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Viewing Behavior in Complex Passages - An Exploratory Eye-tracking Study

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Emergent Research Forum (ERF)

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Abstract

There have been multiple studies focusing on how visual arrangements can impact the viewing behavior of online content, but little research has been done that evaluates the effect of complexity of textual information on viewing patterns. To fill this gap, we studied how users view longer textual passages and how text simplification could impact the viewing pattern for such passages. We extracted a relatively complex passage (18th-grade reading difficulty level) from GRE sample tests. We then simplified it to 12th-grade reading difficulty level using a set of guidelines developed in prior studies. After that, we ran an eye-tracking experiment with 65 participants. Half participants were asked to read the original passage, and the rest were asked to read the simplified version. The results showed that text simplification substantially impacted the viewing behavior, notably it increased attention to the last parts of the passage.

Keywords

Eye-tracking, viewing behavior, text simplification, reading comprehension, pupillometry.

Introduction

Textual information plays a significant role when it comes to communicating important content (Djamasbi et al. 2016). Research, however, shows that users often do not read textual information carefully or ignore it altogether. For example, prior studies show that users read only about 20% of the text provided on the webpage (Neilson 2008). Some recent studies suggest that simplifying textual content can improve attention to the content (Shojaeizadeh et al. 2017). Despite the importance of text in communicating important information, little work has been done to examine how text simplification can impact overall viewing behavior and attention to content, particularly for long passages that naturally require more cognitive effort. The result of such an investigation can provide insights for improving user engagement. Hence, in this study, we explored to see if text simplification could increase attention to textual information, that is, encourage people to read more of the available text. Additionally, we were interested to see whether text simplification could impact the distribution of attention. Studies show that attention to content decreases from top to bottom, e.g., people pay more attention to information that is placed on top of a page compared to information that is placed on the bottom of a page (Faraday, 2000). We were interested to see whether text simplification could impact this viewing pattern and the order by which top to bottom sections are viewed. To address these research questions, we selected a relatively difficult passage (18th-grade reading level) from GRE sample test practices. We then created a simplified version of the passage (at the 12th-grade reading level) using the set of plain language standards developed in prior research (Djamasbi et al. 2016). We conducted a between-subject study where participants were presented with one of the two versions of the passage: original passage (OP) or a simplified version of the passage (SP). As in prior eye-tracking research in reading (Djamasbi et al. 2016), we used fixation, pupillary data, and saccade to examine

the difference in the viewing behavior of the participants. Fixation and pupillary data serve as reliable indicators of attention. Saccades reflect shift in attention.

Background

When it comes to reading tasks, eye movement metrics such as fixations, saccades, and pupillary response have been proven successful in finding reading behavior and cognitive effort (Shojaeizadeh et al. 2017; Djamasbi et al. 2016). Many researchers have used pupil dilation to measure cognitive efforts in different tasks related to textual information. Shojaeizadeh et al. (2017) used pupil dilation to find the relationship between cognitive load and pupillary response that required reading text passage (18^{th}-grade reading level) from an actual website when compared to its simplified version (10^{th}-grade reading level). Their study results showed that text simplification significantly impacted pupil dilation (Shojaeizadeh et al. 2017). In another study, Djamasbi et al. (2016) examined the viewing behavior and performance of two groups of participants using original (10^{th}-grade reading level) and simplified text (5^{th}-grade reading level). They used metrics like fixation duration and saccade amplitude for data analysis. They discovered that participants in the simplified text conditions performed significantly better when it came to answering questions about the text (Djamasbi et al. 2016). Both of the aforementioned studies used shorter passages from websites. In this study, we extend these prior studies by examining viewing behavior for a more complex and longer text passage using the same eye-tracking metrics that were used in the studies mentioned above. We also employed some other eye-tracking metrics (some from prior studies, some developed by our team) to study viewing behavior.

