Visual Distractions Effects on Reading in Digital Environments: A Comparison of First and Second English Language Readers

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ABSTRACT

Reading in digital environments can be very distracting. Using eye-tracking technology, we investigate if text readability affects distraction rate, eye movements, and reading comprehension in a visually distracting digital environment. We compared an easy-to-read text and a hard-to-read text on both first language English (L1) readers and second language English (L2) readers. Text readability was measured using the standard readability formulas such as the Flesch-Kincaid Grade level. Results show that text readability does cause different eye movements and produce reading comprehension results that deviate from what is normally expected. Readers are affected more by the distractions when reading easy-to-read text compared to when reading hard-to-read text. Furthermore, L2 readers are affected more than L1 readers. These findings can be used in the design of eLearning materials when distractions cannot be overcome.

Author Keywords

Eye gaze; eye tracking; reading behaviour; distractions; L1 readers; L2 readers

ACM Classification Keywords

H5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

INTRODUCTION

Digital environments make vast amounts of information quickly and easily available. Partly for these reasons, we read more now than ever before. However, these environments are dynamic, frequently distracting the user with alerts, advertising, and social media amongst other distractions. It has been shown that auditory distractions, such as background noise, impair reading comprehension (Sörqvist et al., 2010). This raises the question of whether visual distractions have negative effects on readers. In the case of educational material, irrelevant and attention grabbing images or animations alongside text material have negative effects on learning (Clark & Mayer, 2011; Harp & Mayer, 1998; Mayer et al., 2001; Sung & Mayer, 2012). Our hypothesis is that visual distractions have a negative impact on reading behaviour and comprehension.

We explore this hypothesis by also investigating the effects of task difficulty on the extent to which the visual distractions impact reading behaviour and comprehension. This is due to the fact that whilst auditory distractions have been found to impair proofreading performance and prose recall, the impairments only occurred when the reading task was easy (Halin et al., 2014a, Halin et al., 2014b). Our investigation differs from previous research, as we will investigate visual distractions rather than auditory distractions. This is because digital environments can contain many visual distractions such as having dual screens open with Facebook showing on one screen, advertising on webpages, or simply the pop-up alerts given by many applications such as email.

Adding to this, we explore the effects that visual distractions have on eye movements and reading behaviour. Eye tracking has been shown to be an effective way of analysing human behaviour, particularly reading (Rayner, 1998) and to some degree indicates where the reader's attention lies.

The objective of this study is to investigate the effects of text readability on the rate at which participants are distracted during reading in a digital environment. Readability is determined by readability formulas such as the Flesch-Kincaid Grade level. The premise is that digital environments can be visual distracting. The effects of this on reading behaviour will also be investigated. Furthermore, we investigate the effects of text readability and distractions on first language English (L1) and second language English (L2) readers.

In this study eye gaze data was collected from participants who read text in a visually distracting environment. More precisely, participants are distracted by images that change at constant rates. An eye tracker was used to record and monitor eye gaze of participants. We hypothesize that: 1) Easy-to-read text will induce more distractions than hard-to-read text; 2) Subsequently, eye movement, reading behaviour, and comprehension will be negatively affected more when reading the easy-to-read text compared to the hard-to-read text; and 3) The

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effects of distractions for English as a first language (L1) and English as a second language (L2) readers will be different. Note that text readability was measured using the standard readability formulas such as the Flesch-Kincaid Grade level. Easy-to-read texts have low readability scores indicating low levels of education needed to comfortably read such texts. Conversely hard-to-read texts have high readability scores indicating intricate structure and long words and so are difficult to read.

This paper is organized into the following sections: background information; user study methodology; results and discussion; and conclusions and further work.

BACKGROUND

Reading in a digital world

Digital environments are dynamic and immersive. The rise of the Internet and ever growing expansion of the World Wide Web has seen an increase in reading amongst many cultures (Bohn & Short, 2009). This increase is only getting larger with the proliferation of mobile technology such as smart phones and tablets.

We are reading more but does reading from digital text affect the way we read or the outcomes of that reading? It is a question that has been posed by many since the advent of modern computer use. The debate on the effects of such digitisation and rapid access to vast quantities of information is not limited to the effect it has on memory. The debate ranges from ergonomics (Dillon, 1992, 2004), reading comprehension and effects on learning (DeStefano & LeFevre, 2007; Dillon & Gabbard, 1998; Mangen et al., 2013; Rockinson-Szapkiw, et al., 2013).

