The Effect of Screen Size on Reading Speed: A Comparison of Three Screens to Print

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Abstract. Many students are starting to rely on screens to consume their textbooks rather than paper. Does the screen have an effect on reading speed according to its size or when compared to traditional paper? In this study, 64 men and women started the experiment with a different device and read four short stories for 10 minutes each. Participants read on a 17" computer screen, a paperback book, a 10" tablet and a 3" cell phone screen. The number of words they read were counted and the actual words read per minute were calculated. No significant effect of reading speed was found across the screen sizes or the book. Individual participant's reading speed was remarkably consistent across all of the devices suggesting that reading speed does not vary with presentation mode for a brief period of time.

Keywords: reading speed · screen size · book · tablet · cell phone · font size · e-textbooks · textbooks

1 Introduction

Significant improvements have been made in electronic displays which have improved the clarity. Display technology has moved away from CRT (Cathode Ray Tube) screens toward LCD (liquid crystal display) screens. LCD technology allows for the better reproduction of images and fonts. This has reduced the amount of hardware needed and allowed engineers to develop smaller screens with sharper resolution. Screens are typically measured diagonally from top right to bottom left.

Presently, several devices are marketed as reading devices (i.e. Kindle, iPad) for pleasure and for use as a replacement to textbooks. We know from previous studies that some of these devices will enhance the perception of letter forms by supporting various design factors [1]. Comparing the devices during reading will suggest attributes that contribute positively and negatively to usability and to reading.

The processes involved in the perception of letters is a topic of recent concern because of the proliferation of electronic reading devices and the suggestion that these devices would be suitable replacements for textbooks [2]. Previous research indicates that perception of objects is a natural process that humans can do fairly easily (e.g., [3], [4]). Historically, some studies in this area have found that people have difficulty reading on electronic screens.

One of the first studies done by [5]Gould, Alfaro, Finn, Haupt and Minuto (1987) suggested that there was no difference between reading on a CRT (Cathode Ray Tube) screen and the paper. Subsequent studies have found a fundamental

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disagreement. One group argues that paper will never be replaced because of its inherent qualities of portability, long battery life, and the physical sensation of holding a book [6]. The other group suggesting that it is simply a matter of time before all reading material will be electronic and we should adapt. Up until recently, the general consensus has been that reading speed is severely hampered by a display with poor quality of font reproduction.

Some of the more recent studies have found no difference between screen sizes and paper. For example, [7] compared the speed of reading between paper, a computer, and a mobile device to see if there was a difference between the three. They tested for an interaction between font size and the type of screen size. In this study, 54 women and 70 men who were about 23 years old participated. First, they read on paper in three different font sizes; 10 point, 12 point and 14 point fonts. As the font size increased on paper so did the reading speed for both men and women. The next test was done on the computer with the same fonts in the same sizes. In the computer results, the speed was faster when the font increased as well. The results from the computer also showed that reading off the computer was faster than reading off of the paper. The last test was done on a mobile device with a small screen. A specialized software was used for text visualization. For the mobile testing, it was found that women have a faster reading speed than men. It was also found that when scrolling top to down a faster reading speed was achieved compared to scrolling side-to-side. The highest reading speeds come when the font size is 14 on paper or a computer and when able to scroll top-down on a mobile device.

Another study [8] measured the time it took the participants to locate words and the time it took them to read different material on a phone. Software was installed in the phone to create a circular display on the phone. The software was put on a Nokia Lumia 920 with a screen size of 4.5in. diagonally. The simulated circular display was 3.2in. Three different text layouts were used on the device (cropped, overflow and adaptive). Two different reading materials were used in this experiment, one being for the reading baseline and the other a more detailed read. When given the phone, participants would see a start button and whenever they were ready they could hit start. To measure the reading time, a hidden timer was installed within the software. When participants would hit the start button the time would start, when they hit the end button the timer would stop. To measure word locating, the timer on the software was also used. The participants were asked questioned based on the article they just read and were asked to find one keyword and tap on the key word to indicate that they were finished. The results from this study was that out of the three different layouts used for all subjects, the adaptive layout was found to have the best reading results. The cropped layout had fewer words in the screen and caused the participants to skip lines and scroll more becoming distracting. When comparing all three layouts, participants' performance was not significantly different.