Methodology

We conducted a laboratory experiment for this study, where we used Tobii x300 eye-tracking device to collect eye movement data. We used Tobii Studio version 3.2.3, I-VT filter with 30 °/sec saccadic velocity threshold, and 100ms fixation threshold to process raw gaze data into fixations and saccades (Shojaeizadeh et al. 2017). We recruited a total of 65 participants from a college campus in the northeastern part of the United States. The participants included both students and employees. Their ages ranged from 18 to 70 years, with an average of 37 years. We extracted a passage (18^{th}-grade reading difficulty level) from GRE sample tests, which was simplified to 12^{th} grade reading difficulty level using a set of comprehensive rules using the plain language standards (Djamasbi et al. 2016). For the passages, we used Helvetica font, font size 28px, and line-height 3. Each participant was assigned to read only one of two versions of the same passage (either OP or SP). To measure the perceived difficulty of the passages, participants were asked to answer the Subjective Mental Effort Questionnaire (SMEQ) (Sauro et al. 2012) immediately after reading the passage.

Data Analysis

Out of the 65 participants, five participants had less than 80% gaze sampling percentage. To stay consistent with the recommendation of prior research (Kruger et al. 2013), we removed the data of these five participants from further analysis. In both simplified and original versions of the passage, each paragraph was divided into separate Areas of Interest (AOI), as customary in eye-tracking studies (Djamasbi 2014). AOIs refer to specific regions of displayed stimulus, for which raw gaze data can be extracted (Djamasbi 2014). As displayed in Figure 1, OP and SP were divided into 3 AOIs. Because the text simplification procedure turned the first paragraph in OP into two paragraphs in SP, the first AOIs in these two different passages have a different number of paragraphs. The rest of the AOIs in these passages contain the same number of paragraphs.

We used fixation duration, saccadic amplitude, and pupillary responses to analyze viewing behavior as previous studies have validated them for successful detection of cognitive activity (Shojaeizadeh et al. 2017; Djamasbi et al. 2016). Since the number of words varied across the paragraphs in each passage, we normalized fixation duration in our analysis by dividing the total fixation duration in each AOI by its respective word count. Additionally, we assessed the level of attention to text within each AOI by calculating the ratio of total fixation to total visit duration (Djamasbi et al. 2019).

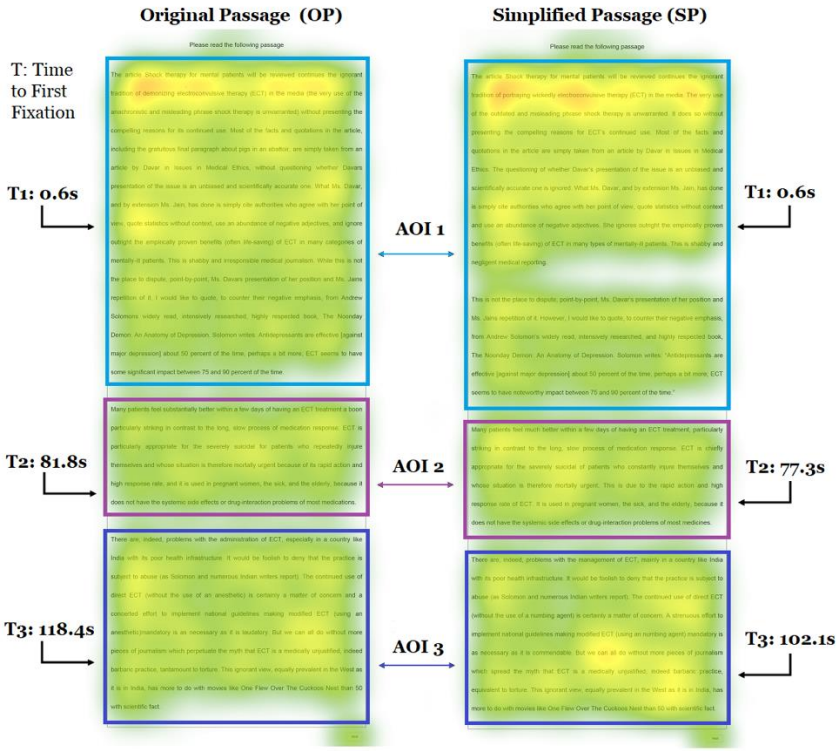

Figure 1. Heatmaps and Viewing Pattern (OP on the left and SP on the right)

Results

To measure the perceived level of difficulty of the two passages, we used the SMEQ survey (Kruger et al. 2013). Average SMEQ scores showed that OP was perceived significantly more difficult to read than SP (one-tail p-value=0.03) (see Figure 2).

