Evaluating a Speed Reading Technique using Eye Tracking

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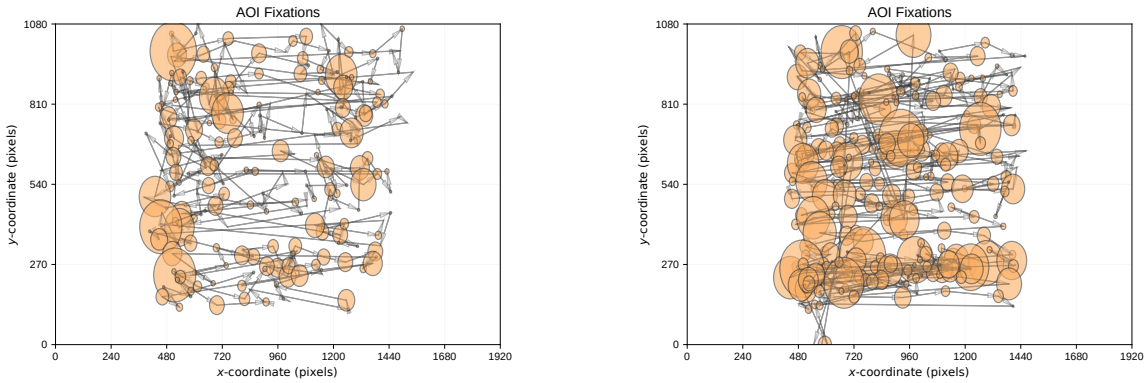

Figure 1: Illustration of scan paths when reading a passage. On the left, a reader is using the speed reading technique and on the right a reader is reading the same passage at normal speed.

ABSTRACT

The idea of speed reading, reading significantly faster than the average college-educated reader, is enticing. Eye-tracking technology is used to evaluate the effectiveness of a speed reading technique. Using a Gazepoint GP3, novice participants were evaluated on time to completion and comprehension of a selection of passages from the SOLPASS Elementary School Reading Assessment. The experiment was within-subject design during data collection but later changed to between subjects for data analysis purposes due to data corruption. We found a statistically significant difference in the mean number of fixations in between normal readers and speed readers. There was a low correlation between comprehension and reading speed; and between comprehension and the number of fixations, suggesting that speed reading techniques did not materially reduce understanding in readers.

KEYWORDS

Eye tracking, Speed reading, K coefficient

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1 INTRODUCTION

Speed reading is a technique in which a reader increases their reading speed while maintaining their comprehension level [12]. The idea of speed reading has been a concept that has intrigued many since 1959 when Evelyn Woods released her Reading Dynamics course. Since then speed reading has been rising in popularity. The average college-educated adult would be considered a good reader. These readers can generally read at a speed of 200 to 400 words per minute. Speed readers have been able to surpass this level. For example, Anne Jones, a six-time speed reading champion, was able to read a Harry Potter book in 47 minutes and recounted the details. She can read 4,700 words per minute. Another speed reader by the name of Howard Berg can read as many as 25,000 words per minute with complete comprehension [14].

The biggest concern when it comes to speed reading is the relationship between speed and comprehension. While speed reading sounds appealing, reading at such a high level may come with some negative effects. Keith Rayner, an expert in eye tracking and eye anatomy, suggests that after a reader surpasses 400 words per minute, there is a severe effect on comprehension [12]. Readers with low reading speed may show some improvement after enrollment in a speed reading course, however, once they can read the average speed of a college-educated adult, their comprehension scores drop again. There also tends to be a drop in comprehension the more difficult the designated passages become.

Despite these concerns regarding comprehension, speed reading can be extremely beneficial compared to slow reading in certain scenarios.

"Speed, enjoyment, and comprehension are closely linked with one another and with the amount of practice a reader gets. Any of these factors can provide the key to getting us out of the vicious

circle (reads slowly, doesn't enjoy reading, doesn't read much, and doesn't understand) and into the virtuous one (reads faster, reads more, understands better, and enjoys reading)" [1]

Readers who read slowly tend to fixate from word to word and linger on each fixation [2]. This style of reading is labor-intensive and frustrating. Many readers may benefit from using speed reading techniques to make the reading process more engaging and interesting.