Electronic text (eText)

Electronic text (eText) is the general term for digital presentation and storage of text. eText is read via digital device, such as a computer, laptop, tablet, smart phone, or eReader. The advent of these devices has meant that eText is becoming more prevalent. The digitisation of text has spawned a great deal of research into what effects this has on the reading process. Initially, much research went into comparing reading digital to paper based texts (Dillon, 1992; Rho & Gedeon, 2000). 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 (Dillon & Gabbard, 1998). However, as Dillon points out this is due to the complexity in interpreting the results from many studies. We now give a brief overview of differences that have been found in the context of educational materials.

Hypertext is a prominent form of eText, in that it is the primary form delivery of information on the web. Broadly, a hypertext document enables the reader to navigate via links to other resources or pieces of text. The resulting structure of hypertext documents can be complex and require the reader to make decisions about where to go next. The consensus now is that hypertext structure negatively impacts the reading processes due to increased cognitive demand needed for decision-making and visual processing (DeStefano & LeFevre, 2007).

Hypertext is of course not the only form of eText. Quite often documents are read that are linear, such as PDFs (portable document format) or eBooks (electronic books). Such eTexts are therefore closer to traditional print media. When print and PDF text comprehension was tested on students it was shown that students who read the print version of the text achieved significantly higher comprehension results than those who read a PDF version (Mangen et al., 2013). However, looking at the issue more abstractly, it has been shown that students who purchase electronic textbooks perform no differently in a university course (Rockinson- Szapkiw et al., 2013).

Paper offers advantages over digital presentation, which has been studied to provide design suggestions for better reading technologies (O'Hara & Sellen, 1997). These include supporting annotation, quick and easy navigation, as well as control of spatial layout. Indeed the physical manipulations afforded by paper medium make paper based text efficient and intuitive to use (Takano, Shibata et al. 2014). 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 (Takano, Shibata et al. 2014). However, with growing knowledge of the differences in interaction between paper and digital environments, digital environments can be improved to bridge the gap. Proofreading quality is better when reading paper as compared to reading from a tablet device (Shibata and Takano 2014). Interestingly the authors note that participants were more interactive with the text in paper format. Meanwhile, eText does itself have advantages over paper that include increased accessibility, easy storage and retrieval, ubiquity, and flexibility. Flexibility refers to the ability to dynamically change the way text is read. Changes can be simple, such as font size, colour, or typeface. These changes can also be more complex, such as verbalisations of the text, embedded definitions, and links to background information (Anderson- Inman & Horney, 2007). The reader controls such simple changes; conversely, the eText can be transformed to promote learning and comprehension. Horney and Anderson-Inman (Anderson-Inman, 1999) produced a typology of resources for supported eText. These include presentational, navigational, translational, explanatory, illustrative, summarising, enrichment, instructional, notational, collaborative, and evaluation resources. The typology is a list of ways in which eText can be supported; they vary vastly in method and purpose. Perhaps for this reason there is no consensus which supports should be provided (Anderson- Inman & Horney, 2007). Additionally, the sequence in which questions and text are presented to students affects not only their measures reading comprehension but also their perceived comprehension and their reading behaviours (Copeland and Gedeon 2014). The presentation sequence affects how thoroughly students read paragraphs within the text (Copeland and Gedeon 2014). In this way the presentation sequence can be manipulated to influence how students interact with the learning environment as well as how they learn the material.

Many studies have considered navigation through eTexts as it is considered a non-trivial text to accomplish in electronic form (Dillon, 2004). Studies have investigated navigation in eBooks (McKay, 2011) and periodicals (Marshall & Bly, 2005) as well as the impact of screen size on document triage (Loizides & Buchanan, 2010).

Additionally, the effects of highlighting, hyperlinks, fonts, distractions such as alerts, as well as embedded videos and sounds have long been investigated. The insight gained from these studies is beneficial in designing online reading materials. Inappropriate highlighting of words negatively affects reading comprehension whereas appropriate highlighting enhances comprehension (Beymer & Russell, 2005). The effects of font and font size used in eText have been investigated, where the focus has been on comparing serif and san-serif fonts (Bernard & Mills, 2000; Beymer, et al., 2008; Mansfield, et al., 1996). Smaller font sizes tend to induce slower reading speeds (Bernard & Mills, 2000; Beymer et al., 2008). This was found to result from increased fixation duration (Beymer et al., 2008).

