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Effect of changes in line length and spacing on speed of reading from the Tablet PC

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EFFECT OF CHANGES IN LINE LENGTH AND SPACING ON SPEED OF READING FROM THE TABLET PC

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ABSTRACT

EFFECT OF CHANGES IN LINE LENGTH AND SPACING ON SPEED OF READING FROM THE TABLET PC

By Victoria L. Dulchinos

The purpose of the present experiment was to determine the effect of changes in line length, interline spacing, as well as screen type, on speed of reading from the Tablet PC as measured by the "Tinker Speed of Reading Test." Reading speed was recorded in milliseconds for each participant. The present study examines the hypothesis that line length, interline spacing, and screen type have an effect on reading speed. The thirty-two participants were presented with 160 text items to read in four different conditions of line length and spacing. We did not find a main effect of line length, spacing, or screen type on reading speed. An interaction between spacing and screen type was found. The results demonstrated that for the tablet screen, reading the text items was faster in the single spacing condition, while for the desktop screen reading the text items was faster in the double spacing condition.

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Introduction

With the increasing amount of time that we spend reading text from a computer screen rather than from traditional printed medium, a thorough examination of the task of reading from the screen is required. Web designers and authors of electronic text should not overlook the importance of the research of typographical variables as they pertain to reading from the screen. At the very least, it should be understood that one cannot apply printed text typographical guidelines to the presentation of text on the screen. (Grabinger & Osman-Jouchoux, 1996)

In Dillon's (1992) review of the literature on reading from paper verses screens, he concluded that the most common experimental finding from this body of work was that silent reading from the screen was significantly slower than reading from paper. Dillon stated that evidence suggests a performance deficit of between 20% and 30% when reading from the screen. Additionally, Dillon (1992) suggests that "single variable" explanations are insufficient to capture the range of issues involved in reading from the screen. Dillon (1992) examined some of the factors responsible for the slower reading speed in his review of these studies. Character size as well as other physical attributes of text in addition to screen characteristics, such as screen background color, resolution, and room lighting have impacted these data; nevertheless it has been accepted that people do read more slowly from the screen. (Gould et al, 1987a)

There has been an increase in the amount of reading we do from the computer screen in recent years, as well as improvements in the quality of the screen characteristics. The lightweight Tablet PC offers a new screen type allowing the reader to handle the screen in the same manner as one would handle a pad of paper or a book. This configuration makes the task of reading from the tablet functionally analogous to the task of reading printed material. Marketing of digital magazines and e-books is geared toward the Tablet PC. This includes Microsoft's Cleartype technology, which is supposed to "make words on the screen appear just like words in a printed book" (eBook Formats). Terms such as immersive reading and extended interactive reading are being used to market this new technology. This marketing approach suggests the marketability of a reading scenario from the computer screen functionally analogous to that of reading from printed text. Does making the screen type similar in size and weight to a pad of paper or a book result in improved reading efficiency as compared to reading from a desktop screen?

Variables Affecting Reading From Paper and Screen

There are a number of factors to consider when examining the research on reading from the screen. The fact that the technology has been improving at a rapid rate impacts the results of the research that has been done on reading from the screen in that the comparison of results across studies may not be valid because of variations in screen qualities and characteristics. While screen quality is still improving, it may now be the time for a re-examination of the parameters of the task of reading from the screen. It is also important to note that screen characteristics are separate from typographical characteristics of text. (Gould, 1987a; Dillon, 1992)

Another factor making the interpretation of the research results difficult is that the perception of the reader's ease of reading is not always equal to the reader's actual increased efficiency. (Dyson and Kipping, 1998) Preference ratings or other subjective reports may not be sufficient to identify the most effective format for text on the screen.

