Eye Movements and Reading Behavior of Younger and Older Users: An Exploratory Eye-Tacking Study

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Abstract. Baby boomers and millennials form two major user groups that tend to exhibit different behaviors when viewing online information. Because important online information is often communicated via text, understanding the differences in the way textual information is scanned by these two user groups allow designers to better meet the needs of each group. Our results showed that saccadic amplitudes were strong predictor of user age groups when they were reading a relatively long and difficult text passage. These results help to improve online reading experience by examining metrics that can unobtrusively capture and compare the overall reading experience of younger and older users. The results are also relevant to research in designing advanced decision tools that use eye tracking to detect cognitive effort to respond to user needs.

Keywords: Eye tracking · Baby boomers · Generation Y · User performance
Online reading · Eye movements

1 Introduction

Baby Boomers, born between 1946 and 1964 (age in 2017, 53 to 71) are the second largest generation in the U.S. With 74.9 million people in 2015, they make up 26 percent of the total U.S. population [1]. People 65+ represented 14.5% of the population in the year 2014; they are expected to grow to be 21.7% of the population by 2040 [2]. The internet provides a number of benefits for older adults. It is used as a means of communication via E-mail, chat rooms, discussion groups, and direct messaging. The Internet also contains a wealth of medical information that can be particularly useful for older adults when health becomes a greater issue and concern [3]. Important online information is often conveyed via text-based communication. Thus, examining the reading behavior of older users and comparing it to those of younger users allow designers to better meet the need of both user populations. Additionally, recent research calls for designing advanced systems that can respond to user needs in real time. To achieve this goal, various studies are needed to identify eye movements that can reliably detect user experience [4]. To address this need, in this study we examined eye movement factors that are likely to reflect the overall reading experience of baby boomers and younger generation. To this end, an eye tracking study was

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conducted with 20 participants including 10 young generation and 10 baby boomers. The task required each participant to read a text passage about law and to provide answers to a set of questions about the passage, while the participants' eye movements were recorded by a high speed eye-tracking device. The main objective of the study was to investigate a range of eye movement data that prove to be important in reading behavior and to examine whether these eye movements can reliably predict user age group and performance. This investigation not only facilitates a better understanding of the differences in reading behavior between the two generations but also contributes to research that aims at designing advanced system [4]. Identifying eye movement metrics that reliably predict a user's age group can help designing adaptive systems that can respond to older and younger users appropriately in real-time.

2 Theoretical Background

2.1 Baby Boomers and Young Generation: Differences in Online Experiences

Literature indicates that older users may expend more cognitive effort when processing online information. For example, past research demonstrate that older adults are slower in cognitive processing from younger people [5]. Based on the cognitive theory of aging, slowdowns of cognitive processing in older adults can explain the age related differences between older and younger adults [6, 7]. Furthermore, research shows that because of a numerous factor such as social, cognitive, psychological, and physical factors as well as overall differences in life experience, baby boomers often have different usability issues as compared to young adults [8].

Existing psychological eye-tracking literature has also reported older adults exhibit more cognitive effort during reading. For instance, it is known that older adults read more slowly and make more fixations and regressions than younger readers [9–11]. Examining eye movement characteristics, Rayner et al. [12] asked young and old adults to read sentences containing target words that varied either in frequency (low-frequency vs. high-frequency target words) or in predictability (low-predictable, medium-predictable, or high predictable target words) to determine whether frequency and predictability interact with age when these target words are read. They learned that older adults make more fixations, longer fixations and more regressions (backwards movements to re-read text). Another study, comparing older and younger adult's differences, suggests that older adults perform at a reasonable level; they are as successful in reading as younger adults, but it seems that they make more effort in reading as demonstrated by longer fixation durations [13].