We used fixation metrics to examine the impact of text simplification on order and distribution of attention. To examine the viewing order of the AOIs, we used the "time to first fixation" (Djamasbi 2014). The results showed that text simplification did not affect viewing order; in both passage conditions, the AOIs were viewed from top to bottom (see Figure 1). Text simplification, however, impacted attention distribution. While in both passages, the first AOI received the most attention from the participants, in OP, the reader's attention (i.e., fixation duration) decreased as the participant moved from one AOI to next. In SP, on the other hand, the reader's attention decreased as the participant moved from AOI1 to AOI 2, but increased in AOI 3 (see Figure 2). The overall average fixation duration was also statistically different between the two passages (p-value=0.03).

Shift in attention, which was measured by saccade amplitude, was larger in OP compared to SP, but the difference was not significant (p-value=0.22), except for the last AOI (p-value= 0.05) (see Figure 2). The larger shift in attention could be interpreted as more time searching for information in OP compared to SP. Saccades refer to ballistic eye movements between fixations. Saccade amplitude refers to the path that a saccade travels when moving from one fixation to another (Holmqvist et al. 2011; Nystrom et al. 2010).

Next, we looked at pupillary responses: pupil dilation and variation. Pupil dilation (PD), which refers to the change in the diameter of the pupil, tends to be larger when a user faces a higher cognitive load (Hyönä et al. 1995). Participants in this study had significantly larger pupil dilation in OP than SP (p-value=0.00) (see Figure 3). Our result, however, did not show a significant difference between pupil dilation variation (PDV) (p-value=0.42), which refers to the rate of change in pupil size (Jiang et al. 2013) (see Figure 3).

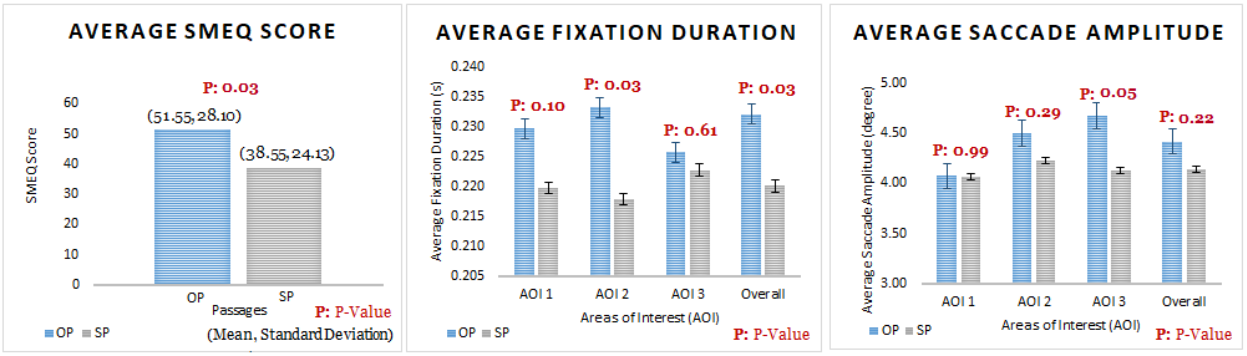

Figure 2. Average SMEQ Score, Average Fixation Duration, and Average Saccade Amplitude

We also examined the normalized fixation duration (total fixation duration/ word count) for OP and SP. Our results showed no significant difference in normalized total fixation duration between OP and SP (p-value=0.85) when we compared the entire passage containing all three AOIs. However, when we compared each AOI separately, we observed that AOI 3 had a significantly higher normalized fixation duration in SP (p-value=0.00) (see Figure 3), indicating improved attention to the last part of the passage.

