# Mitigating distractions during online reading: an explorative study

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***Abstract*—Reading online can be difficult due to the distractions of digital environments. In this paper we present a user study in which participants' eye gaze was recorded as they read text in a visually distracting environment. We explore two distraction mitigation signals using real-time eye gaze data to investigate whether the effects help reduce distraction rate as well as aid recovery from distractions. These signals involved adding a signal to the last word read before a distraction occurred to show the reader where they were up to. We compared these experimental conditions on both first (L1) and second (L2) English language readers and for easy and difficult to read texts. The results demonstrate that the mitigation signals helped recovery from a distraction by drawing participants' attention back to the text as well as indicating from where to recommence reading. We conclude with recommendations on implementing distraction mitigation signals in text.**

***Keywords—eye tracking; distractions; reading; human computer interaction***

## I. INTRODUCTION

Digital environments make vast amounts of information readily available. However, these environments are dynamic, distracting the user with alerts, advertising, social media, and other distractions. It has been shown that auditory distractions, such as background noise, impair reading comprehension [1] and that visual distractions lead to disruptions in cognition [2]. In the case of educational material, irrelevant and attention grabbing images or animations alongside text material have negative effects on learning [3, 4]. However, distractions can be avoided by using attention guiding to ensure that important information is seen [5]. Our hypothesis is therefore that attention guidance can be used to help reduce the disruption of visual distractions during reading.

We explore this hypothesis by also investigating the effects of text readability on the extent to which the visual distractions impact comprehension and distraction rate. We know that auditory distractions impair proofreading performance and prose recall, but the impairments only occur when the reading task is easy [6, 7]. In digital environments many visual distractions are possible, such as the reader having dual screens open with Facebook showing on one screen, advertising on webpages, or simply the pop-up alerts used by many applications such as email. Additionally, past research has shown that there is an effect of such visual distractions on L2 readers when reading easy readability text [8].

The objective of this study is to investigate whether attention guiding can be used to mitigate distractions for test with different readabilities. Adding to our previous research, we investigate the effects of text readability and distractions on first language English (L1) and second language English (L2) readers. Distractions are induced using images that change at constant rates in a side bar. An eye tracker was used to record and monitor eye gaze of participants. Using this live data we implemented a signal to trigger on the last word read before a distraction.

We hypothesize that the easy readability text and the L1 readers will be associated with higher distractions rates, and that the mitigation signals will reduce distraction rates and will help the reader recover after distraction.

This paper is organized into the following sections: background; method; results and discussion; and, conclusion and further work.

## II. BACKGROUND

### A. *Reading in a digital world*

The question of whether reading digital text affects the way we read or the outcomes of reading has been posed by many since the advent of modern computer use. The debate ranges from ergonomics [9, 10], reading comprehension and effects on learning [11-14].

### B. *Electronic text (eText)*

Electronic text (eText) is text that is presented and stored digitally and so is read using a digital device, such as a computer, laptop, tablet, smartphone, or eReader. The ubiquity of these devices has meant that eText is becoming more prevalent. This has spawned research into the effects digital presentation has on the reading process. Initially, much research went into comparing reading digital to paper based texts [9, 15]. In general, the literature has shown that there is little evidence to support claims that one method of display is better than another in terms of improving comprehension [12]. However, as Dillon points out this is due to the complexity in interpreting the results from many diverse studies.

Quite often documents are read that are linear, such as PDFs (portable document format) or eBooks (electronic books), which are closer to printed text. When comprehension from reading print versus PDF is tested, it was shown that students who read the printed version of text achieved significantly higher comprehension results compared to those who read the PDF version [13]. Conversely, it has been shown that students who purchase electronic textbooks perform no differently in a university course [14].