An extensive body of research exists on the reading of printed text. (Tinker, 1963) This research thoroughly considers many parameters of the reading task, including font type and size, line width and margins, arrangement of text on the page, distance and angle of the reader to the printed text, background color, and text color. The research literature on printed text demonstrates that there are a number of parameters of text that affect reading efficiency. Tinker (1963) established a broad set of guidelines for the various parameters of printed text including line length and interline spacing depending on font, size, leading, margin size, etc. The effect of interline spacing on the clarity and comfort of printed text has been investigated by Wilkens. (1987) Wilkens suggested that reading provokes 'eye-strain' and even seizures in susceptible individuals because of the striped properties of text. (Wilkens, 1987) Wilkens determined that the clarity of text could be improved by increasing the spacing between lines of text. Poulton (1972) determined that the separation of lines of text affects legibility. Specifically, Poulton (1972) suggests that the clarity of printed text can be potentially increased at no extra cost by increasing the separation between lines slightly and decreasing slightly the mean horizontal spacing between the centers of letters.

Tinker and Paterson (1929) examined the effect of changes in line length on reading speed of printed text. They found that a shorter line length of 3 to 3.5 inches (75-90 mm) was optimal, with a longer line length of 7.3 inches (185 mm) being the slowest to read. They suggest that the longer line lengths require greater lateral eye movement and increase the chance that the reader would lose their place in the text.

These same parameters need to be thoroughly understood in terms of how they impact reading text on the screen. This includes parameters relevant to the new technology such as size and resolution of the monitor, distance of the reader from the monitor, background color, and text color. The research literature on reading from the screen discusses a number of parameters that affect reading speed. Jubis (1991) found no effect of variation in text justification on reading-time of CRT-displayed text. Jorna and Snyder (1991) found that image quality determined differences in reading performance with CRT displayed text. Gould et al (1987b) demonstrated that when characters on the screen appear similar to those on paper and when a high-resolution screen is used, differences in reading efficiency between the two presentation media are lessened. But, Dillon (1992) advised caution in the interpretation of these results and suggested that the reading task employed may have been an artificially constrained reading scenario for the purpose of experimental control.

Recent research on reading from the computer screen has focused on line spacing as a typographical variable of interest. Muter and Maurutto (1991) show that reading speed and comprehension are equivalent for high-quality (enhanced format) CRTs and the printed media. They suggest, "the paperless office may be imminent after all". The enhancements implemented in the screen condition by Muter and Maurutto (1991) include double spacing, negative contrast, Chicago boldfaced font, proportional spacing of characters within words, three space indentation of every other line to facilitate return sweeps, left justification only, 85 characters per line (cpl), eight space indent of the first line of each paragraph, horizontal separation of three spaces between sentences. The reading material used in this study was Munro's "The complete Works of Saki". There were 12 pages per story. The text encompassed 20.5 X 13.5 cm area of the screen, with an average of 12 rows of text per page.

When considering the spacing used in Muter and Maurutto's (1991) study, it seems that the increase in interline spacing is quite large. These spacing enhancements include double spacing with triple spacing between sentences, indentation every other line with eight space indent of first line of each paragraph. Muter suggests that there is little or no cost to the use of these enhancements (the additional space used) as there would be in the printed condition. Perhaps there is a cost, since the need for scrolling or paging to move through the text would be increased. Another cost is the decrease in the amount of information that could be displayed on each screen. There is an argument for displaying a large amount of information on the screen at one time. It may be more efficient to read and process large portions of text without interruption of scrolling. Interline spacing appears to be important when considering its effect on reading efficiency because interline spacing will have a large impact on the amount of information on each 'page' or screen as well as an impact on the degree of scrolling and paging required to move through the document.