Regarding reading speed and comprehension, eye tracking is a helpful technology as it can capture reading-related objective metrics to assess the usefulness of speed reading. Furthermore, the eye-tracking metrics can provide insights into the cognitive load a user feels when deliberately using speed reading techniques to read a passage. Certain metrics that can help assess the readers' cognitive load are fixation duration suggesting difficulty in reading and number of fixations suggesting the importance of a section in the passage [5].

1.1 Background

Speed reading techniques have long been used by readers to quickly skim over the details of a text and save reading time. Using these techniques, a reader's reading speed increases, but their relationship with an increase in the level of comprehension is convoluted. Some studies suggest that if moderate comprehension is needed, speed reading tools can only help in reading a passage faster, and there might not be any advantage of speed reading on comprehension if higher comprehension skills are needed [12]. Here it is important to mention that reading fast without using any speed reading technique does not show any increase in comprehension even when easy comprehension is needed, so it is important to understand what these techniques are to better understand the effect of speed reading on reading speed and comprehension. Some previous work suggests that there is a less than significant difference between the expert speed-readers and novice readers regarding the comprehension scores if time pressure is not an independent variable[10]. There is a strong correlation in-between reading speed and comprehension when adults start to learn a new language reported by past research [7].

There are many approaches and techniques speed readers may use to attain their desired speed and comprehension levels, such as re-reading, reading within your vocabulary, and reading the text of fixed length and lexicon [8]. "Skimming is a type of speed reading where readers visually search for indicators of the main idea of the text in question" and "Scanning is the process that naturally follows skimming. Essentially, through scanning, readers create a visual hierarchy of information extracted through skimming and this method is useful to help the reader get a general understanding of the text [9]. It is also the easiest method of speed reading to learn and put into practice. The literature about a speed reading technique like scanning where key information like names, ideas, facts, and numbers are extracted is not available, suggesting a gap in research. It would be interesting to see the effects of such a simple technique on reading speed, cognitive load, and differences, if any, in between the comprehension of a passage with and without using this technique.


There was a kingdom long, long ago. It was ruled by a king who loved riddles. Once every year the king made a new riddle. He gave a prize to the person who could solve the riddle.

There was a baker who also lived in this kingdom. Everyone agreed that he baked the finest breads. The baker had almost everything he needed except for a horse. If the baker had a horse, he could sell his fine breads from one end of the kingdom to the other.

One year the king made a new riddle that puzzled everyone. "I will give a prize to the person who can solve my riddle," the king said. "Whoever wins will have the pick of one of my strongest horses."

He then drew a line down the middle of the courtyard. "Make this line shorter without erasing any part of it," the king challenged.

People came from far and wide. They looked at the line and squinted at it. They even put their noses to the ground and scratched their heads.

"How can you make a line shorter without erasing any part of it?" the people in the crowd asked each other.

Some of the villagers tried, however. The dressmaker kicked dirt over the line to hide it. The farmer poured water over the line to make it disappear. None of these attempts worked, and the people went home disappointed.

Everyone was puzzled about how to solve this new riddle.

A week passed, and nobody had any new ideas. Then one day the baker came into the courtyard with a bag of flour.

"Your Majesty," the baker said to the king, "I can make your line shorter without erasing any part of it."

The baker opened his sack of flour. He poured out a line of flour right next to the king's line. The line the baker made was longer than the king's line.

"Now, good king," the baker smiled, "your line is shorter."

The people were amazed. The king laughed and clapped his hands. "You have won the prize. I will give you a horse of your choice."

The baker was thrilled. Now he could sell his breads from one end of the kingdom to the other.

Figure 2: Passage 1, taken from the SOLPASS database of reading passages and questions

1.2 Hypotheses

In this experiment, we hypothesize that by using the speed reading technique, the participants' reading speed and reading comprehension will increase. We also hypothesize that the fixation duration and number of fixations will decrease, and the number of saccades will increase.

2 METHOD

2.1 Participants

A total of 13 college students participated in this study (4 females and 8 males and one preferred not to mention; Mean age= 22.77; SD = 2.8). In various classes at Clemson University, participants were recruited through emails and general announcements. All participants had normal or corrected vision. We assumed that all university students could read and comprehend the passages while pursuing undergraduate or graduate education. Clemson University's Institutional Review Board approved this study.