Paper offers advantages over digital presentation, which has been studied to provide design suggestions for better reading technologies [16]. These include supporting annotation, quick and easy navigation, as well as control of spatial layout. Indeed the physical manipulations afforded by the paper medium make paper based text efficient and intuitive to use [17]. Moreover, paper allows readers to perform multiple actions at once, whether the actions are on the same document or across documents, which is a limiting factor of digital reading devices [17]. Proofreading quality is better when reading paper as compared to reading from a tablet device [18]. The authors note that participants were more interactive with the text in paper format.

However, with growing knowledge of the differences in interaction between paper and digital environments, digital environments can be improved to bridge the gap. Further, eText does itself have advantages over paper that include increased accessibility, easy storage and retrieval, ubiquity, and flexibility. Many studies have also considered navigation through eTexts as it is considered a non-trivial text to accomplish in electronic form [10]. Studies have investigated navigation in eBooks [19] and periodicals [20] as well as the impact of screen size on document triage [21].

### C. Images and text

It is generally accepted that including images along with text is beneficial to the learning process, the basis of which lies in dual coding theory [22]. Mayer [22] proposed five design principles for multimedia education, of which presenting text with images is a key principle. Yet, it has been shown that images or animations must be relevant to the learning materials to provide the benefit [3, 4, 23]. Use of seductive images, those that attract attention but are irrelevant to the learning materials have been shown to have a negative effect on learning because the images draw the reader's attention away [4, 23]. The effects of seductive images explored using eye tracking suggest that readers with low working memory capacity are affected more as they spend longer looking at the seductive images than those with high working memory capacity [23]. Another image type that is used in learning materials is decorative images, which are irrelevant to the learning material but not attention grabbing. Whilst it has been shown that decorative images do not negatively impact learning, they do not improve learning [4].

### D. Visual distractions during online reading

Irrelevant and attention grabbing images can be considered distractions from the text rather than helpful resources. Simplification and reduction of distractions is best when aiming to avoid unnecessary cognitive load [24]. Indeed visual distractions from unnecessary elements have been shown to lead to disruptions to cognition [2]. The extent of the impact of these distractions is aligned with the complexity of the task, where impairments on prose recall and proofreading performance only occurred when the reading task was easy [6, 7].

Digital environments provide many distractions within themselves. One such distraction is computer mediated communication technologies such as instant messaging (IM). Whilst using IM during reading does not appear to negatively impact reading comprehension, extensive used of IM is associated with lower reading comprehension scores as well as lower GPA scores [25].

### E. Mitigating distractions

Attention guidance can be used to minimize distractions by providing visual cues using colors to emphasize relevant parts of animations [26], or by zooming in on parts of animations [27], and signaling parts relevant parts of diagrams by adding temporary color changes [28]. Using eye tracking data has been found to enhance the effectiveness of attention guiding [26, 28].

## III. Method

### A. Participants

Data was collected from 66 (28 female) participants with an average age of 21.7 years (standard deviation of 3.9). All participants had normal or corrected to normal vision and were primarily (n=54) recruited from a first year Computer Science course on Web Development and Design offered at the Australian National University (ANU). The remaining participants were all students from ANU. Participants were divided into two groups; those that first learnt to read in English, denoted L1, and those that first learnt to read in another language, denoted L2. There were 42 L1 participants and 24 L2 participants.

### B. Design

The study used a between-subjects design with 3 independent factors: 1) text difficulty; 2) distraction mitigation signal; and 3) whether English was their first reading language. There were two levels of text difficulty, three distraction mitigation signal conditions, and two language groups. All participants were exposed to the same distracting environment.

We experimented using two distraction mitigation signals and had a control condition, these conditions are denoted and described as:

**Condition A:** Cue is yellow highlighting and bolding the last word the reader fixated on.

**Condition B:** Cue is the last word the reader fixated on colored grey and italicized.

**Condition C:** No cue applied to text

The aims of these conditions are to explore the effects of bringing the readers' eyes back to the text, in particular the point they were up to in the text. Secondly, rather than actively drawing their attention back to the text, just give the reader a signifier of where they are up to in the text to help when they do focus their attention back on the text. In both cases the reader will feel the presence of the system monitoring them. The question is whether the cues reduce the effect of distraction? The remainder of this section discusses the design of the texts used, the distracting environment and finally the mitigation techniques.