A similar finding occurred from a study looking at expert older users working at an investment company, Fidelity. In their first study, they examined the behavior of expert older adults (50–69) while working in the office and used the web daily, compared to younger colleagues (20–39) [14]. The results showed that older adults spent on average 42% more time looking at the content of the pages than did the younger adults. Older adults also spent 51% more time looking at the navigation areas as compared to the younger adults. Their results also suggest that older participants distributed their gaze more widely across the pages and read more of the text than younger users did. In another study, researchers examined preferences for web page presentation, and reported that baby boomers had longer fixations on large images and search bars as compared to their younger counterparts [15]. Similarly, in another study, Zaphiris and Savitch [16] compared older (58–87) and younger (19–27) web users browsing health information sites of varying depth of hierarchy, and observed that older adults looked at more of the page and spent longer considering which link to choose. However, the researchers found no significant difference in reading speeds. Chadwick et al. [8], conducted two usability studies to investigate the differences between older and younger adults in completing a task using a prototype employee/retiree benefits Fidelity's website. In their first study, researchers examined whether there were differences in how older adults interacted with the Web and whether changes in text size would affect performance. Users completed tasks on the website using various text sizes. Researchers learned, from the results of the study, that older users (55 years or older, mean = 69.2) had significantly more difficulty using the Web than younger users (55 and younger, mean = 35.9). In their second study new participants performed the same tasks on a version of the site that was redesigned to address the usability problems encountered by older users in the first study, with the purpose of improving the performance of older adults. They concluded that performance improved significantly for both older and younger users, they also observed that older users read more text and often read all of the text on a screen [8]. Additionally, they found that older adults were particularly cautious and not confident about clicking on links that were nouns, like Accounts. When they changed those links to actions, like Go to Accounts, both older and younger users were faster and more confident.

A different study [17] examining the differences between old and young adults in reactions to a set of homepages through a laboratory experiment captured users' reactions using self-report measures and eye tracking. The results of this study showed that both generations reported similar aesthetic preferences, and both generations preferred pages that had images and little text. However, the two generations also displayed differing online viewing behavior and preferences. For instance, eye tracking data revealed that Baby Boomers had significantly more fixations on web pages that they found less appealing and their fixations covered more of the pages than Young Generation. In addition, Baby Boomers reported a significantly higher tolerance for clutter (more web components) on a page [17].

Another study [28] looked at the differences between older and younger users in information search behavior. Participants were asked to complete a search task related to health information on three different websites. The study investigated whether age or other factors such as gender, educational background and frequency of internet use had an impact on navigation patterns, the use of the search box, effectiveness, efficiency and user satisfaction. According to the findings of the study, older users were less likely to make use of the search box than younger users. In addition, younger users were more successful in accomplishing the search task and were much faster than their older counterparts in completing the task. Although the results showed that there were some difference between older and younger users in fulfilling an information search task the most impactful factor on information search behavior was not always age. For example, when comparing the navigation patterns of older people using internet daily with those of younger age group no significant differences were observed between the two groups.

2.2 Eye Movements and Information Processing

Fixation and saccade are two major eye-movements that represent the information processing behavior [23]. Fixation are a collection of relatively stable gaze points on a part of stimuli that are close to each other in proximity and time. Saccades refer to small rapid movements of the eye when it jumps from one fixation to another [27]. Due to their nature, fixations reflect our attention to a part of stimuli that the eyes are fixated on [19, 24]. A number of studies have associated fixation related metrics such as fixation count and fixation duration as measures of information processing. For example, the number of fixations within an area of investigation (AOI) has been used to compare cognitive processing of millennials and baby boomers when viewing a web page [17]. Eye movements have been also used to understand how textual information is processed [18, 19]. For example, Campbell et al. [20] and Gustavsson [21] used eye movements to detect whether a person was reading a text or not. Similarly, eye movements were used to detect whether users read or skim textual information [22]. When reading English, fixation duration is around 200–300 ms, with a range of 100–500 ms and saccades range in duration between 10–20 ms for short between word saccades, and between 60–80 ms for longer saccades from end of one line to the beginning of another line [23]. Majority of saccades during reading English are made from left to right, however, in skilled readers, about 10–15% of the saccades are regressive, they are backward saccades to the previously read words or lines [23]. In general, saccades during reading are divided into two categories: (1) Progressive saccades in the direction of reading text, (2) Regressive saccades, or backward saccade to the opposite direction of reading [23]. Short within-words regressions can be due to problems in processing the currently fixated word [23]. Longer regressions (more than 10 letter spaces back along the line or to another line) are because of the difficulties in comprehension, or may be because the text is particularly difficult and the reader cannot understand the text [23].