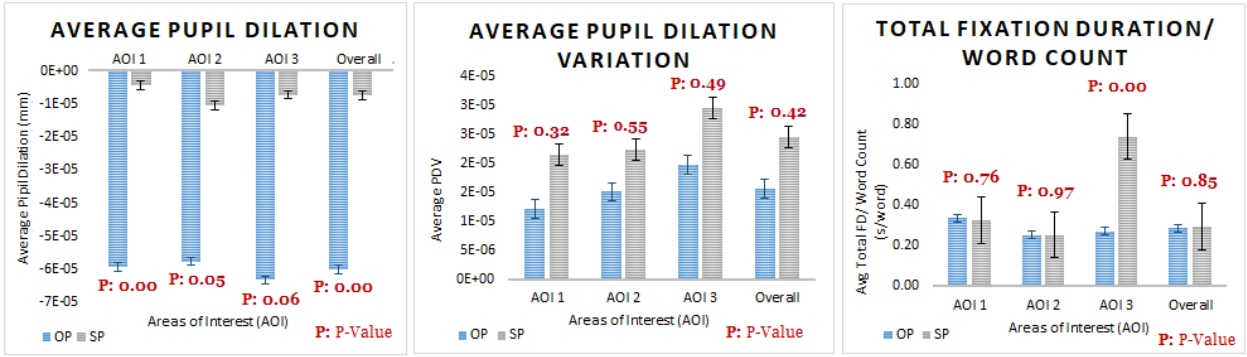

Figure 3. Average Pupil Dilation, Average Pupil Dilation Variation, Total Fixation Duration/ Total Visit Duration

We also looked at the ratio of total fixation duration to total visit duration, which indicates the percentage of time participants spent reading during an AOI visit (Djamasbi et al. 2019). Additionally, we calculated total fixation count divided by word count to normalize fixation frequency for each AOI. Our results showed no significant differences between passages for these two metrics (p-values=0.90 and 0.52) (see Figure 4).

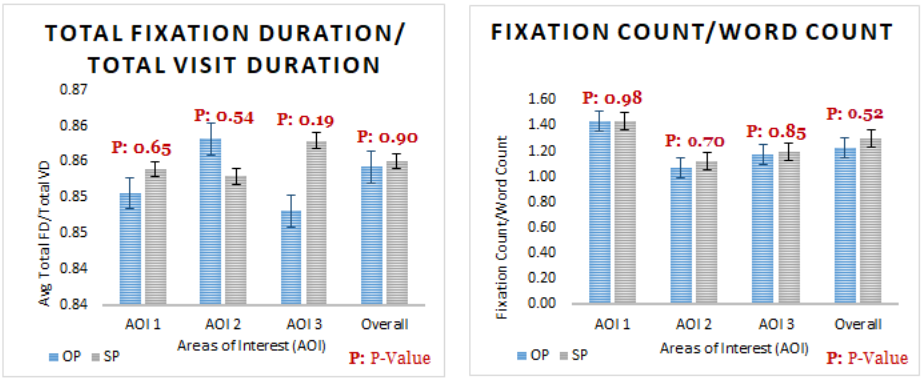

Figure 4. Total Fixation Duration/ Word Count and Fixation Count/ Word Count

Discussion

The objective of this study was to examine whether text simplification can impact the intensity and distribution of attention to relatively long and complex textual information. To achieve this goal, we selected a passage from the GRE test and developed a simplified version of it by using operationalized guidelines from prior studies (Djamasbi et al. 2016). The results of the SMEQ survey showed that the operationalized guidelines were indeed effective in simplifying the passage; participants rated the simplified version of the passage significantly easier to read. The eye movement analysis also revealed significant differences in viewing behavior between the two passages supporting that text simplification can improve attention to content. The significant differences in pupil dilation at both page and AOI level provide compelling evidence for the differences in cognitive activity between the two pages supporting SMEQ scores. Fixation metrics showing that the last AOI in SP received more attention than the last AOI in OP are also providing interesting insight. Typically attention decreases from top to bottom when people view online material (Faraday, 2000). This pattern was also observable in viewing behavior for OP. Our result, however, showed that text simplification increased attention to the last AOI in SP. This change in viewing behavior has important implications because the last part of a document usually entail important information, such as summarized content that provides conclusions. Although not tested in this study, our results showing improved engagement with SP suggest that text simplification is likely to improve performance on tasks that rely on information provided in the text. Future studies are needed to test this possibility.

Limitations

Our study was limited to participants from a college campus. A more diverse population may help to extend our results and help make new discoveries. Similarly, we used only one complex text passage. Using multiple passages with various topics is needed to help generalize our findings.

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