The effect of line length and method of movement (scrolling and paging) has been investigated by Dyson and Kipping. (1998) They found that the effect of line length on reading rate is relatively small and does not appear to be entirely reliable across different experimental designs. While Tinker and Paterson found that reading short line length text was faster than reading long line length text when reading printed text, Dyson and Kipping suggest that there is "some indication that people can read a long line of 100 characters in a relatively efficient way, compared with very short lines" (p. 176) when reading from the screen. It is suggested that there is some benefit to longer line lengths because of the reduction in required scrolling. Dyson and Kipping also suggested that reading patterns may adjust according to line length. Reading may take place while scrolling through documents with shorter line lengths, but not necessarily while scrolling through documents with longer line lengths. Dyson and Kipping's study included line lengths ranging from 25 to 100 cpl. There was a paging condition and a scrolling condition. The text was presented on a screen with an area of 11.25 X 8.5 inches. The font used was Arial in a size of 10 point with 12 point interlinear spacing. The text was left justified, and paragraphs were signaled by a first line indent of 0.15 inches. Dyson and Kipping (1998) found that reading rates increased as characters per line increased. Their results show that while reading from the screen, a 4-inch line length produced the slowest reading rate while the 7.3 inch line length produced the fastest. They also found that paged documents were read faster than scrolled documents at 25 and 55 cpl.

In a more recent study, Dyson and Haselgrove (2001) investigated the effects of two reading speeds (normal and fast) and different line lengths on comprehension, reading rate, and scrolling patterns. The experimenters found a reduction in overall comprehension when reading fast, but the type of information recalled was not dependent on speed. Dyson and Haselgrove (2001) found that effective reading at normal and fast speeds is supported by a medium line length (55 cpl). For the reading task of their study, 55 cpl produced the highest level of comprehension and was also read faster than short lines. Dyson and Heaselgrove (2001) found that effective readers can only be defined in relation to the aims of the reading task, which may favor either speed or accuracy.

There is probably a tradeoff between increased and decreased interline spacing as well as a tradeoff between increased and decreased line length. The benefits of decreased interline spacing and increased line length include increased density of text on the screen as well as an increase in the amount of information displayed at a time limiting the amount of scrolling or paging required. The possible costs to decreased interline spacing and increased line length may be a decrease in reading efficiency due to a decrease in the density of information present on the screen. It may be important to examine the interaction between line length and interline spacing, as there may be a relationship between these two variables.

The purpose of the present experiment is to determine the effect of changes in line length and interline spacing on speed of reading as measured by the "Tinker Speed of Reading Test". Another purpose of the present experiment is to determine the effect of screen type, tablet verses desktop, on speed of reading as measured by the "Tinker Speed of Reading Test".

There are two questions of interest in the present experiment. The first hypothesis states that based on the results of the studies of reading from printed text and reading from the screen cited above, reading speed while reading from the screen is a function of line length and interline spacing. Based on the work of Muter and Maurutto, (1991), double spacing and a line length of eighty-five characters should result in better reading speed than single spacing and shorter line length. Based on the line length study conducted by Dyson and Kipping (1998), a longer line length of one hundred characters should result in more efficient reading than a shorter line length. A second focus is to determine if given the same formatting conditions of spacing and line length, reading speed is a function of screen type, tablet vs. desktop. The fact that the tablet configuration of the screen is similar in weight and size to a book or a pad of paper makes reading from a screen in this format analogous in function to the task of reading from printed text in the form of a book or a pad of paper. Because reading from the tablet screen is analogous in function to the task of reading from printed text, we expect reading speed to be faster in the tablet configuration than in the desktop configuration.

Method

Participants

The 32 participants were college students ages 18 and above from San Jose State University participating in partial fulfillment of a General Psychology course requirement. The participants reported that they were proficient in the English language, and that they had normal or corrected visual acuity.

Apparatus

A Toshiba Protégé 3500 Tablet PC computer with a 12" flat screen color monitor was used to present the stimuli to the participants. The resolution of the monitor is 1024 by 768 pixels. The Tablet PC can be used with the screen in the desktop or laptop type orientation or the screen can pivot and fold down so that the screen is face up while the computer is closed in the tablet orientation of screen. E-Prime software was used to develop, run, measure response time, and analyze the results of the experiment.