2.3 Research Question

The discussed literature suggests that (1) eye movements can be used to understand the cognitive processing during reading, and that (2) there is significant differences between younger and older adults' online reading and web experience. Our research question is whether we can distinguish the age group of a user (younger/older) from eye-movements data when they read textual information. As Loos and Bergstrom [29] aptly put it, to better serve older and younger users it is important to have a deeper understanding of the differences in behavior between these two populations and to investigate how differently older adults interact with online information as compared to their younger counterparts.

Because important information is often communicated via text, in this study grounded in cognitive linguistic literature, we focused on examining the differences between older and users in reading textual information only, in particular, whether we can predict user population (older vs. younger) via eye movements. In this study, we also investigated the relationship between eye movements and performance. We addressed our research questions by designing an eye tracking laboratory experiment. Eye tracking is a natural method for examining how people process information. Eye tracking is broadly used in HCI research and facilitates accurate measurement of online user experience unobtrusively. In particular, researchers have used eye tracking to gain a more complete understanding of the older adults' needs when using websites and mobile applications [29]. The following section provides the methodology used in conducting the eye tracking experiment and the methods used in analyzing the eye movement data.

3 Methodology

This section provides a brief review of the laboratory experiment that was conducted to collect eye movement data used in this study. Furthermore, it provides details on the method used to process the eye-movement data captured from a number of participants who completed a cognitive task online.

3.1 Task and Participants

The task selected for this study included reading a passage and answering to three questions about the passage. The passage was selected from a pool of GRE sample practice passages available on www.majortest.com. The topic of passage was about law and included 553 words. The passage yielded an overall readability score of 16.1 (Flesh-Kincaid grade level = 16.5, Gunning Fog Index = 20.1, Coleman-Liau Index = 9.7, SMOG Index = 15.8, Automated Readability Index = 18.1) which corresponded to a rather difficult reading level. As in prior research [26], the readability score was measured using the online tool: https://readable.io/text/. Participants were recruited among college students and staff from a northeastern university at US. Out of 20 participants, ten were among young generation (age range of 18–30) and the other ten were baby boomers (age range 53–70). Each participant received incentive for their participation in the study.

3.2 Eye-Tracking Study

A commercially available eye tracking device, Tobii X300, was used to collect eye movement data of each participant during reading. This remote eye tracking device can capture eye movements unobtrusively at the rate of 300 samples per second. The eye tracker was calibrated for each participant before starting the task. This process requires participants to observe a moving dot on the eye-tracking screen. Tobii software version 3.4.5, and I-VT filter with 30°/sec saccadic velocity threshold was used to process raw gaze data into fixations and saccades.

3.3 Eye-Movement Preprocessing

Studies suggests that older user are more "patient" than younger users when they view online material. They are likely to expend more cognitive effort when scanning a web page and tend to scan more areas on the web page [8, 17]. This difference in behavior is likely to be observed via saccadic eye movements when processing textual information. Willingness to expend more cognitive effort is likely to reveal itself in saccadic eye movements, which represent effort to move the eyes from one area of interest and refocus it on another area of interest. The list of saccadic eye movement metrics that we used in our study are displayed in Table 1.

Table 1. List of eye tracking metrics

1	Regressive Saccade Count	4	Average Progressive Saccade Amplitude[a]
2	Progressive Saccade Count	5	Average Regressive Saccade Amplitude[a]
3	Average Saccade Duration		

[a]*Saccade Amplitude* (measured in degree) refers to the visual angle that a gaze travel during a saccade

Eye movement data obtained from the eye tracking software included the x and y-coordinates of the participant's eye location on the screen (pixel), whether the eye movement was a fixation or saccade, and the duration of fixation or saccadic event in milliseconds. Additionally, the software provided the visual angle (measured in degree) that a gaze travel during a saccade (saccade amplitude). Table 2 displays the algorithm that we developed to calculate regressive and progressive saccades using x and y-coordinates of two consecutive fixation points. According to Rayner [25] regressive saccades are backward saccades to a word or a line which were occurred earlier in the text, and hence they can be computed based on the positional information of consecutive fixations [12, 23]. We calculated regressive saccades as those in the opposite directions of reading (to the negative of x- and y-direction with respect to the top left corner of the screen delineated as x = 0 and y = 0).

