Article • Reading Comprehension and Eye Movement Abilities: A Comparison of Digital and Print Presentations

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ABSTRACT

Background: As the world moves toward an increasingly digital age, differences in reading between digital and paper presentations become more pertinent. We aimed to contribute to the evidence in order to answer the question: Is there a difference in reading ability when comparing paper and electronic formats?

Methods: Optometry students (n = 50) aged 20-35 years old were recruited for this study and were screened for any abnormalities of their visual acuity or binocular system. Eligible subjects were randomized to read either a computer passage or paper passage first. Comprehension, reading speed in words per minute, fixations, and regressions were measured for each group via the infrared technology of the Visagraph III™.

Results: For the computer passage, the average comprehension percentage was 77.5±14.5, and for the paper passage, 80±14.8. Average words per minute for the computer passage were 276.7±72.04, and for the paper passage, 238.1±56.0. Average fixations for the computer passage (right eye only) were 82.4±19.6, and for the paper passage, 104.6±22.1. Average regressions for the computer passage (right eye only) were 9.1±6.2, and for the paper passage, 10.4±5.8. Two-tailed paired t-test statistics were used to analyze the data for each of the reading components. There was no statistically significant difference when comparing the computer to paper presentations for either reading comprehension or regressions. A statistically significant difference was obtained for reading speed $t=2.67$ ($p<0.01$) and fixations $t=-4.74$ ($p<0.001$).

Conclusions: Subjects reading the computer passages had a statistically significant faster reading speed compared to those reading the paper passages. Subjects reading the paper passage had a higher fixation rate compared to the computer group, which may have contributed to the slower reading speed. Further research is needed to see whether these results are repeatable in a younger cohort.

Keywords: digital device, eye movements, reading speed, Visagraph

Introduction

There is no question that digital devices are becoming increasingly prevalent. In classrooms, many students are using digital devices for reading or other homework assignments. A 2014 survey from the American Optometric Association found that 83 percent of children between the ages of 10 and 17 years estimate that they use an electronic device for three or more hours daily.[1] A 2015 report from the National Center for Education Statistics confirmed that 94 percent of 3- to 18-year-olds have access to a computer at home.[2] Several states across the country have given students the option of online schooling for high school classes; colleges continue to offer online classes; and many books, both recreational and reference,

are available in some type of digital format. With this movement toward digital reading, especially in the classroom, the question arises: Is there a difference in reading skills between digital presentation and traditional paper? A few studies have attempted to answer this question, with varying results.

Kretzschmar et al. compared reading speed, eye movements, and brain activity via EEG on three types of media (paper, tablet, and e-reader) with two cohorts (young and elderly adults).[3] They also evaluated whether subjective preference of material type had an effect on the reading results. While an overwhelming number of their subjects preferred traditional paper text as their reading modality, the younger cohort demonstrated relatively similar fixation rates in all reading forms. The elderly adults did have longer fixation durations in the e-reader and paper compared to the tablet computer, but overall, there was no statistically significant data to support that reading on digital media devices was significantly different from paper.[3]

Data published within the past decade seems to support that paper presentations allow for better comprehension while reading. Mangen et al. explored reading comprehension in Norwegian students.[4] Subjects read two passages in print and then the same two passages in PDF format on a computer, with comprehension assessed following the conclusion of reading the passage. They found that students reading on paper had higher comprehension scores compared to students who read the paper electronically as a PDF.[4] Another study by Ackerman and Lauterman also evaluated reading comprehension among eighty university students on both paper and digital forms.[5] Subjects read five texts under various time conditions: two texts were timed; two texts had no time limit; and one text had no time limit, but subjects were interrupted while reading.[5] They found that paper readers had better comprehension scores, but not for the interrupted passage.[5]

There are many questions as to whether digital devices cause increased symptoms when reading. Anecdotally, optometric clinicians see a growing number of patients with near-point complaints related to near work, much of which is being done electronically. Multiple recent studies evaluating blink rate on digital platforms compared to paper presentations have shown that decreased blink rate while reading is more likely a result of the cognitive demand of the material and not the type of presentation.[6,7] With conflicting evidence in the small body of literature that is available on this topic, we aimed to contribute evidence to answer the question: Is there a difference in reading ability when comparing paper and electronic formats?

Methods

Recruitment

This study was conducted at the Michigan College of Optometry between February and April 2018 in the University Eye Center Clinic. Optometry students aged 20-35 years were recruited for this study through verbal measures. This study was approved through the institutional review board (IRB) at Ferris State University. All subjects signed a written consent form before any clinical data was obtained.