The increased ease at which we can now locate information has changed the way in which we now remember information (Sparrow et al., 2011). Knowing the collective memory of the Internet is available for use anywhere and anytime as an external memory device means that we often do not remember what we read on the web. Instead we have a stronger memory of where to find information.

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 (Mayer, 1999). Put simply, the activation of two cognitive subsystems results in more effective learning. In this way Mayer (1999) proposed five design principles for multimedia education, amongst which using words and images is principle. Images indeed have a large effect in real word scenarios such as educating patients in health care. Images improve understanding of health care instructions and change adherence such instructions (Houts et al. 2006).

However, it has been shown extensively that the images or animations must be relevant to the learning materials (Clark & Mayer, 2011; Harp & Mayer, 1998; Mayer et al., 2001; Sanchez & Wiley, 2006; Sung & Mayer, 2012). 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 readers attention away Sanchez & Wiley, 2006; Sung & Mayer, 2012). The effects of seductive images were 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 (Sanchez & Wiley, 2006). 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 (Sung & Mayer, 2012).

It is recognised that the use of eye tracking to further analyse the effects that multimedia presentation has on learning (Mayer, 2010). Much of the current research however has focused on fixation duration spent in areas of region (see review by Mayer, (2010)). As Hyona (2010) points out this fixation duration leaves out much of the moment-to-moment behaviour that eye tracking is good at capturing.

Distractions during Reading

Irrelevant and attention grabbing images can be considered distractions from the text rather than helpful resources. In this way, explicit testing of distractions has shown similar results. In particular, auditory distractions such as background noise have been found to impair reading comprehension (Sörqvist et al., 2010). The extent to the impact of these distractions is aligned with the complexity of the task, whereby, impairments on prose recall and proofreading performance only occurred when the reading task was easy (Halin et al., 2014a, Halin et al., 2014b).

Distractions such as television provide both visual and auditory disturbance. Computer use in front of a television has shown that people switch between the two medias frequently and that they are not underestimating the extent of how frequently they are switching (Brasel & Gips 2011). Whilst not directly related to reading these results emphasise the importance of investigating how distractions affect readers in a digital environment.

As stated, 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 (Fox et al., 2009). Whilst IMing during a reading task does not negatively impact reading comprehension scores (Bowman et al., 2010; Fox et al., 2009; Jacobsen & Forste, 2011) it negatively impacts the time taken to complete the reading task (Bowman et al., 2010; Fox et al., 2009).

IM is not the only distraction ever-present in digital environments. Recently the use of social media has proliferated in use, especially amongst the young generations. These are the generations now studying so the effects of such technology on learning are indeed important. It has been found that students who use Facebook spend less time studying and have lower GPAs (Kirschner & Karpinski, 2010).

Reading and Eye Movements

Tracking a reader's eye has long been used to measure the reading process (see review by Rayner (1998)). This is due to the fact that the eye moves in well-studied ways during reading, which can be broadly characterised as fixations and saccades. When reading English, fixation duration ranges anywhere between 60-500 milliseconds and is generally about 250 milliseconds (Liversedge & Findlay, 2000). Saccadic movement is between 1 and 15 characters with an average of 7-9 characters. The majority of saccades are to transport the eye forward in the text when reading English; however, a proficient reader exhibits backward saccades to previously read words or lines about 10-15% of the time, termed regressions. Long regressions occur due to comprehension difficulties, as the reader tends to send their eyes back to the part of the text that caused the difficulty (Frazier & Rayner, 1982).

Comprehension of text can have significant effects on eye movements (Rayner et al., 2006). Factors such as semantic relationships and ambiguities have different effects on eye movement, causing them to deviate from the default reading process. For example, syntactically ambiguous sentences induce regressions to resolve the comprehension problems (Frazier & Rayner, 1982). Eye movements have been shown to reflect global text difficulty as well as inconsistencies within text (Hyona, et al., 2003; Rayner et al., 2006). More difficult text causes more fixations, more regressions, and longer fixation duration time. Eye movement has also been shown to indicate reading comprehension and reading skill (Underwood et al., 1990).