2.2 Stimulus

Participants were presented with two elementary-level passages from the SOLPASS website (solpass.org), accessible online for free. Both passages had different themes and had no relationship with each other. The passages were scaled to fit the screen while conducting the experiment, and Times New Roman font was used for both passages as illustrated in figure 2 and figure 3. Each passage was approximately 400 words long.

2.3 Apparatus

A 23.8" Dell desktop monitor with a resolution of 1920 x 1080 was used for the experiment. The participants used a wired mouse and keyboard to input responses whenever needed. Eye tracking metrics were collected by a Gaze Point 3 (GP3) desktop-mounted eye tracker at a sampling rate of 60 Hz and accuracy of 0.5-1 degree. The participants were seated on a chair in front of the monitor at an approximate distance of 60 cm. (see figure 4)

Figure 3: Passage 2, taken from the SOLPASS database of reading passages and questions

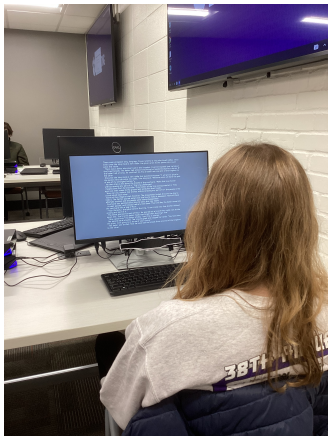

Figure 4: A subject reading the stimulus while having their eyes tracked

2.4 Experimental Design

The study was a 2*x*1 within-subject experimental design investigating the effect of speed reading versus normal reading on reading comprehension and speed. The participants performed normal reading tasks and then performed speed reading tasks after training. The order of presentation of the passages was randomized and therefore some participants received passage 1 for normal reading while other participants received passage 1 for speed reading. They were asked 8-9 questions per passage to gauge how the participants comprehended the passages. The dependent measures were reading speed, reading comprehension, and eye-tracking metrics (fixation duration, saccade rate, scan path, number of fixations on the AOIs, and K coefficient).

2.4.1 *Considerations When Evaluating Comprehension.* [12]

Measuring a participant's comprehension of a passage can be challenging. A common technique is calculating their reading speed in words per minute and then scoring them based on their performance on multiple-choice questions about the passage. However, this method has flaws because it does not consider the participant's comprehension of the passage. Some studies try to overcome this problem by using open-ended questions, but these are difficult to grade objectively. Other studies use a binary approach, where participants who score above a certain threshold are considered to have understood the passage. However, this method is problematic because it is difficult to set a consistent threshold across different passages.

For this study, a different approach is taken. Instead of comparing participants to each other, the focus is on measuring changes in comprehension scores after introducing speed reading techniques. The passages and questions used in the experiment must be standardized to do this effectively.

2.5 Procedure

Before the experiment, each participant was asked to fill out a pre-assessment questionnaire that collected general demographic data like gender, age, SAT score, and information regarding any visual impairments that may influence the output of the experiment. The participants were then informed about the experiment, and they were allowed to ask any questions regarding the experiment. The participants were then required to provide verbal consent to participate in the study. The eye tracker was calibrated to each participant's eyes, and the calibration was validated for accuracy before every reading task. After calibration, participants were reminded to keep their head position as still as possible without causing discomfort.

In the first reading task (normal reading task), one of the two passages was presented to the participants, and then they were asked to read the passage at their normal reading speed. During this task, various measures, such as the fixation duration, saccade amplitude, and K coefficient, were collected using the eye tracker. After reading the passage, the participants were asked 8-10 questions related to that passage to assess how well they could comprehend it. Then the participants were asked to complete the NASA-Task Load Index (NASA-TLX) survey (see appendix), which helped us understand the perceived workload on the participants. Before the second reading task (speed reading task), the participants were informed about various speed reading techniques, and a quick video about eye movements when utilizing these techniques was shown to them. The participants were asked to use the technique shown in the video to read the second passage. A calibration and validation activity was performed again before the second reading task. Comprehension questions related to the passage were asked after completing the second task, and a NASA-TLX survey was collected from the participants. After completing all the tasks, the participants were thanked, and the researcher's contact information was provided to them in case they have questions or concerns related to the experiment.