Eligibility

In order to participate in the study, investigators screened subjects for any abnormalities of their visual acuity and binocular system. Subjects had to achieve best-corrected visual acuity of 20/25 or better in each eye at distance and near. We evaluated near phoric posture via unilateral and alternating cover test. All subjects who had strabismus, near exophoria greater than or equal to 6 prism diopters in magnitude, or near esophoria greater than or equal to 2 prism

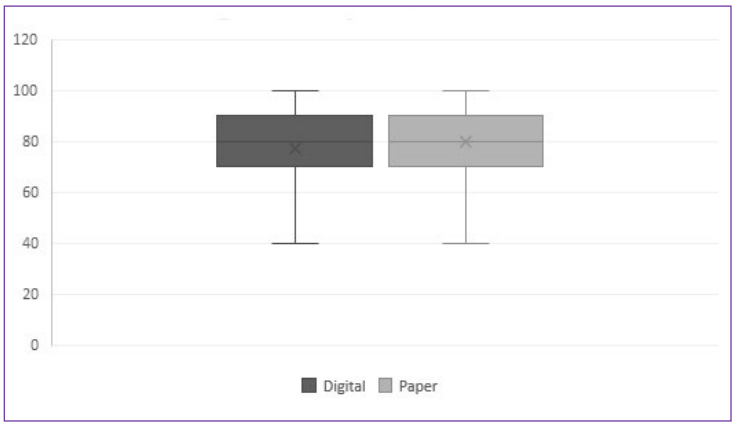

Figure 1. *Comprehension scores*

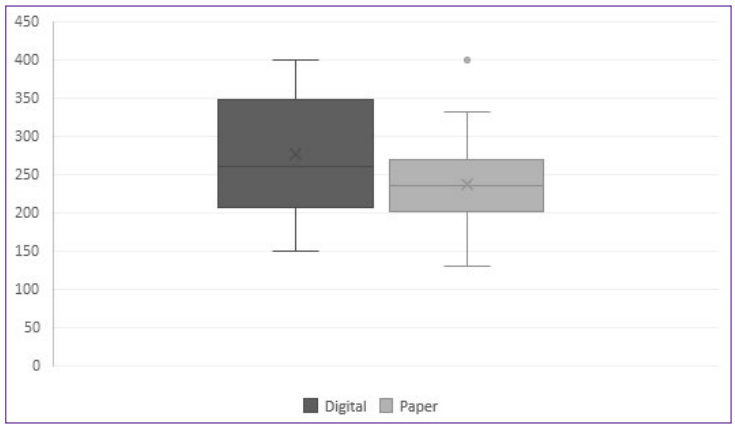

Figure 2. *Reading speed in words per minute*

diopters in magnitude were excluded from the study. Accuracy of the accommodative system was evaluated by Monocular Estimation Method. All subjects needed to demonstrate an accommodative response between +0.25 and +1.00 diopters in order to participate in the study. Any subject outside of this range was excluded from the study. All screening testing and study testing was performed through the subjects' habitual glasses correction.

Procedures

There were 50 subjects who consented to participate in this study. Of those, 10 were excluded because they did not meet the eligibility requirements. Of the 40 eligible subjects who participated, 17 were male and 23 were female. Eligible subjects were randomized to read either a computer passage or a paper passage first. Twenty-one subjects were randomized to the computer group first, and 19 subjects were randomized to the paper group first. Each subject was assigned an adult-level passage from the Visagraph III test library to read. Paper passages from the Visagraph III test library were duplicated as word documents as closely as possible into a computerized format for the electronic presentation. If the subject was randomized to the computer group first, they read one of three Visagraph III paragraphs: Amundsen (n=17), Louis Braille (n=12), or Dorothea Dix (n=11). If the subject was randomized to the paper group first, they read from one of three Visagraph III paragraphs: Clarence Darrow (n=14), John Roebling (n=17), or Houdini (n=9). Once the subject read through the respective passage, the investigator read the ten-question comprehension quiz aloud and typed in the subject's true or false responses. Once the clinical data was obtained for the subject's first presentation type, they began the same process for the other presentation type, but with a different passage. Reading speed in words per minute, fixations, and regressions were measured for each group via the infrared technology of the Visagraph III, and the comprehension score for each subject was also recorded. The total process length was approximately fifteen minutes per subject. Results were analyzed for any statistically significant differences between the two groups in each of the reading subcategories.

Data Analysis

Descriptive statistics are reported as the mean ± standard deviation. The mean scores for each study component (comprehension, reading speed, fixations, regressions) were compared using two-tailed paired t-test. For fixations and regressions, statistics were run on the right eye only due to similar results between the two eyes.

