skim, it is behavior that is much more characteristic of their normal reading style.

Recent evidence has been published which supports the notion that the VDU adversely affected the poor readers' performance. Schwarz, Beldie, and Pastoor (1983) reported that naive users performed separate tasks involving reading, sorting, and line searching more effectively with paging than with scrolling. Their subjects also indicated that paging was preferred to scrolling for performing these

tasks. Their results led the researchers to conclude that scrolled text did not seem to offer any advantages to justify its use. Waern and Rollinghagen (1983), in a review of computer reading, also recommended that inexperienced users utilize the paging mode, simply because it more closely approximates a normal style of reading.

It is probably safe to conclude, then, that the medium had adverse effects on readers in both groups since all subjects were naive users. Previous discussions of reading behavior also makes it clear that the poor readers would be more susceptible to any medium effects than the more competent readers. Again, whether the poor readers' scores were more affected by text difficulty or the medium cannot be determined from the present data. Subsequent research into this area should probably include a static condition as a means of differentiating these sources of variance.

Future researchers should also consider a dependent variable with more sensitivity than the four alternative-forced choice items used in the present study. One problem with this type of question is it can sometimes be answered correctly without reading the text. There is then a chance of introducing prior knowledge as an additional source of variance. Items that are higher in passage dependence may be better suited for determining how much text a subject actually read. Passage dependent items can only be answered on the basis of what has been read, so the results therefore do not reflect prior learning (Tuinman, 1974). Kolers et al. (1981) used true/false items that were highly passage dependent to verify that their subjects were actually reading the text. The subjects had to indicate whether ten statements which followed

each paragraph could be judged true or false based solely on what was read. Dependent measures of this type may provide more valid information on how much text a subject had actually read.

Whether window size would have had a greater effect on performance if other texts had been used is not clear. What is clear, according to the interview responses, is that a majority of subjects in each group did consider the 5-line window as having certain advantages over the 2-line and 10-line sizes. Also, fewer subjects reported losing information in the 5-line size than in either the 2-line or 10-line conditions. This may partially explain their preference for the 5-line window. Better performance was predicted in the 5-line condition because readers would have more time to recheck than in the 2-line condition, and experience fewer line-finding problems than in the 10-line condition. That fewer subjects reported losing information in the 5-line condition seems to support this explanation.

A nearly universal complaint of VDU users is discomfort from eyestrain and eye fatigue. Subjects in this study were no exception, with nearly half reporting some eye fatigue. These results seem somewhat high considering that the subjects were at the VDU for only 20 to 30 minutes. The sensation of eye fatigue may partially explain why only one-third of the subjects in the present study indicated they thought that they would be able to read from the VDU for an extended period of time (one to two hours).

Many aspects of computer reading are still poorly understood. The inherent problem of how to access new information or recheck old material via the VDU remains unsolved. The evidence does not wholly

support Schwarz et al. (1983) in their claim that paging is superior to scrolling for this purpose. For example, the reading material in their study consisted of two pages of unrelated nouns, not text, and the dependent measure, reading time, did not significantly differ between paging and scrolling. Their subjects' major complaint with scrolling was that they had no sense of what "page" they were on. Also, Waern and Rollinghagen (1983) did not conclude that paging was necessarily a better system of access than scrolling, but only that the more dynamic aspects of VDUs would be more use to those "better acquainted with the system" (p. 449). In contrast to the finding of Schwarz et al. that paging was preferred to scrolling, Kolers et al. (1981) found that 60% of their subjects preferred scrolling to a static-page condition. Their subjects had read a total of 16 paragraphs over three experimental sessions before making their choice.

Research into the effects of scrolling on reading behavior should include systematic comparisons of jump and smooth scrolling, with the aim of establishing their uses and limitations. Kolers et al. (1981) reported that their subjects "uniformly disliked" jump scrolling. The researchers did not compare them empirically, however, but used a smooth scroll on the basis of this information. Oleron and Tardeau (1978), on the other hand, used jump scrolling. Although jump scrolling can be difficult to read, especially if lines shift in mid sentence, it does present a static page between shifts. Conversely, readers of smooth scrolling must constantly track the text, since it never stops moving, a situation some readers may not like. Nonetheless, the use of jump scroll in this experiment may also partially explain

why only 33% of the subjects felt they could read from the VDU for an extended period of time.