In this study we were interested in examining overall page scanning behavior. Thus, we excluded shorter regressive saccades that are typically only three character long [25].

3.4 Regression Analysis

To investigate whether the difference in cognitive effort during reading a passage online between older and younger users can be detected through saccadic eye-movements data, a regression analysis was performed using the eye movements given in Table 1 as independent variables. Equation 1 shows the regression model used in this study.

$$f(x) = \sum_{i=1}^{5} a_i x_i + \text{b}, \tag{1}$$

Where f(x) is a binary dependent variable: $f(x) = \begin{cases} 1, & babyboomer \\ 0, & younggeneration \end{cases}$

x_i represents each of the eye metrics shown in Table 1, and a_i are the coefficients corresponding to each metric, and b is the intercept.

Table 2. Regressive and progressive saccade tracking procedure

Locate the origin of the gaze x-y coordinate from eye-tracking system[a].
If
{ absolute changes in Y values of the most recent consecutive gaze points (k-1 and k) is less than a predefined threshold, TH_{inline}[b],

$$|Y_{gaze}(k) - Y_{gaze}(k-1)| =< TH_{inline} \quad (1)$$

then check for the changes in X values of those gaze points, $X_{gaze}(k)$ & $X_{gaze}(k-1)$,

- If $X_{gaze}(k) - X_{gaze}(k-1) < -TH_{inline\_Regress}$,[c]

  {It indicates regressive saccade}

- Else If $X_{gaze}(k) - X_{gaze}(k-1) > 0$

  {it indicates progressive saccade}

}
Otherwise[d]
{check if the reader is looking at the point upper than its previous gaze or lower.

- If $Y_{gaze}(k) - Y_{gaze}(k-1) < -TH_{inline}$,

  {It indicates regressive saccade}

- If $Y_{gaze}(k) - Y_{gaze}(k-1) > 0$

  {It indicates progressive saccade}

}
End

[a] (The origin (0.,0) is on top left corner of the screen in Tobii X300, which means reading a text from left to right would return gaze points with increasing x values, and reading from top of the text down toward next lines would return gaze points with increasing y values)
[b] TH_{inline} is the maximum pixel difference between each lines of the text on interface, which checks whether the reader is in the same line or went to a new line.
[c] $TH_{inline\_Regress}$ is number of pixels that include 3 letter character. This threshold is adopted from Reyner et al. 2009).
[d] The reader is reading from a different line: $|Y_{gaze}(k) - Y_{gaze}(k-1)| > TH_{inline}$

Saccadic eye movements are representative of reading difficulty [23], hence, we expected to detect a correlation between performance and saccadic metrics. To investigate this possibility, we used the following regression model.

$$f(x) = \sum_{i=1}^{5} a_i x_i + \text{b}, \quad (2)$$

Where f(x) is refers to performance measured as the number of correct answers to three multiple choice questions.

As in Eq. 1, x_i represents each of the eye metrics shown in Table 2, and a_i are the coefficients corresponding to each metric.

4 Results

Mean and standard deviation of variables of interest are displayed in Table 3. As the values in Table 3 indicate, younger users on average had longer (in duration) and more saccadic eye movements. This behavior is consistent with previous research that suggests younger users, compared to older users, exhibit less patient viewing behavior [17]. Although as we will discuss further in the discussion section some research suggest that experience may moderate the impact of age on web user experience [13, 28]. Our results also showed that older people had larger saccade amplitude, which indicates that in order to process the provided information their eyes traveled longer distances to scan the text. This eye movement behavior, consistent with previous research [17], suggests a greater degree in willingness to expend cognitive effort to read textual information.