*1) Text Properties*

The experiment involved each participant reading a piece of text with either easy or hard readability. The readability was calculated using several readability formulas and the average of the formulas was used. The easy text has an average score of 10.6 (Table I); this equates to only a high school level of education needed to comfortably read this text. Given that participants are university students the text should be comfortable to read by all participants. However, the hard text has an average score of 18.0 (Table I) indicating that a much higher level of education (approximately postgraduate level) is needed to comfortably read the text. Participants should therefore find it difficult to read.

TABLE I. READABILITY SCORES FOR EACH TEXT TYPE

| Readability Formula | Easy Text | Hard Text |
|---|---|---|
| Flesch-Kincaid Grade Level | 9.5 | 17.8 |
| Gunning-Fog Score | 12.2 | 21.3 |
| Coleman-Liau Index | 12.7 | 15.8 |
| SMOG Index | 9 | 15.2 |
| Automated Readability Index | 9.5 | 19.7 |
| Average Grade Level | 10.6 | 18 |

The text statistics of each text type are shown in Table II. Whilst the number of words is different by more than 100 words the number of characters is kept roughly the same, which in turn equates to the lengths of the text being approximately the same. We can see that the hard text has significantly longer words as well as longer sentences compared to the easy text.

TABLE II. TEXT STATISTICS FOR EACH TEXT TYPE

| Text Statistics | Easy Text | Hard Text |
|---|---|---|
| Character Count | 3,693 | 3,746 |
| Syllable Count | 1,215 | 1,246 |
| Word Count | 764 | 698 |
| Sentence Count | 47 | 22 |
| Characters per Word | 4.8 | 5.4 |
| Syllables per Word | 1.6 | 1.8 |
| Words per Sentence | 16.3 | 31.7 |

The experiment used a between subjects design so each participant was shown either an easy or a hard text to read. After the text was read, participants' comprehension was tested using 10 comprehension questions that were the same for both texts.

*2) Making the environment distracting*

Participants were required to read text in a distracting environment. This involved creating an environment with a controlled level of distraction so that each participant would be exposed to distraction to the same degree. To accomplish this, a sidebar on the right of the screen was added. In the sidebar a picture at the top is changed every 20 seconds. The pictures in this box are different animals, for example a meerkat. Below this in a rectangular box, names are changed at random every 5 seconds. Both are shown in Fig 1. The right sidebar is designed to stay constantly in focus whilst the participant scrolls through the text. This mimics some properties of Facebook pages, while being consistent for each subject.

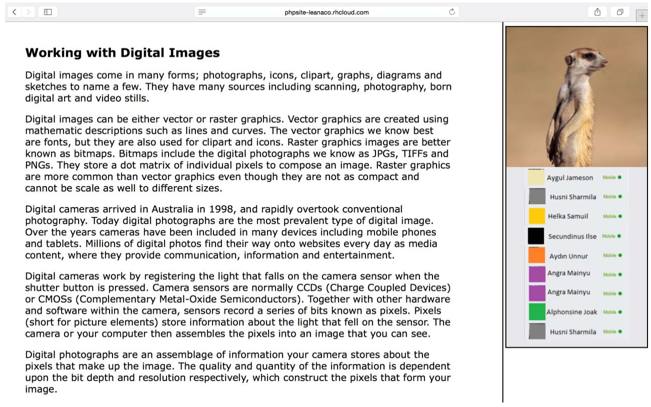


Fig. 1. Example of artificial distracting environment

Distraction mitigating signals are added to the text to show where the reader was up to in the text before they were distracted. This was to investigate whether adding text signals helps the reader recover after reading, and if the participants consider it helpful. Two signals were used in the study, the first is an overt signal and the second is a more subtle signal. In both cases the signal is only applied to the last word the reader fixated on according to the eye tracker, before a distraction drew the reader's eyes away from the text. Both signals were designed so that as soon as the reader looks at the affected word the signal would disappear.