One aspect of VDU reading that researchers should consider more closely is the type of reading that will be done via the VDU. There is a need for systematic research which encompasses a variety of reading materials. Results obtained from light fiction reading are probably not generalizable to technical report reading, for example. Gibson and Levin (1975) have made this apparent with the observation that "there are as many reading processes as there are people who read, things to be read, and goals to be served" (p. 454). The present study used text that approximated college textbook material. As previously stated, these texts were probably too difficult to expect the poor readers to comprehend, given the presentation mode. It is possible that windowing effects would occur with material that is higher in readability. VDU research should be motivated not only by the need to establish parameters that facilitate reading, but also to determine which types of reading are inappropriate at the VDU.

Research should also be guided by how readers choose to define system factors such as paging, scrolling, and windowing. Waern and Rollinghagen (1983) have noted a lack of research into what people "need, want, or are at ease with" (p. 450) when reading from the VDU. They also stress the need to consider individual differences throughout this line of research. The interview data in the present study suggests that readers would choose a variety of sizes if allowed to self-define window size. If this is true, it may be necessary to offer cafeteria-style displays which permit user selection from a variety of display characteristics.

In summary, this experiment has failed to detect any effects of window size on reading ccmprehension. There is no indication that window size affects good and poor readers differently. It is possible that windowing would be a more efficacious variable with other types of text, however. In a way, this experiment has provided information relevant to the question posed by Rosenthal (1979) of whether the electronic display should have the long side vertical, as in most printed material, or horizontal. At least when preference is considered, subjects in this study chose a window that had a horizontal side three times the length of the vertical side. The latest research on scrolling also supports the use of displays that have the long side horizontal. Duchnicky and Kolers (1983) found that reading performance reached asymptote with a window four lines high by 80 characters long. Designers of VDUs should consider these results when incorporating layout features into displays intended for reading.

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APPENDICES

APPENDIX A

Table 3. Number of questions (out of eight) correct in each window condition.

Type of subject	Window Condition		
	2-Line	5-Line	10-Line
Good Reader			
1	6	7	8
2	4	5	6
3	6	6	5
4	6	8	6
5	5	7	3
6	4	4	2
7	5	2	5
8	7	7	6
9	8	8	6
10	4	1	6
11	7	5	3
12	4	5	5
Poor Reader			
1	4	5	3
2	1	4	4
3	2	0	0
4	3	4	5
5	1	4	4
6	1	2	3
7	4	4	0
8	3	4	5
9	1	3	4
10	2	2	1
11	5	3	5
12	5	2	3

APPENDIX B

Table 4. Post-experimental interview results.

Question	Reading Group: Poor	Reading Group: Good	Overall
1. Which window seemed to be the most difficult/distracting?			
a. 2-line	6	6	12
b. 5-line	1	0	1
c. 10-line	5	5	10
d. no difference	0	1	1
2. Which window size seemed easiest to read through?			
a. 2-line	4	2	6
b. 5-line	5	6	11
c. 10-line	3	3	6
d. no difference	0	1	1
3. Which window did you prefer?			
a. 2-line	4	2	6
b. 5-line	6	6	12
c. 10-line	2	4	6
4. Did you lose information/not read some lines?			
a. 2-line	3	4	7
b. 5-line	2	1	3
c. 10-line	4	3	7
d. none	1	3	4
e. all	2	1	3
5. Was line finding a problem?			
a. yes	7	9	16
b. no	5	3	8
6. Did you have to skim the paragraphs?			
a. yes	10	9	19
b. no	2	3	5

APPENDIX B (CONT'D.)

Table 4. (Cont'd.) Post-experimental interview results.

Question	Reading Group: Poor	Reading Group: Good	Overall
7. Was your preferred rate satisfactory?			
a. yes	5	5	10
b. no	7	7	14
8. Were any of the paragraphs familiar to you?			
a. Marxism	1	0	1
b. Migration	1	0	1
c. Mussolini	0	0	0
d. none familiar	10	12	22
9. Was any paragraph more difficult than the others?			
a. Marxism	6	5	11
b. Migration	1	1	2
c. Mussolini	3	0	3
d. none harder	2	6	8
10. Was eye fatigue a problem?			
a. yes	6	5	11
b. no	6	7	13
11. Could you read for extended periods of time using this method?			
a. yes	3	5	8
b. no	9	7	16

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