Stimuli

Passages to be read by the participants were obtained from the Tinker Speed of Reading Test. Use of this test permits speed of reading to be measured by a single variable. A modified version of the Tinker Speed of Reading Test was utilized (Tinker, 1963). This version has 500 items. For the purpose of the present experiment, 480 items were randomly selected from the 500 total items in the test; the remaining 20 items were used in the practice session. The practice session text items were chosen at random from the remaining 20 items not used in the test. The vocabulary employed is relatively simple. Each item contains one word that spoils the meaning. As a check on comprehension, this "spoiler" word is to be noted by the participant and reported orally to the experimenter once they have finished reading the item. The following is a sample item from the Tinker Speed of Reading Test: "Jim is shooting off his firecrackers now, as you can hear. I wish that he had done so at his own home, for it is too much music for me."

In the above item the word "music" is the spoiler word and was to be reported orally to the experimenter after the reading time is measured for that item. For adults (college students or high school seniors), the average percentage accuracy has been demonstrated to be 99.7%. Therefore, this test is a pure test of speed of reading performance uncomplicated by a comprehension factor.

The text was displayed in 9-point Arial font in one of the four formatting conditions; long line-length/single spaced, long line-length/double spaced, short line-length/single spaced, short line-length/double spaced format with characters that were black on a white background. Long line-length is defined as a line of about 90 characters per line (cpl), while short line-length is defined as a line of text about half as long as the long line length or about 45 cpl.

The definition of single and double spacing in the desktop condition takes into account that the average distance of the reader to the screen in the desktop condition was 58 cm. At this viewing distance a .3 mm white space between lines of text in the single spaced condition subtended a visual angle of .30 degrees in the desktop condition. At this viewing distance of 58 cm in the desktop condition a .9 mm white space between lines of text in the double spacing condition subtended a visual angle of .89 degrees.

The definition of single and double spacing in the tablet condition takes into account that the average distance of the reader to the screen in the tablet condition was 46 cm. At this viewing distance a .3 mm white space between lines of text in the single spaced condition subtended a visual angle of .37 degrees in the tablet condition. At this viewing distance of 46 cm in the tablet condition a .9 mm white spaced between lines of text in the double spaced condition subtended a visual of 1.12 degrees

Half of the participants read the material from the Tablet PC in the desktop orientation of screen, while the other half of the participants read the material from the Tablet PC in the tablet orientation of screen. Text items were presented in the landscape orientation for both tablet and desktop conditions.

The participants in the desktop screen condition were asked to sit at a comfortable distance from the screen while reading the items. The participants in the tablet screen condition were asked to hold the screen comfortably in their lap as they would a book. Distance of the reader to the screen was measured in cm for participants in both the tablet and desktop screen conditions after the practice session was completed. At an average viewing distance of 58 cm from the desktop screen, the height of an ascending letter in nine point Arial font subtended a visual angle of .40 degrees. At an average viewing distance of 46 cm from the tablet screen, the height of an ascending letter in nine point Arial font subtended a visual angle of .50 degrees. There was a roughly 25% increase in visual angle when the participants were reading from the tablet. Seating and room lighting were held constant for all participants.

Design and Procedure

A 2 (screen type) X 2 (line length) X 2 (line spacing) mixed factorial design was employed, with screen type as a between subjects variable. Each participant completed a series of sixteen practice passages, four of each of the four conditions of line length and spacing. Then each participant read through 160 experimental trials. There were 40 trials of each of the four conditions. The presentation of line length and line spacing conditions were blocked such that each participant completed all 40 trials within a condition prior to initiation of the next condition. The order of presentation of the four conditions of line length and line spacing was completely counterbalanced. The assignment of the Tinker Test items to the conditions was randomized. To begin the testing period the participant clicked the wireless mouse to initiate presentation of text.

The participant then read the text clicking the mouse again when finished reading the item. After the item was removed from the screen, the participant was prompted to state the spoiler word orally. After the participant stated the spoiler word orally, the correct spoiler was displayed on the screen. At this point the experimenter recorded the accuracy of the stated spoiler word. The participant then was presented with the next item. This process was repeated until the participant read all 160 text items. The speed of reading test took 30 to 40 minutes. The dependent measure was reading speed, which was recorded in milliseconds for each participant.