2.6 Training

The method used to conduct this study is skimming and scanning. They were shown a training presentation to help participants understand exactly what this technique is and how to use it. This presentation included a description of skimming and scanning and a video demonstration. The video demonstration showed a short

passage with eye movements overlayed on top. These eye movements/scan paths were recorded using Gazepoint Analysis.

3 RESULTS

The data from Gazepoint GP3 Eye Tracker was stored and exported using HDFView, and the data analysis was performed using R 4.1.2 software, as well as a custom python pipeline to extract the HDF data into a more easily processed format.

3.1 Change in Experimental Design for Analysis

Just before beginning data analysis, the authors discovered that parts of our collected data had been corrupted. More specifically, we could not obtain eye-tracking data from all readings of *Passage 2*. Due to this, the study was changed to a between-subject design for analysis purposes, where participants in two groups' passage 1 eye tracking metrics (normal vs. speed reading) were analyzed. We had planned on analyzing the data with the within-subject design using a paired t-test to see differences in eye tracking metrics before and after the speed reading technique training. Due to data corruption, we changed it to between-subject and only analyze the passage 1 data. We think the data is still useful, and the results hold as a common passage (passage 1) is used to analyze the objective eye tracking metrics across all participants in two groups (normal reading vs. speed reading).

The passage 2 NASA-TLX ratings will be used along with passage 1 NASA-TLX ratings to assess perceived mental demand and performance ratings. We assume that the ratings will be useful as they depend on the reading task (normal vs. speed) and not on the passage. A paired t-test will assess the ratings before and after speed reading technique training.

3.2 Areas of Interest (AOIs)

Before identifying and analyzing eye-tracking metrics, AOIs were created for each word in the passages (see figure 5 and figure 6). Although the entire passage is our area of interest, we speculated participants might focus more on certain words than others depending on the information it provides. Furthermore, we thought that finding the reading speed would be more accurate this way. But after assessing the scan paths (see figure 1), we realized that the participants did not read in sequence and that the fixations were random. Concluding this, we calculated the reading speed (words per minute) using the following metrics a) time taken to read the passage (minutes), and b) the number of words in the passage.

3.3 Eye tracking metrics

3.3.1 Fixation duration. One-way ANOVA was performed to analyze fixation duration in the normal reading task ($Mean = 0.108sec.$) and in the speed reading task ($Mean = 0.0956sec.$), and it showed that there was no significant effect of the speed reading technique on average fixation duration ($p = 0.3193$, $n.s.$; Figure 7).

3.3.2 Saccade amplitude. In terms of saccade amplitude, one-way ANOVA was performed for the normal reading task ($Mean = 14.10degree$) and speed reading task ($Mean = 13.55degree$), and it showed that there was no significant effect of the speed reading technique on average saccade amplitude ($p = 0.6377$, $n.s.$; Figure 8).