Whilst eye movements are a good way of measuring the observable part of the reading process it is important to note that the limitation in the context of HCI research is that the researcher cannot tell what the reader is thinking or doing at the time of reading (Dillon, 2004). In this experiment the focus is not only on reading but also on investigating where participants overt attention is assigned. Eye gaze indicates, at least partially, where one's visual attention is and so can be used in analysis of interfaces to find where people are looking (Poole & Ball, 2005).

Differences between L1 and L2 readers

The differences between L1 and L2 readers has growing importance given the wide spread and pervasive use of the Internet and World Wide Web. Access to texts that are not written in a reader's native language is now easy and common. The differences between L1 and L2 readers can be seen in their reading behaviours. Kang (2014) found that L1 and L2 English readers performed no differently in comprehension tests and that there was no difference in reading attention distributions or eye gaze patterns. L2 readers took longer to read the text and longer to find answers cues in the text. Notably, L1 readers tend to deal with increases of text difficulty with increased reading efficiency, whereas, L2 reading efficiency decreases (Dednam, Brown et al. 2014).

METHOD

Design

Text Properties

The experiment involved two parts; in the first a participant was asked to read a piece of text with either easy or hard readability. The readability was calculated using several readability formulae and the average of the tests was used. The readability formulae used were, Flesch-Kincaid Grade Level, Gunning-Fog Score, Coleman-Liau Index, SMOG Index, Automated Readability Index. The easy-to-read text has an average score of 10.6 (Table 1), this equates to only a high school level of education needed to comfortably read the easy readability text. Given that participants are university students the text should be comfortable to read by participants. However, the hard-to-read text has an average score of 18.0 (Table 1) indicates that a much higher level of education is needed to comfortably read the text. Participants should therefore find it difficult to read.

	Grade	
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*

Table 1. Readability scores for each text type.

The statistics of each text type are shown in Table 2. 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.

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.

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

Table 2. Text statistics for each text type

Making the environment distracting

Participants are 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 distracted in 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. This is shown in Figure 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.

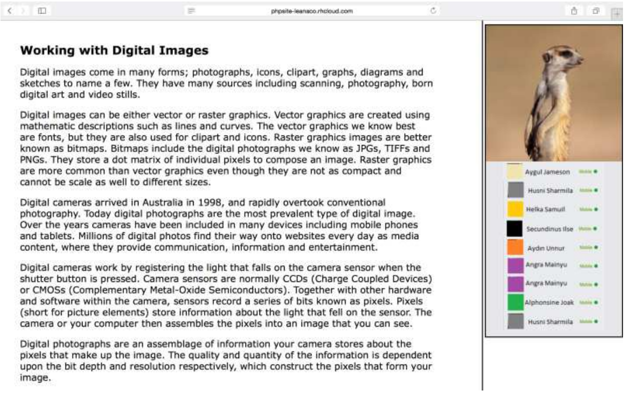

Figure 1. Example of distracting environment

Participants

Data was collected from 22 (8 female) participants of average age 21.7 years (standard deviation 3.0) took part in the experiment. All participants had normal or corrected to normal vision.

Participants were primarily (N=18) recruited from a first year computer science course on Web development and design offered at the Australian National University (COMP1710). The remaining participants are all students from ANU.

Participants were divided into two groups; those that first learnt to read in English signified by L1, and those that first learnt to read in another language, L2. There were 14 L1 participants and 8 L2 participants.

Participants filled out a pre-experiment questionnaire to reveal their use of distracting technologies. 17 stated that they use social media, however all participants stated that they use email and instant messaging technology. Additionally all participants stated that they often use social media, emails and / or instant messaging while they are reading learning materials for university, for which 19 stated that they get distracted by these technologies while they are studying.

Materials and Procedure

The experiment duration was approximately 30 minutes. First, the experiment was explained to participants and then they were asked to read and sign a consent form. Participants were given a pre-experiment questionnaire. Calibration of the EyeTribe eye tracker was performed until 'perfect' calibration was obtained according to the tracker. A 9-point calibration protocol was used, shown in Figure 2. 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.