Table 3. Mean and standard deviation for the eye movement variables for each age group

	Younger users	Older users
Regressive saccade count	124.3	106.9
Progressive saccade count	480.7	455.7
Avg. Saccade duration (msec)	28.51 (±3.25)	25.50 (±3.23)
Avg. Progressive saccade amplitude (degree)	3.65 (±0.34)	4.20 (±0.34)
Avg. Regressive saccade amplitude (degree)	4.94 (±1.90)	5.06 (±1.26)

Table 4 displays the results of regression analysis as modeled by Eq. 1. As the results show the two groups did not differ significantly in regressive saccades. However, the progressive and regressive saccade amplitudes, as well as saccade duration and progressive saccade counts were significantly correlated with the age group of the users. The results also show a stronger effect for the relationship between progressive and regressive saccade amplitudes and age of the users (as attested by the stronger p value and larger beta value). These results suggest that saccadic eye movements may serve as a reliable predictor of users' age group.

Table 4. Results of regression analysis for different age groups as dependent variable and eye movements as independent variables $R^2 = 0.87$, Adj $R^2 = 0.83$

Eye movement metric	t-stat	P-value	Beta
Regressive saccade count	1.27	0.22	−0.1
Progressive saccade count	**2.47**	**0.02**	**0.19**
Avg. Saccade duration	**2.14**	**0.04**	**0.12**
Avg. Progressive saccade amplitude	**8.38**	**7.9E−7**	**−0.59**
Avg. Regressive saccade amplitude	**5.88**	**3.9E−5**	**−0.40**

As mentioned earlier after reading the passage each participant was asked to provide answers to three questions about the passage. To further explore the differences between young generation and baby boomers we looked at the difference in performance of these two groups using two sample t-test. The results revealed no significant difference between the two age groups in performance. The results of the t-test support the results reported in Table 3, showing no significant differences in regressive saccades between the two groups. The observed behavior support previous research that showed while older adults were slower in cognitive processing, they performed relatively similar to younger adults [8].

Table 5. Results of regression analysis for performance as dependent variable and eye movements as independent variables $R^2 = 0.61$, Adj $R^2 = 0.15$

Eye Movement Metric	t-stat	P-value	Beta
Regressive saccade count	0.93	0.37	0.32
Progressive saccade count	0.36	0.73	0.13
Avg. Saccade duration	0.02	0.99	−0.00
Avg. Progressive saccade amplitude	0.42	0.68	0.13
Avg. Regressive saccade amplitude	1.96	0.07	0.60

We were also investigated the relationship between eye movements and performance. In other words, we examined whether we can use eye movements to predict the reading comprehension performance of users. To do so, we ran a regression on performance as the dependent variable and saccadic eye movement variables (Table 2) as independent variables. Therefore, in the regression analysis we used performance as a categorical variable with different values of {0, 1, 2, 3}, where zero corresponds to no correct answers at all, and three corresponds to answering all the questions right. Since the performance of the two groups was not significantly different, we did not separate the two age groups. The results of regression analysis are shown in Table 5.

As the results in Table 5 show only one of the eye metrics, meaning, average regressive saccade amplitude (t-stat = 0.02, p-value = 0.07, B = 0.71) was almost significant. Thus, our results suggest that regressive saccade amplitude, given a larger sample size, may serve as a predictor of reading comprehension.

5 Additional Analysis

In the previous section we examined saccadic eye movements that may predict user age group and/or reading comprehension. We used saccadic eye movements because we expected that younger and older users show differences in the way they scan the text for reading. In this section we look at possible differences between the two user groups in regards to fixations. Note that consistent with prior research, fixations with durations shorter than 100 ms were filtered out from the fixation data [25].