**Signal A:** Highlighting (yellow) and bolding the last word read before a distraction, shown in Fig. 2.

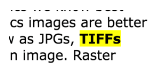


Fig. 2. Example of signal A; highlighting and bolding of the last word read before a distraction.

**Signal B:** Italicizing and making the last word read before a distraction grey, shown in Fig. 3.

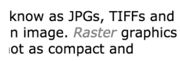


Fig. 3. Example of signal B; greying out and italicizing the last word read before a distraction.

The aim of the two text signals is to explore the effects of bringing the readers' eyes back to the text, in particular, where they were up to in the text. Secondly, the signals are designed to only give readers a signifier of where they are up to in the text to help when they do focus their attention back on the text.

## C. Materials and Procedure

The experiment duration was approximately 30 minutes. First, the experiment was explained to participants, after which they were asked to read and sign a consent form. Participants were given a pre-experiment questionnaire designed so that we could gauge participants' use of potentially distracting technologies. The questions asked of the participants are: Do you use social media, email and/or instant messaging? Do you often use social media, email and/or instant message while you are reading course materials? Do you find that you are distracted by these technologies during study? Response to the questionnaire was in the form of likert scales with the responses being: Never; Once a month; Once a week; Once a day; 2-5 times per day; 5-10 times per day; and 10+ times per day.

Calibration of the EyeTribe eye tracker was performed using a 9-point calibration protocol. According to the EyeTribe software, perfect calibration is the optimal calibration result and equates to accuracy being < 0.5°. The eye tracker recorded eye gaze at 30Hz.

The experiment was run on a MacBook Pro 13" and participants were free to move their heads, however, they were asked to stay relatively still while the tracker was on.

After the calibration routine, participants read the text whilst their eye gaze was being monitored and recorded. Finally a post-experiment questionnaire was given to the participants. In the post questionnaire participants were asked if they were: 1) distracted whilst reading; and 2) whether they thought this had an impact on their understanding. In the conditions where a text signal was used, participants were also asked if they thought the text effect 1) reduced their distraction rate; and 2) helped them to start reading the text again.

## IV. Results

### A. Pre-experiment questionnaire data

From the questionnaire 50 participants stated that they use social media, however all participants (n=66) stated that they use email and instant messaging technology. Additionally, 65 of the 66 participants stated that they use social media and/or emails and/or instant messaging while they are reading learning materials for university. Not surprisingly we found that participants who are distracted with the highest frequency are those who use the technologies most.

When asked how regularly they use these technologies whilst reading learning materials, 46% of these participants stated that they use these technologies more than 10 times per day. With 56 stated that these technologies distract them while they are studying. As Brasel and Gips [29] point out, people underestimate the amount they are distracted so this level could in fact be a lot higher. This establishes that participants have quite a high level of usage of communicative technologies and on average are quite distracted by them while they are studying.

The questionnaire data also shows that there are discrepancies in participants' ratings of distractions versus their ratings of use of the technologies. This is most prominent in the case for the participant who stated they never get use communication technologies whilst reading learning materials, yet the participant also stated they are distracted by these technologies during study more than 10 times a day. This is obviously contradictory.

### B. Distractions

In all cases there are low distraction rates, as shown in Table III. On average L1 participants only look away from the text about 5 times and L2 participants only about 4 times. Even when participants did get distracted they spent relatively little time looking at the distraction. For the L1 participants, only about 2.4% of the fixations were recorded on the distraction area and only 1.9% for the L2 participants. Our expectation was that there would be a higher level of distraction. However, two key points can be made from these results; firstly, the L2 participants tend to be distracted less than the L1 participants, and secondly, there is considerable variation in the distraction of participants, as seen in the large standard deviations. The latter point suggests that the amount to which an individual is distracted is largely based on the characteristics of that individual.