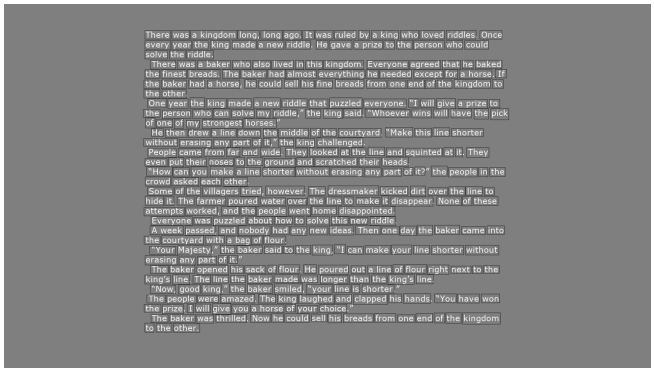

Figure 5: Areas of Interest for Passage 1

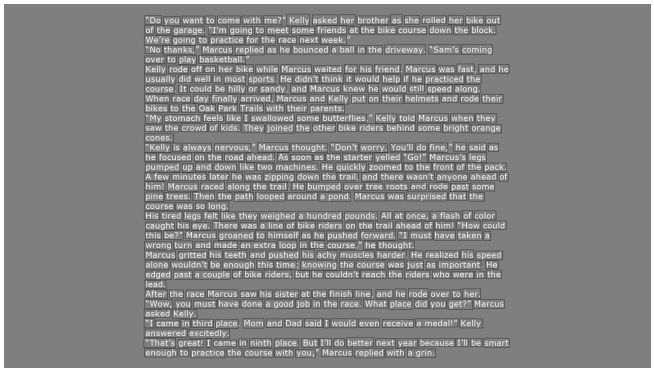

Figure 6: Areas of Interest for Passage 2

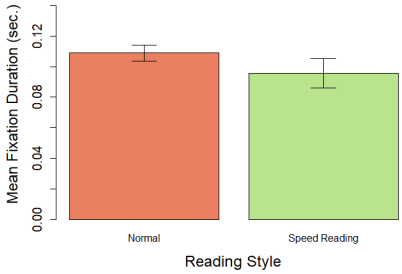

Figure 7: Average fixation duration for Reading style. Whiskers represent ±1 SE (Standard Error).

3.3.3 K coefficient. One-way ANOVA was performed for the normal reading task ($Mean = 0.0019$) and speed reading task ($Mean = 0.0033$). There was no significant difference in the average K coefficient value ($p = 0.8298$, $n.s.$; Figure 9).

3.3.4 Number of Fixations. A one-way ANOVA was performed to evaluate the significance of speed reading technique on the number of fixations. The average number of fixations was lower in the speed

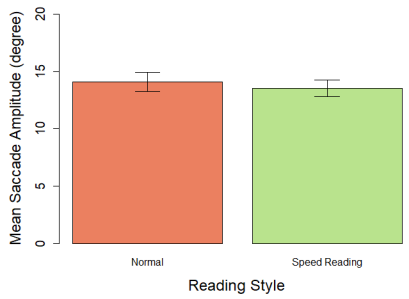

Figure 8: Saccade amplitude plot. Whiskers represent ±1 SE (Standard Error).

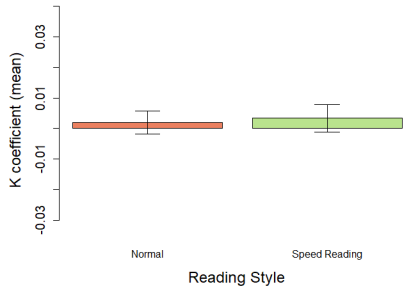

Figure 9: Average K coefficient. Whiskers represent ±1 SE (Standard Error).

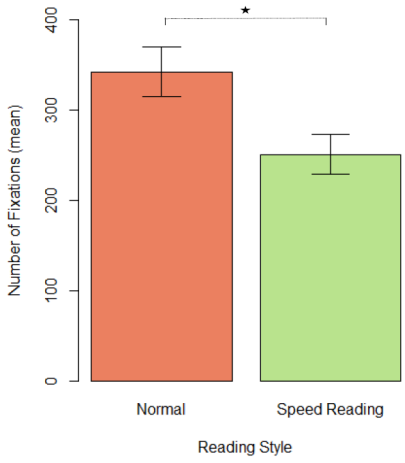

Figure 10: Average Number of Fixations. Whiskers represent ±1 SE (Standard Error). Significant differences (p<0.05) are marked

reading task ($Mean = 250.625$) and showed a significant difference from the normal reading task ($Mean = 342.2$) using the technique ($p = 0.0254, s.$; Figure 10).

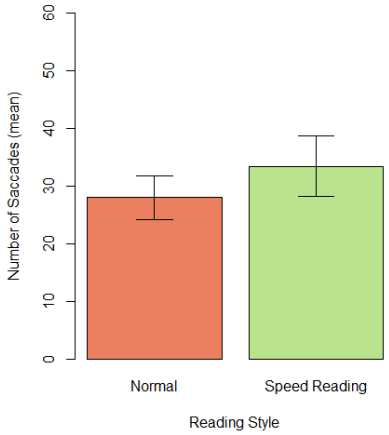

Figure 11: Average Number of Saccades. Whiskers represent ±1 SE (Standard Error).