Results

Forty subjects completed the study. For the computer passage, the mean comprehension percentage score was 77.5±14.5, and for the

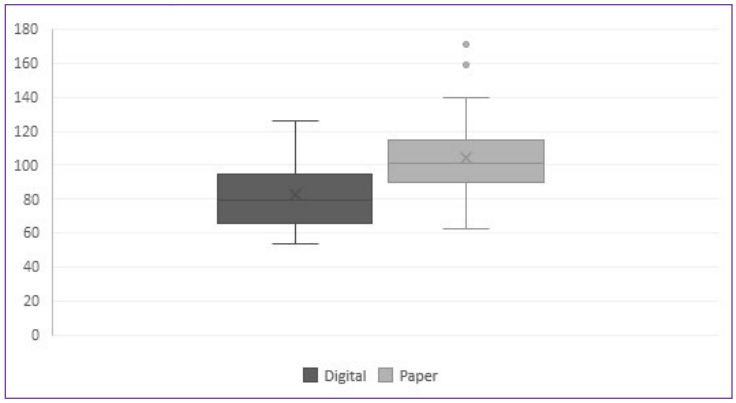

Figure 3. *Fixations (per 100 words) OD*

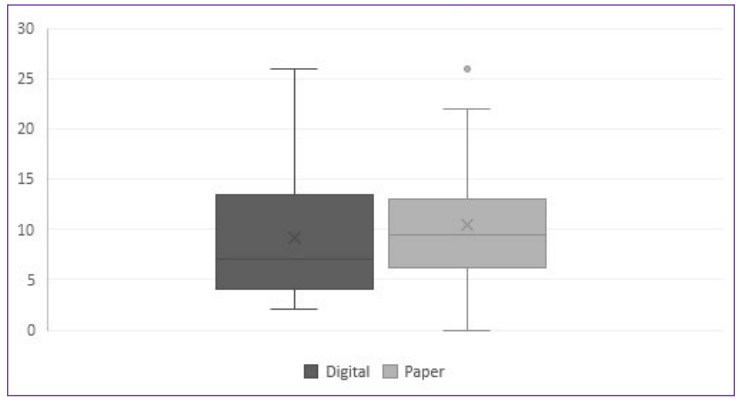

Figure 4. *Regressions (per 100 words) OD*

paper passage, the mean comprehension score was 80±14.8 (Figure 1). The mean reading speed in words per minute for the computer passage was 276.7±72.04, and for the paper passage, the mean was 238.1±56.0 (Figure 2). The mean number of fixations per 100 words for the computer passage (right eye only) were 82.4±19.6, and for the paper passage, the mean was 104.6±22.1 (Figure 3). The mean number of regressions per 100 words for the computer passage (right eye only) was 9.1±6.2, and for the paper passage, the mean was 10.4±5.8 (Figure 4). There was no statistically significant difference when comparing the computer to the paper presentations for either reading comprehension ($p<0.45$) or regressions ($p<0.33$). A statistically significant difference was present for both reading speed ($p<0.01$) and fixations ($p<0.001$). Results from the computer passage were faster, with fewer fixations.

Discussion

We aimed to assess whether there was a statistically significant difference in various visual skills while reading in a digital compared to a paper format. Based on previous literature, we did not think that there would be a statistically significant difference in comprehension between the two modalities. However, we were unsure whether there would be a difference for the other reading factors. This study concluded that there was not a statistically significant difference between presentations for comprehension or regressions. This is not surprising, given the nature of the reading material, which was a low demand for the education level of our subjects. However, we did find a statistically significant difference for reading speed and fixations, with the paper passage taking longer to read and having more fixations per passage. We suspect that these results may be partly attributable to the fact that subjects recruited for this study are accustomed to studying and reading on various types of digital devices. This may have skewed the data to faster times for digital presentations. This study may not be repeatable for a younger cohort, who may be learning to read or who may not be as accustomed to using digital media. Second, the involvement of each individual only took around 15 minutes per subject. The investigators do not consider this timing as prolonged near work, and the length of the reading may have an effect on the overall results.

There were several limitations to our study. We did not take into account mental attitude before reading the passages. Previous studies have evaluated preferred study/reading method and mental attitude towards different genres of reading material before conducting their research.[3,5] It may be of value to ask subjects their preferred reading method and to divide groups into paper-preference and computer-preference cohorts to compare final scores.