Results

Only the reading times for the correct response items were included in these analyses. The average percent accuracy of the participant's spoiler word responses to the Tinker Speed of Reading test was 97.7%. The mean search times for correct responses were analyzed in a 2 (screen type) X 2 (line length) X 2 (line spacing) mixed analysis of variance (ANOVA). Screen type was the between subjects variable. The results of this analysis demonstrated that contrary to the hypothesis that reading speed while reading from the screen is a function of line length and interline spacing there was no main effect of line-length, $F(1,30) = 1.53$, $p = .226$ or line spacing, $F(1,30) < 1$. Additionally, the second hypothesis that reading speed is a function of screen type was not supported as there was no main effect of type of screen, $F(1,30) < 1$. There was an interaction of screen type by spacing, $F(1,30) = 13.34$, $p = .001$.

Table 1 presents the single and double spacing means for both the tablet and the desktop screen conditions. It can be seen that for the tablet screen the mean reading time

Table 1

Mean Reading Time in Milliseconds

	Line Length		
Screen Type and Spacing	Long	Short	Mean
Tablet Single	7486	7601	7543
Tablet Double	7951	7951	7951
Desk Top Single	7872	8116	7994
Desktop Double	7379	7610	7495

is faster in the single spacing condition with a mean reading time of 7543.9 ms, SE = 396.60, and a mean reading time of 7951.5 ms, SE = 425.38 in the double spacing condition. For the desktop screen the mean reading speed of 7495.1 ms, SE = 423.73 time is faster in the double spacing condition than a mean reading time of 7994.2 ms, SE = 424.46 in the single spacing condition.

Discussion

The results of the analysis of the mean reading times from the four conditions of line-length and line spacing failed to show statistically significant support for the hypothesis that reading speed from the tablet or desktop screen is a function of line length and line spacing. The results of this analysis also failed to show support for the second hypothesis that reading speed from the tablet screen would be faster than reading from the desktop screen. The present experiment did find a statistically significant interaction between line spacing and screen type.

Figure 1 shows the mean reading times for the two conditions of spacing in both the tablet and desktop screen conditions. By looking at Figure 1, it can be seen that for the tablet screen, the single spacing condition resulted in lower mean reading times than the double spacing condition, while for the desktop screen the double spacing condition resulted in the lower mean reading time than the single spacing condition.

Only the reading rate results of the desktop screen are consistent with the findings of Muter and Maurutto (1991) who found that increased spacing enhanced reading speed from the computer screen. The results of the present experiment demonstrate that for the tablet screen, reading the text items in the single spacing condition is more efficient than reading them in the double spacing condition. These results suggest that reading from the tablet is somehow different than reading from a traditional desktop or computer screen. In the Muter and Maurutto (1991) study reading from printed text was compared to reading from the screen. The experimenters were attempting to show that reading enhanced text, which included increased spacing, from the screen could be as efficient as reading un-enhanced, single spaced printed text. Muter and Maurutto (1991) reported a reading rate of 251 and 245 words per minute (wpm) without a correction for comprehension. This result was then converted to an "effective rate" by multiplying the wpm by the proportion correct on a comprehension test. In comparison to Muter and Maurutto's (1991) results, the results of the present study yielded the fastest reading rate of 240 wpm for the accurate items only in both the tablet, single spacing and desktop, double spacing conditions, while the slower reading rate of 225 wpm was the resulting reading rate in the tablet, double spacing and desktop, single spacing conditions.