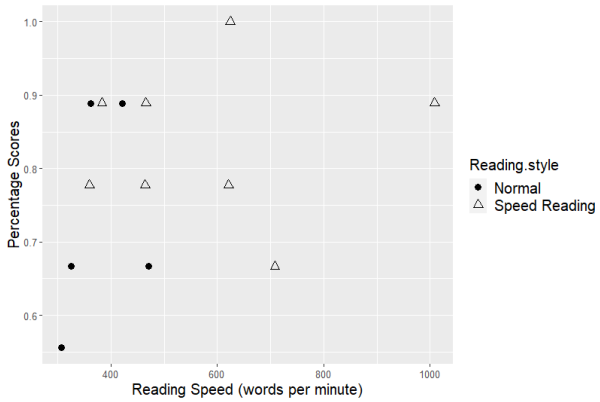

Figure 12: Percentage score vs. Reading Speed

3.3.5 Number of Saccades. A one-way ANOVA was performed to analyze the difference in the number of saccades between the normal reading task ($Mean = 28$) and the speed reading task ($Mean = 33.4$). The analysis showed no significant difference ($p = 0.4106, n.s.$; Figure 11).

3.4 Comprehension Scores

We performed a person's correlation test to understand the relationship between reading speed, the number of fixations, mean saccade amplitude, and mean fixation duration on the comprehension score in passage 1. For the comprehension scores, the analysis showed a low positive correlation with reading speed ($r = 0.29; p = 0.34$; Figure 12), low negative correlation with the number of fixations ($r = -0.23; p = 0.46$; Figure 13), low positive correlation with saccade amplitude ($r = 0.11; p = 0.72$); and low negative correlation with fixation duration ($r = -0.26; p = 0.39$).

Figure 13: Percentage score vs. Number of Fixations

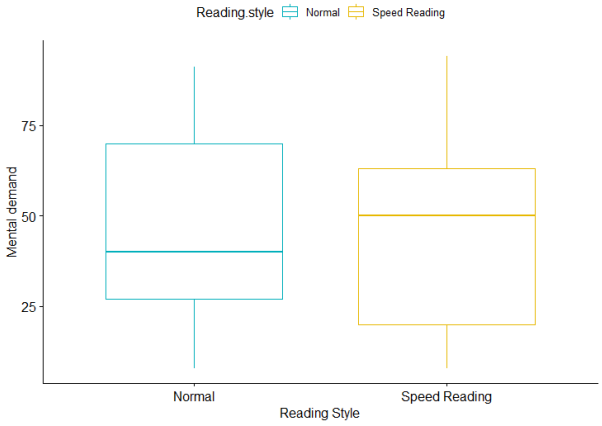

Figure 14: Perceived Mental Demand Rating Before and After Training

3.5 NASA-TLX metrics

3.5.1 Mental Demand. A paired sample t-test was performed on perceived mental demand ratings during normal reading and speed reading tasks (after training)(see figure 14). The analysis showed no significant difference in mental demand ($t(12) = -0.103; p = 0.919$), although the perceived mental demand incurred during the speed reading task ($Mean = 44.6$) was slightly higher than during the normal reading task ($Mean = 43.6$).

3.5.2 Performance. A paired sample t-test was performed on perceived performance ratings during normal reading and speed reading tasks (after training)(see figure 15). The analysis showed no significant difference in performance ($t(12) = 0.914; p = 0.378$), although participants felt that they performed slightly better during the normal reading task ($Mean = 65.2$) than during the speed reading task ($Mean = 55.5$).

3.6 Discussion

Overall, as initially hypothesized, a mean number of fixations showed a significant increase due to the speed reading technique.