After the calibration routine participants read the text whilst their eye gaze is being monitored and recorded. Participants then answer 10 comprehension questions about the text. The comprehension questions are always the same set, no matter the text reading level. Finally, a post-experiment questionnaire is given to the participants. In the post questionnaire, participants are asked:

1. Were you distracted whilst reading the text?
2. Do you think the distraction affected your understanding of the text?

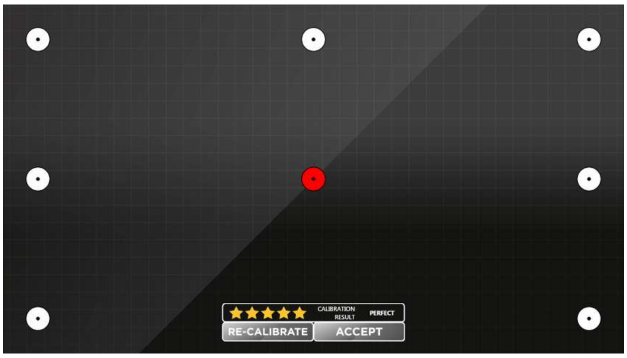

Figure 2. Example of the 9-point calibration screen used in the experiment showing that perfect calibration was accomplished.

DATA PREPROCESSING

The raw eye gaze data collected from the eye tracker consists of x,y-coordinates recorded at equal time samples. Fixation and saccade identification was performed on the eye gaze data. To detect fixations the dispersion threshold identification algorithm (Salvucci & Goldberg, 2000) was used. The duration threshold was set to 150ms and the dispersion threshold was set to 30 pixels.

Once the fixations have been identified, eye movement measures were derived to characterise the reading behaviour. The measures used in this analysis are:

Number of fixations, page total and per region: From the fixation identification algorithm the number of fixations observed for the page is calculated. This page total is then divided into where the fixations occurred on the page, namely, if the fixations were recorded whilst in the text area or the distractions area of the page. The number of fixations can be affected by the reading behaviour, text difficulty, and reading skill (Rayner, 1998). Additionally, this provides insight into how long participants were distracted, as well as the frequency at which they were distracted.

Total fixation duration (seconds), page total and per region: Again from the fixation identification algorithm the number of fixations observed for the page is calculated. The sum of the durations of these fixations is calculated and once again divided into the regions on the pages. Again this is calculated for the text area and distraction area of the page. This measure is useful in global text processing analysis (Hyona et al., 2003) because this measures immediate as well as delayed effects of comprehension.

Reading analysis: For the fixations that were recorded for the text only region, reading analysis was performed. Using our combination of two reading detection algorithms (Buscher et al., 2008; Campbell & Maglio, 2001), this is the percentage of saccades classified as being part of reading (read ratio), skimming (skim ratio), and scanning/searching (scan ratio). Additionally, the longest reading sequence was calculated, which comprises the number of sequential fixations calculated as being part of reading behaviour, as per the reading detection algorithm.

RESULTS

Eye movements

The comparison of eye movements for the easy-to-read and hard-to-read texts as well as L1 and L2 readers is shown in Table 3.

	Easy Text		Hard Text	
Eye Movement Statistics	**L1**	**L2**	**L1**	**L2**
Total # fixations	452	560	564	400
Total fixation dur (m:ss)	1:33	2:23	2:08	1:35
% fixations in out of text area/ total # fixations	2.0%	4.2%	2.0%	2.1%
# of distractions	4	6	5	4
Reading ratio	40%	66%	54%	57%
Skim ratio	25%	17%	29%	24%
Scan ratio	35%	17%	16%	19%
Longest reading sequence	37.6	71.8	68.4	69.0

Table 3. Comparison between text types of fixation statistics

Statistical analysis with MANOVA analysis shows that there are no differences between the eye movements for easy-to-read and hard-to-read texts. Furthermore, there are no statistical differences between the L1 and L2 readers. In other words, not only were the readers' behaviour similar under both degrees of difficulty but also they were no different for the L1 and L2 readers. This is contrary to past research that firstly, text readability affects eye movements (Rayner, Chace et al. 2006) and secondly that there are differences in eye movements between L1 and L2 readers (Kang 2014). The lack of differences in both cases indicates that the distracting environment does indeed affect eye movements.