Gould et al (1987b) used proofreading as an experimental task to explore the reasons for reading from the screen being slower than reading printed text. They conducted a series of six experiments in which the quality of the text that was presented on the screen was improved, resulting in screen reading rates as fast as reading from paper. The improvements to the text on the screen included the use of character fonts that resembled those on paper (rather than dot matrix fonts), dark characters on a light background that are anti-aliased (i.e., contain grey level), and the use of screens that had relatively high resolution (e.g., 1000 X 800 pixels). The experiments conducted by

Figure 1

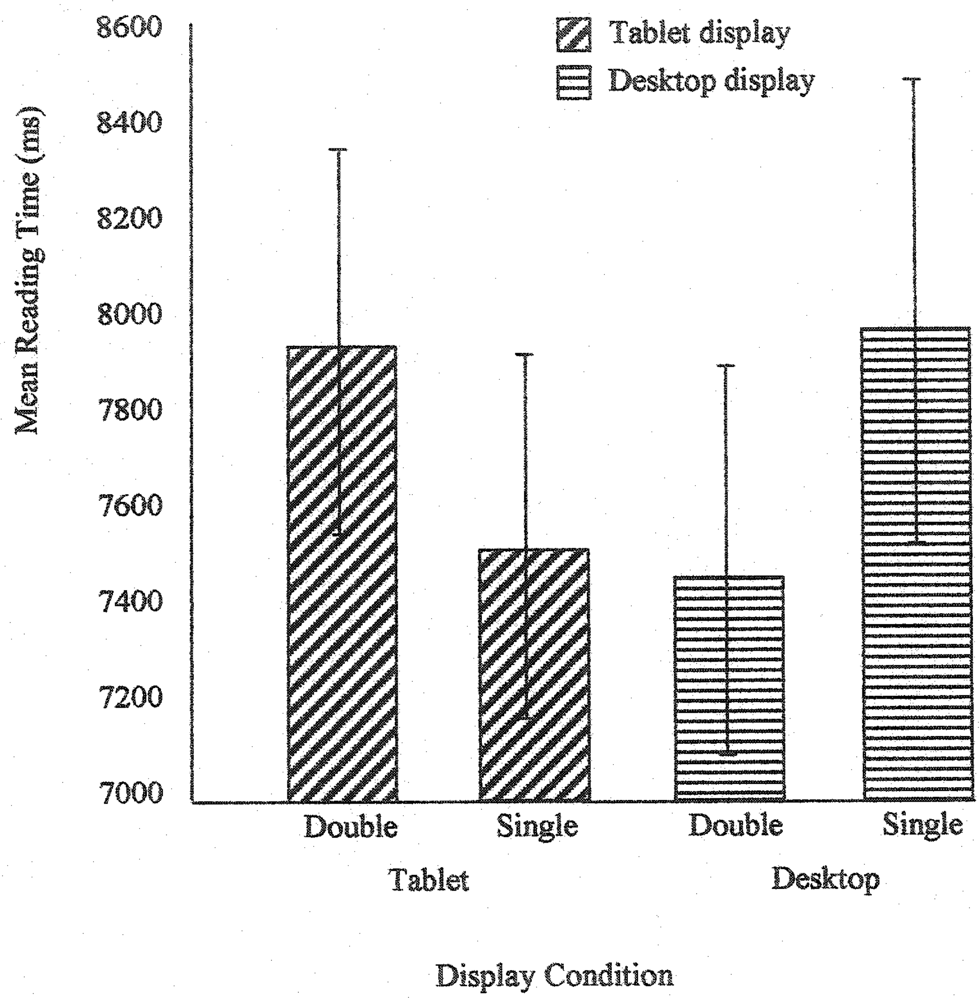

Figure 1. Mean reading time of single and double spacing conditions in the tablet and desktop screens showing the screen by spacing interaction.

Gould et al (1987b) did not examine the effect of line spacing on reading rate as they held line spacing constant in the screen and paper reading conditions. In comparison to the 225-240 wpm reading rate in the present study, the reading rate in the Gould et al (1987b) experiments were in the range of 190 to 220 wpm.

Dyson and Kipping (1998) examined the effects of changes in line lengths ranging from 25 cpl to 100 cpl on reading rate. Looking at the results of the present study in the context of the work of Dyson and Kipping (1998) it is noted that their results yielded reading rates of 230 wpm to 255 wpm, and the reading rates obtained in the present study were in the range of 225 wpm and 240 wpm.