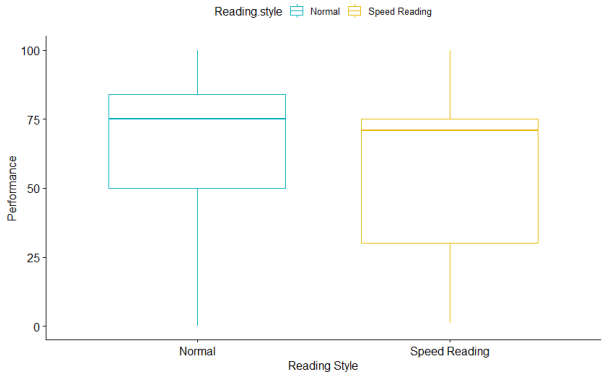

Figure 15: Perceived Performance Rating Before and After Training

Due to the limited number of participants, we could not find a significant difference in mean fixation durations. This suggests that participants could understand the training paradigm used in the experiment. The video demonstration of speed reading with an overlay of eye movement the training module seems to have helped participants to understand and replicate the speed reading technique in their speed reading task. This also suggests that a simple training intervention to inform users about a speed reading technique can be effective. We hypothesized that the mean saccade amplitude will be significantly higher in the speed reading task. Still, interestingly, saccade amplitude in the normal reading task was slightly higher, although not significantly different than in the speed reading task. This might be because the participants are re-reading previous sections in the passage during normal reading, whereas eye movements in speed reading are quite consistent. Also, the mean number of saccades in speed reading tasks was higher than hypothesized but not significantly different.

To understand the relationship between reading speed and visual information processing in a reading task, we performed an analysis of K coefficient data collected during the study. We wanted to understand the effect of reading speed on participants' information processing strategy (serial/focal or parallel/ambient) that participants might use in normal and speed reading tasks. This can also be analyzed by separately analyzing the increase in the duration of fixations and decrease in saccade amplitudes [11]. But the literature studying this phenomenon has suggested that when a participant sees something interesting to focus on (focal processing), longer fixations are followed by shorter saccades. In contrast, in ambient processing, shorter fixations are followed by longer saccades [4][15]. Therefore, we decided to analyse a novel parametric scale (K coefficient) to understand visual processing in a speed reading task. Positive K value indicates that long fixations are followed by short saccades suggesting focal processing, and negative K value indicates that short fixations are followed by long saccades suggesting ambient processing [6]. We found positive mean K values for both tasks. Still, interestingly, our results showed a higher mean positive K value in the speed reading task, although not significantly different than the mean positive K value in the normal reading task. In the speed reading task, as the participants used a technique to scan

and extract important information quickly, they might have actively searched for important information instead of in a normal reading task and focused more on the identified important information.

Comprehension scores showed an ambiguous result with a very low correlation with reading speed or number of fixations. It seems that the comprehension questions asked after reading the passage were either too easy or too difficult. We need to develop better testing paradigms.

We collected subjective measures using the NASA-TLX questionnaire to understand the influence of the training on participants' perceived mental demand and performance. Participants showed no significant difference in perceived mental demand suggesting that they felt efficient in using the speed reading technique. Interestingly, the participants felt they performed better in the normal reading tasks and it might be because they might have felt more satisfied with the comprehension and felt more connected to the contents of the passage in the normal reading task than in the speed reading task, but there was no significant difference in performance ratings as well.

3.7 Conclusion

Overall, the results show that participants were able to understand the technique through the training module, and they were able to implement the technique for reading. On the other hand, comprehension scores showed less correlation with eye-tracking measures. There was a lack of significant difference in terms of fixation duration and saccade amplitude, probably because of the low number of participants. Eye tracking is a useful technology to understand the information processing aspects involved in a reading task as demonstrated by mean K coefficient statistical analysis.

3.8 Future Work

Satisfaction plays a key role in training/technique adoption [13]. Thus future work can involve use of eye tracking in analyzing user satisfaction after a training intervention. While the training module developed by the authors lead to a statistically-significant reduction in the mean number of fixations for participants engaged in speed reading techniques, the training methodology is untested. Additionally, research to identify the best pedagogical technique for training participants in speed-reading techniques could vastly improve statistical significance in future studies. To properly identify the word a participant was focused on, the authors made the passage font as large as it would fit on the screen. While this improves the salience of data collection, participants reported the size of the text created an unnatural reading experience. To correct this, future studies attempt to better utilize more precise eye-tracking technology to emulate eye movements on smaller and more condensed text. The authors will consider re-running the experiment with the original within-subjects design.

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4 APPENDIX A: NASA TASK LOAD INDEX

The NASA Task Load Index is a validated, standardized set of questions that can be used to assess the perceived workload of a specific task [3]. The TLX consists of six subscales representing independent variables: mental, physical, and temporal demands, frustration, effort, and performance. For this work, the NASA TLX was used to assess the impact of the additional mental load of performing speed reading techniques. After reading each passage, participants were asked to complete the NASA Task Load Index.