(a) Young Generation (b) Baby Boomers

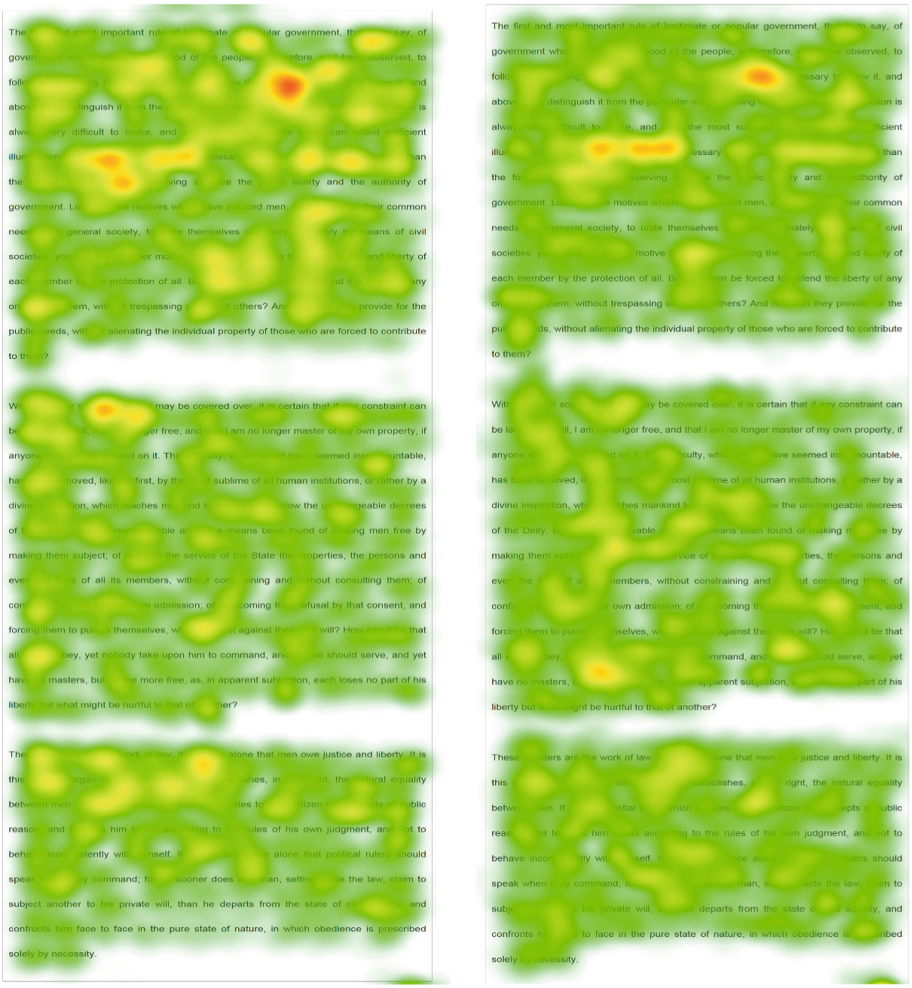

Fig. 1. Heat map of aggregated gaze duration – a comparison between (a) young generation and (b) baby boomers

Figure 1 shows the heat map of aggregated gaze duration between the two groups of users, (a) for young generation and (b) for baby boomers. Green corresponds to minimum gaze duration, and red corresponds to maximum gaze duration (10.58 s in this heat map), which is the aggregation of gaze duration over all the participants who read the passage. The heat maps of total gaze duration do not seem to reveal significant differences between the reading behaviors of the two groups of users.

In addition to qualitative analysis using heat maps we also conducted a regression between different age groups as dependent variable and fixation eye metrics as independent variables. The result of regression analysis is given in Table 6. As the results show fixation metrics, such as average fixation duration and average fixation count, were not significantly correlated with the age group of the users.

Table 6. Results of regression analysis for different age groups as dependent variable and eye movements as independent variables $R^2 = 0.033$, Adj $R^2 = -0.08$

Eye movement metric	t-stat	P-value	Beta
Fixation count	0.44	0.66	0.05
Average fixation duration	−0.66	0.52	−0.08

6 Discussion and Conclusion

In this research we examined the differences between young and old adults in online reading experience by comparing their eye movement behavior. Past research indicates that older adults are likely to expend more effort when processing information [5, 8–12, 17, 28].

Building on the previous research we examined whether we can detect differences between the two user groups reading textual information. Because we were examining overall reading behavior (over the entire text passage) we expected to see differences in saccadic eye movements. The results show that saccadic eye movements (both regressive and progressive), as well as saccade duration and saccade counts in reading was a significant predictor of the user age group. Our results extend previous literature in reading [e.g., 23, 25]. First, in our study we focus on overall passage reading rather than sentence or word by word processes. Second, our results suggest that saccadic metrics may serve as a strong predictor of users' age group. Third, the results indicate that average regressive saccade amplitude may serve as a predictor of reading comprehension. These findings have important implications for capturing online and/or screen reading experience of textual information. For example, it can be used to examine the impact of text simplification on reading experience [26] for one or both age groups.