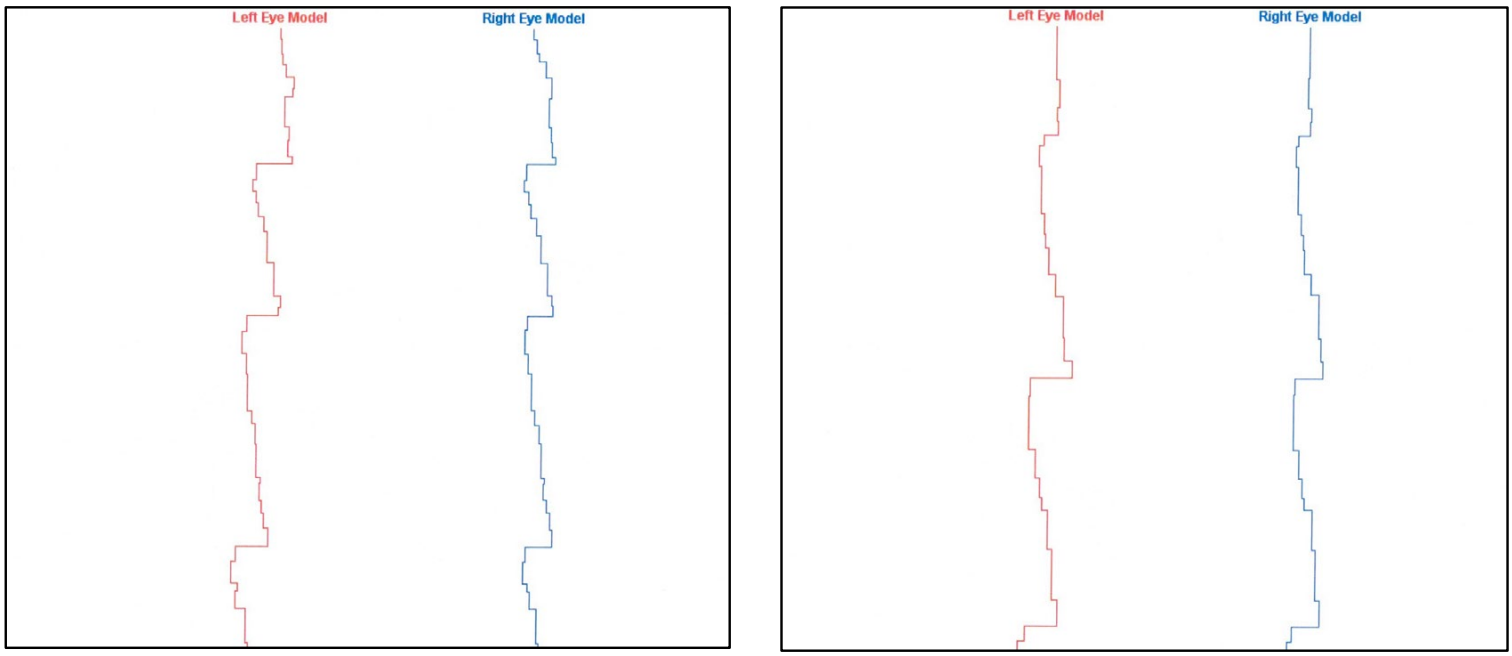

Figure 5. *A sample staircase pattern for a subject reading in the paper (left) and digital (right) modality. There were fewer return sweeps for the computer passage, as there were fewer lines per passage.*

Finally, the Visagraph III does not have electronic copies of their texts. As such, the researchers manually recreated the passages electronically, with attention to font type, size, and spacing to match the paper texts as closely as possible. Despite best efforts, there were differences between the computer and paper texts. Reading a sentence in English occurs from left to right, with a return sweep to the next sentence. A return sweep is defined as finishing a sentence and returning gaze to the left to begin reading the next line below. Although each presentation was copied word for word, there were fewer lines in the computer passage than the paper passage, resulting in fewer return sweeps for the computer passage cohort (see Figure 5). This could have artificially increased the reading speed for the digital format, as subjects had to make fewer return sweeps. However, the number of lines in the text should not have had any impact on fixations, which were also statistically different between the two cohorts.

Conclusion

For adult optometry students, subjects read faster when using digital print compared to paper print, without any effect on comprehension. Further study is needed to see whether these results would be repeatable in cohorts of different ages, over longer periods of near work, with material of higher cognitive demand, or with other types of digital devices.

Conflicts of Interest

The authors of this paper have no financial arrangement with any of the companies or products described in this paper and have no financial disclosures.

Acknowledgments

The authors thank their students for their participation in this research study.

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McDowell P, Shank A. Reading comprehension and eye movement abilities: A comparison of digital and print presentations. Optom Vis Perf 2019;7(5-6):309-14.