TABLE III. Distraction rates for each experimental condition

| Text Condition | Signal Condition | % fixation out of text | | Number of distractions | |
|---|---|---|---|---|---|
| | | *L1* | *L2* | *L1* | *L2* |
| Easy-to-read | A | 2.4±3.0 | 1.8±2.5 | 5.9±3.2 | 3.8±5.0 |
| | B | 2.3±1.4 | 1.3±3.7 | 5.0±2.2 | 2.3±1.0 |
| | C | 1.9±8.3 | 3.9±23.0 | 3.6±2.3 | 5.8±3.3 |
| Hard-to-read | A | 1.8±11.1 | 1.5±3.1 | 4.4±5.3 | 5.3±2.5 |
| | B | 3.8±12.1 | 1.4±3.0 | 6.3±3.8 | 2.5±2.4 |
| | C | 2.1±4.7 | 1.6±1.1 | 5.4±4.9 | 3.5±3.1 |

### C. Participants' perceptions

After the reading and comprehension tasks, participants were asked if they were: 1) distracted whilst reading; and 2) whether they thought this had an impact on their understanding. Of participants, 82% stated that they were distracted whilst reading and 61% stated that it did affect their comprehension.

There is no difference found in the perceptions between L1 and L2 readers using Chi-square test for independence ($\chi^2(1)=1.99$, $p=0.16$) but there is a relationship between the language group and whether the participants thought the distractions affected their understanding ($\chi^2(1)=4.99$, $p=0.03$). Of the L1 participants, 50% thought the distractions affected their understanding, whereas 79% L2 participants thought the distractions affected their understanding.

Again using the Chi-square test for independence, the distraction mitigation signal conditions were found to have no relationship to whether participants thought they were distracted ($\chi^2(2)=0.26$, $p=0.88$) nor whether they thought the distractions affected their comprehension ($\chi^2(2)=0.72$, $p=0.69$). Finally, text difficulty was found to have no relationship to whether participants thought they were distracted using Chi-square test for independence ($\chi^2(1)=0.88$, $p=0.35$) nor whether they thought the distractions affected their comprehension ($\chi^2(1)=0.74$, $p=0.39$).

#### 1) Perceptions of distraction mitigation signals

For the conditions where the distraction mitigation signals are applied to the text participants were also asked, 1) did you find that the text effect reduced your distraction? And, 2) did you find that the text effect helped you to start reading the text again? The results from this in general point to three main findings; firstly, that the majority of participants did not notice the signal in condition B. Only 2 out of 22 participants thought that the signal in condition B helped reduce their distractions however, 14 of these participants did not even see that there was a signal. Unsurprisingly, only 3 participants in the B condition stated that the signal helped them recover after reading.

The second point is that whilst the signal was meant to be applied with the last word read, this was seldom the case. That is, limitations in the eye tracking accuracy impacted the effectiveness of the signal. This was not picked up in condition B since a large majority of participants did not even notice the effect. However, in condition A the signal was more noticeable and hence the limitation was detected. For condition A, 7 of the 22 participants found that the signal reduced their distraction rate. Whilst this is a small subset, for those that it worked for it did do the job it was supposed to do with participants noting: "*Yes it showed me I was distracted*" and "*Yes as it went a bright colour and reminded me I should be reading*". But for the rest of the participants the signal was not working correctly with participants noting "*It actually distracted me more than the pictures did because it went to something that I either hadn't read yet or already read",* "*No, it was the reason why I distracted.*" and "*Nope. Very random*."

Even with the effect not working correctly, 12 of the 22 participants stated that they thought it helped to start reading again. So even for participants who stated that the effect was not working correctly, they still found it helped, mainly because it drew their attention back and made them re-read text. Participants stated: "*It did bring me back to the text a bit.*", "*Some help, it always drag my attention to the start point to read again.*" "*Yes - but it was a bit behind so I re-read the sentence I had previously read*", "*Well it made me reread things*", and "*Yes, I kind of forgot what I was reading after I saw the text effect, and then I just read from the highlighted text again*".