Fixation metrics such as fixation duration or fixation count were not significant in identifying the differences between the two age groups in our study. We also did not observe any major differences between the aggregated fixation duration of the participants on the passage, according to Fig. 1. This may be because in this study we focused on passage level reading experience and not on the sentence or word level analysis. For example, we did not consider the effect of word predictability or word frequency in fixation duration during reading. Additionally, our sample size was small; by expanding our sample size we may also see significant differences in fixation metrics between old and young users.

Our analysis examining the relation between performance and eye movement revealed that reading comprehension performance was almost significantly correlated ($p = 0.07$) with regressive saccade amplitude. Because, regressive saccades represent cognitive effort in reading, these results show that regardless of age group, the more people were willing to go back and reread information the better they performed the task. It is likely that with a larger sample size the relationship between regressive saccade and performance becomes stronger. Further research with a larger data set is important because it can help to determine whether we can predict a user's reading performance from their eye movement behavior.

Overall our findings are consistent with previous literature that have indicated that there are differences between young and old adults in online reading and web experience [5, 7, 12–14, 17, 28]. For example, Rayner et al. [12] investigated the differences between older and younger adults in reading and learned that older adults make more fixations, longer fixations and more regressions. We also saw significant differences between regressive saccadic eye movements among younger and older adults during reading (Table 4). Another study, comparing older and younger adult's differences in web usability [28] showed that there is some difference between older and younger users when they search for information on the web, as far as the effectiveness, efficiency and user satisfaction are concerned. Overall, our results showed that user population (younger vs. older) when they read textual information can be predicted using the eye movement data. We add to the previous research by investigating the eye movements that are representative of cognitive processing during online reading, and by focusing on the passage level reading rather than sentence level reading, and by comparing the reading behavior of younger and older adults on a relatively long and difficult text passage.

7 Limitations and Future Research

As in any other research our study is not without limitations. Such limitations, however, provide opportunity for directing future research efforts. For example, future studies, including some of our own planned experiments, are needed to test text passages with different content other than law to see whether similar results are obtained. Expanding population to a larger number can also help enhancing the generalizability of our results.

Our results showed that regressive and progressive saccadic amplitude predict user age group. The text used in our study was relatively difficult. Future research, comparing saccadic metrics between the two age groups for text passages with various difficulty levels, is needed to see whether saccade amplitude is a robust predictor of user age when reading online text.

Prior research demonstrates that experience can impact behavioral differences between younger and older users in web usability [13, 14, 28]. According to Loos and Hill et al. [13, 28] daily internet experience usage seems to have greater impact on web usability and navigation patterns of older people than their age. In this study, we did not control for web experience because we focused on reading textual information only. That is, we did not include web components such as navigation bar or links in our experiment. Further research is needed to replicate our study as web content to test whether the inclusion of other web components and their related tasks (e.g., navigations, visual search behavior, etc.) can impact our results and to test how web experience can influence results observed in our study.

In the current study all participants were recruited from university environment and they all had college level reading background. Since research shows that experience has an impact on web usability [13, 28] we plan to take into consideration user's self-reported level of reading experience in our future analysis and examine its possible effects on user experience.

8 Contributions

Effective communication of textual information is key in providing many important online services for both older and younger users. Our results showed that progressive and regressive saccadic amplitudes as well as saccade duration and progressive saccade counts were strong predictor of user age groups. These results suggests that we can potentially predict the age group of the user and/or their reading performance unobtrusively via their eye movements. However, future research is needed to extend our results. There is evidence that familiarity with the web can moderate age effects on web usability [13, 28]. Whether familiarity with web impacts the age related eye movements effects during reading observed in this study when reading text heavy websites needs further research. This information would be of great value to research in designing advanced systems that can use eye movements to respond to user needs [4].

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