When looking at the experiments performed by Dyson and Kipping, a limitation of the present study becomes apparent. The difference between the line lengths of 45 cpl and 90 cpl used in the present study may have been too small to produce an effect of this variable on reading speed. A future study might include a greater range in the line length variable studied. By including a shorter line length than 45 cpl and a longer line length than 90 cpl, a potential effect of line length on reading rate may be detected. Future work should endeavor to better define the conventions for the typographical formatting of line length and how changes in line length effects reading speed from the desktop or tablet screens.

Another limitation of the present study and a factor that makes comparison of these results to the previous studies difficult is that the reading paradigm used in the Tinker test is constrained. There may be a limitation of using the Tinker test in that the text items are only about 30 words each, while the text used in all of the other cited studies of reading from the computer screen is lengthy text passages pulled from novels, short stories or periodicals. The limited number of lines of text in the reading material of the Tinker text items may have impacted the effect of the spacing independent variable on reading speed. There may not have been a sufficient number of lines of text to detect the potential effect of spacing on reading speed.

A possible explanation for the single spaced condition resulting in a faster reading speed in the tablet screen condition relates to the idea that single spaced text is frequently used in books. Reading from the tablet is functionally analogous to reading from a book. So, perhaps since reading single spaced text is common when reading from a book, it is read faster when reading from the tablet screen since it is functionally similar to a book.

Future studies might more precisely control the seating for participants reading from the tablet screen to see if this might impact the results of reading from the tablet. A future study might examine the impact of a variety of distances and angles to the tablet screen on reading speed. It should also be noted that the text was read in the landscape orientation of the screen in both the desktop and the tablet screen conditions. It might be interesting to study the difference between reading the text in portrait verses landscape orientation from the tablet screen and comparing those results to reading from the desktop screen.

Although the Tinker Test may have limitations in terms of the small number of words per text item, there still may be value in attempting to evaluate these formatting parameters (line spacing, line length as well as font type) utilizing the Tinker test as it was used to evaluate these same formatting parameters of printed text. Future work also might include manipulations of font size in conjunction with manipulations of line-length to determine the optimal line length for the various font sizes.

As the e-book is accepted as a new reading medium, the results of this study suggest that perhaps the conventions for reading from the desktop screen may not apply to reading from the tablet screen. Typography conventions for reading from the desktop screen still need to be defined, and perhaps a separate set of typography conventions will apply to alternative screens such as the tablet.

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Appendix

Human Subjects-Institutional Review Board Approval Letter

San José State
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To: Victoria Dulchinos
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From: Pam Stacks, *Pam Stacks*
Interim Academic Vice-President
Graduate Studies & Research

Date: August 6, 2003

The Human Subjects-Institutional Review Board has approved your request to use human subjects in the study entitled:

"Effects of Change in Line Length and Intraline Spacing on Speed of Reading from the Tablet PC ."

This approval is contingent upon the subjects participating in your research project being appropriately protected from risk. This includes the protection of the anonymity of the subjects' identity when they participate in your research project, and with regard to any and all data that may be collected from the subjects. The approval includes continued monitoring of your research by the Board to assure that the subjects are being adequately and properly protected from such risks. If at any time a subject becomes injured or complains of injury, you must notify Pam Stacks immediately. Injury includes but is not limited to bodily harm, psychological trauma, and release of potentially damaging personal information. This approval for the human subjects portion of your project is in effect for one year, and data collection beyond August 6, 2004 requires an extension request.

Please also be advised that all subjects need to be fully informed and aware that their participation in your research project is voluntary, and that he or she may withdraw from the project at any time. Further, a subject's participation, refusal to participate, or withdrawal will not affect any services that the subject is receiving or will receive at the institution in which the research is being conducted.

If you have any questions, please contact me at (408) 924-2480.

cc: Dr Kevin Jordon