The next study, [9] Dundar and Akcayir tested elementary school students in the United States on their comprehension and reading speed on both printed and electronic devices. Twenty students were divided into two groups. One group read off paper and the other read off a tablet. Qualitative and quantitative data was collected through reading speed and reading understanding. Speed was calculated by the number of words that the student read correctly out loud. Comprehension levels were calculated by a level of understanding chart. Opinions of students collected from interviews afterwards stated that most of the students preferred the tablet because of the smaller size, being able to change the font and letter size easily, being able to scroll instead of flip pages and the novelty of reading from the tablet. Even though there was a big difference in preference for the tablet, there was no significant difference in the reading speed and reading comprehension between the tablet and paper.

Foasberg [10] wanted to find out which college students preferred; electronic or paper when reading and why they preferred one over the other at different times. She had students keep a diary and record information about their reading habits for 12 days. They recorded 1.) Why they were reading 2.) What was the format 3.) The location where they were reading and 4.) Length of the reading. Students preferred paper based reading when it was for a class and they preferred electronic based reading when it was a short article or recreational reading. The genre of the readings was also recorded; researchers found religious genres took the longest time to read while non-academic article took the shortest amount of time.

Siegenthaler and colleagues [11] wanted to test to see if the printed format and an e-book format created the same reading response. In this experiment, eye movement was recorded to track the movement while reading off the two separate devices. Because of the eye tracking system, participants were 60 cm away from the reading material. The participants were given two hours for the reading and in-between both reading formats, they were asked to talk about their experiences and give their opinions. They found that the eye movements for the e-book is very similar to the eye movement on print. Participants reported no difficulty with either of the two formats. The study did find that the participants had longer fixation times while reading the printed book.

Tveit and Mangen [12]wanted to see if there was a gender difference in reading on a screen or book in high school students. There were 143 students, 71 boys and 72 girls with an average age of 15 years old. The experimenters wanted to see if the students would lose interest or gain interest when switching devices mid-story. The experimenters also collected demographics, native language, and reading habits. Students were given a story to read and were given 15 minutes then were told to stop and switch as they continued to read the same story. Thirteen percent of the participants did not notice a difference when reading on the two different devices. The students who enjoyed reading in their spare time reported that they preferred the paperbound print version over the e-book version.

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These most recent results suggest that there is no difference in reading speed between electronic books and paper books. However, research does not indicate if the size of the screen has an effect on reading speed. In this study, we compared the size of the screen to a paper book of average size.

People read on screens of many different sizes throughout the day. Individuals who read long emails, browse webpages, documents, and view forms on small format screens. Throughout a typical day, a single individual may read text on five or more screens. They may read on the display screen on their phones (3-inch LCD screens), their laptops (17-inch screens), their car's navigation system (5-inch screens), their tablet (10-inch screens) and their television (25-inch screen). The amount of text read on each different type of screen may vary. However, a person is likely to be reading several paragraphs of text on a small phone screen as a laptop screen.

We wondered if the size of the screens had an effect on reading speed. We also wondered if the reading material had an effect on reading speed on the different screens. Would a person read faster or slower with the same book on different screens as Tveit and Mangen had done? Would a person read faster or slower if they were reading a novel from the 1900s compared to a text written in 2005?

1 Method

Design

We constructed a mixed design experiment with screen size as the factor. The screen size consisted of four levels, mobile phone (3"), tablet (10"), laptop (17"), and paper material (approximately 5" x 8" book). The dependent measure was the number of words that a participant could read in ten minutes. Participants read four stories in the same book. They read stories in The Dubliner's [13](Joyce, 1914) or Blink (Gladwell, 2005).

Participants

Sixty-four participants between the ages of 18-37 years old volunteered for the study. These participants were undergraduate college students who received course credit for their participation in the study. There was a mean age of 20 years with a standard deviation of 4.76 years. Overall, 13 men and 42 women (9 participants did not indicate gender) participated in the experiment. Participants performed at the norm on the Nelson Denny reading comprehension test with a mean score of 50% (SD = 20%). There was a medium correlation found between reading speed and the score on the Nelson Denny reading test r (53) = 0.28.