This brings us the third point that perhaps it is useful to consider the signal not being on the word that was read before distraction occurred but slightly behind that point, inducing re-reading of the text.

## V. Discussion

In this study we investigated two methods for mitigating distractions during reading. The insights gained from this study come from several directions, the first of which is in regards to the pre-experiment questionnaire about usage of distracting technologies during study periods. All participants stated that they use emails and IM but the surprising information comes from the fact that a large majority (98%) of participants use social media and / or email and / or instant messaging while they are reading materials for university. And 85% of participants admit that these technologies distract them while studying. Almost half (46%) of the participants are using these technologies more than 10 times a day and 85% of them are using these technologies at least 2 times per day. Perhaps more interesting is that 65% of participants admit that they are distracted by these technologies during study at least 2 times per day. This indicates that people are getting distracted whilst reading and studying and therefore there is a need to mitigate these distractions.

We hypothesized that the easy-to-read text and the L1 readers would be associated with higher distractions rates. The results show that L2 readers tended to be slightly less distracted than L1 readers. Interestingly though, it was the L2 participants who stated that the distractions affected their understanding whereas the L1 readers tended to think that the distraction did not affect them.

The hypothesis that the easy-to-read text would be associated with higher distraction rates was based on past research that auditory distractions impair proofreading and prose recall task performance when the task is easy and not when it is hard [6, 7]. However, there are several differences between this experiment and those studies on auditory distractions [6, 7]. These differences are the distraction type and the way in which the text is made difficult to read. In our experiment the visual distractions we used may not have been distracting enough. Participants on average fixated about 2% of the time in the distractions area which is a very small percentage and raises the question of whether the environment is actually "highly" distracting or not.

In post experiment discussion many participants noted that they realized that the experiment was designed to distract them. This raises the question of whether having a more realistic distracting environment would indeed be more distracting. Examples of this include having pop-up notifications during the reading task, and making the side bar filled with the participants' Facebook data.

Finally, we hypothesized that the signals would reduce the distraction rate and help the reader recover after being distracted. Neither signal used in the experiment was found to affect the distraction rate; however, the distraction rates themselves are quite low. Even though on average participants were distracted about 5 times during the reading task, the distractions were short with only about 2% of recorded fixations lying on the distractions. Therefore, it is not surprising that the mitigation signals had little overt effect. Additionally, the distraction rates are highly variable between participants indicating that some participants are much more easily distracted than others.

### *A. Implications for eLearning*

The pre-experiment questionnaire shows that there is a problem with participants being distracted by communication technologies whilst studying. There is a need to mitigate these distractions and help students in their learning. Attention guiding could be used to both minimize distraction of the learner as well as draw the learner's attention to the important or relevant parts of the learning material.

Another use of adaptive eLearning is to overcome the effects of distractions. Detection of distractions of readers could be used to determine whether text should be reshown to students. Additionally, labelling parts of the text that the reader was highly distracted during reading could be used to either show the student where they were distracted or be used to control what content is re-shown to the student, where the parts of text that the student was highly distracted during reading could be re-shown.

## VI. CONCLUSION & FUTURE WORK

The study showed interesting results about the presence of distractions during reading and the potential of distraction mitigation signals. However, more participants should be analyzed with better implementation of the distraction mitigation signals. Follow-up experiments are suggested to address these limitations of the experiments.

Given the relatively low distraction rate observed in this study, it is suggested that the environment be made more distracting and have more overt distractions. In this way we could see if an even more distracting environment causes more distractions and therefore has a more prominent effect on eye gaze and reading behavior. The optimal setting for this would be the use of wearable eye trackers that monitor the student being distracted off the laptop screen as well. Thus, we can induce more distractions such as those that come from mobile phones or televisions, as well as the onscreen distractions that were proposed. Additionally, we observed that some participants are more easily distracted than others, trying a within-subjects design would control for this.

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