Materials

We used the books: The Dubliners by James Joyce (Joyce, 1914) and Blink by Malcolm Gladwell [14](Gladwell, 2007). For the Dubliners, participants read the chapters; "The Sisters", "Two Gallants", "A Little Cloud", and "An Encounter". For Blink, participants read the chapters; "The Statue that Didn't Look Right", "The Theory of Thin-Slicing", "The Locked Door", and "The Warren Harding Error".

Procedure

As the participant was greeted and consented, they filled out a sheet of demographic information and then took a standardized reading test, the Nelson Denny [15](Brown, 1960). Then, they were seated at a computer desk with the first device. The device that they started with was determined by the pre-coded condition to which they were assigned. Participants were unaware of the different presentation order or which book they would read.

The participant was asked to read the chapter for 10 minutes. The research assistant kept time using the stop watch function on a cell phone. At the end of ten minutes, the research assistant asked the participant to stop and keep their finger on the place where they stopped reading. The research assistant recorded the last four words that the participant read. Then, the participant answered reading comprehension questions and rated their satisfaction with the device. Afterwards, they were given the next device and read the next chapter for ten minutes. Once all four devices had been used, the participant was debriefed. Participants read either Blink or the Dubliners on all three screens and the book.

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2 Results

Reading speed was calculated by determining where the last four words that the participant read were located within the story using Microsoft Word's word count function. If the four words that were recorded occurred more than twice in a given story, that data was marked as undetermined and excluded from the data set. There were seven instances of this in the entire data set.

For the first hypothesis, did participants read faster on any of the three devices or the book? We found participants did not read significantly faster on one screen or book over the other F (3, 138) = 0.04, p = 0.989. Overall, participants read at an average speed of 179 wpm (SD = 63 wpm).

For the second hypothesis, did participants read faster on one book compared to the other? We found that participants read the book Blink faster than the book The Dubliners, t (221) = 1.77 p = 0.03. The participants read the Blink book faster by an average of 75 words per minute.

We collected self-report data on a diagnosis of a reading disability. We wondered if the screen size had an effect on these individuals and conducted a separate analysis. Seven of the participants tested reported that they had been diagnosed with a reading disability. Their reading speed was not significantly different by device. F (3,18) = 1.03, p = 0.40. the mean reading speed for the book was 156 wpm (SD = 69 wpm); for the tablet the mean speed was 146 wpm (SD = 71), for the computer = 196 wpm (SD = 102), for the mobile phone the mean speed was 157 (SD = 65).

Participants preferred to read a paperback book with nearly half of the participants putting this as their top choice (n = 30). Thirteen participants chose the tablet as their top choice, three participants chose the computer while two participants chose the mobile phone. Fifty-three percent of the participants reported to have rented an e-textbook. Of these, 18 participants had rented an e-text more than once.

3 Discussion

We found that screen size does not have an effect on reading speed when the participants read for a short amount of time. This is supported by previous research. For example, in [9]Dundar, H., & Akçayır, M. (2017) they asked children to read on a computer screen and on a printed piece of paper. There was no significant difference in speed between the two devices (t = 0.811, p > .05) or in reading comprehension (t = 0.67, p > .05).

In Gould, Alfaro, Finn, Haupt, Salaun, and Minuto (1987)[5], 40% of the participants had no difference between the computer and printed reading material on a Cathode Ray Tube (CRT) screen. We believe that as technology improved and the frequency of reading on screens increased, the population as a whole became accustomed to reading on screens for short durations.

Reading for short durations of time reflect no difference in processing speed across different screen sizes or between the screen sizes and a similarly sized book. In this study, participants' screens had the same font size as was the default setting of 14 point which is slightly larger than The Dubliner's book font size of 11 point and the same as Blink's book font size of 14 point. In this instance, the participants did not mention that The Dubliner's font size was remarkably smaller and this difference did not seem to impact their ability to read the book rather than the larger font size on the three screens.

While we planned on using the comprehension questions in the analysis, we were unable and chose to focus on reading speed. Future work should determine sufficient comprehension questions and implement a rubric for assessing the same question across the two texts. We found that in novels such as The Dubliners, literal questions produced a ceiling effect. True comprehension questions were inconclusive as interpretations differed in short passages.

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