Whilst there are no statistical differences between the groups, what can be seen is that the L1 and L2 readers are affected differently by the easy-to-read and hard-to-read text. While there was an increase in eye movement measures, such as fixations, fixation duration reading ratio, between the easy and hard texts for the L1 readers, we can see an opposite trend for the L2 readers.

In all cases there is a low distraction rate, that is, on average participants only look away from the text about 5 times. Additionally, when participants looked away they did not spend comparatively long looking at the distractions. This is concluded from the observation that only about 2% of the fixations were recorded on the distraction area. Notably, the percentage of fixations on the images is twice this, at 4%, for the L2 readers under the easy text condition. This implies that the L2 readers are more affected by the distractions in the easy text condition compared to the hard.

Reading Comprehension

After reading the text participants were asked to complete 10 comprehensions questions to assess their understanding. The comparison of results is shown in Table 4.

Reader Type	Text Type	Mean Comprehension score (/10)
L1	Easy	7.9
	Hard	7.7
L2	Easy	6.3
	Hard	5.0

Table 4. Comparison of comprehension scores between text types

While the text readability level was found to not have an effect on comprehension scores, reader type was found have an effect (p=0.0026). From Table 4 this appears to be due to the fact that for the hard text the L2 readers perform much worse than the L1 readers. Indeed L1 readers perform quite well on average, at close to 80% correct.

Questionnaire data; participants' perceptions about the distractions

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. All participants except 3 stated that they were distracted. However, when asked to comment on their distraction or lack of distraction, the 3 participants stated; *"The changing pictures caught my attention a few times as well as something changing in the list of contacts"*, *"I looked at the images to the right which may have counted as a distraction"* and finally, *"not really, maybe a bit by curiosity of what was on the right side at first and also only when the lion appeared for some reason."* At a rudimentary level, these participants had their attention drawn away from the text and the reading process to focus on the images. When asked if they thought the distractions affected their understanding of the text, only 1 of these 3 participants said that they did not think it had affected their understanding. So whilst 3 participants said they were not distracted only 1 participant in the group thought they were not distracted and that the distractions did not affect their understanding.

Of these 3 participants only 1 is an L2 reader and the other 2 are L1 readers. Accordingly, there is no difference in perceptions between L1 and L2 readers (χ^2=0.01, p=0.91).

The same number (63%) of participants thought the distractions affected their comprehension for both the easy and hard texts. Consequently, there is no statistical difference between them in perceptions of how the distractions affected understanding based on text difficulty. Finally, there was no statistical difference between the L1 and L2 readers who thought the distractions affected their comprehension (χ^2=0.70, p=0.40).

DISCUSSION

In this study we compare reading easy-to-read and hard-to-read texts in a visually distracting environment to investigate if text difficulty is related to observed distractions. The questions analysed are 1) Does text with easy readability make readers more distracted than text with hard readability? 2) Subsequently, is reading behaviour and comprehension negatively affected in the easy text condition compared to the hard text condition? 3) Is this consistent for L1 and L2 readers? We have designated text difficulty based on the readability measured via readability formula such as the Flesch-Kincaid Grade level.

From the results it can be seen that for this study there was no difference in eye movements when reading harder text (see Table 3) and that there was no difference in reading comprehension between the types of text (see Table 4). Two interesting aspects of this finding that are contrary to what is expected based on past research. The first is that past research has shown that L1 and L2 readers have the same comprehension but that they have different eye movements during reading, as well as take longer to read (Kang, 2014). Yet we have found that this is not the case in an environment that is distracting. In fact what is shown in Table 3 is that for the hard text, the L1 readers have not only more fixations on average but also a longer fixation times compared to the L2 readers. This is likely to be an effect of compensating for the distraction. Similarly, under normal conditions no difference in comprehension scores between L1 and L2 readers would be expected (Kang, 2014).

Additionally, L2 readers perform significantly worse than the L1 readers at the reading comprehension test. This is could be due to the fact that the distracting environment affects L2 readers' eye movements, and therefore reading behaviour, more. This is supported by the fact that their eye movements are similar to L1 readers. However, we cannot conclude that this is the case, as we did not use a condition where no distractions, for example no images just a blank white sidebar, are given to the readers. Such a condition would allow for a baseline for eye movements and reading comprehension.

Secondly, there are no significant differences between the easy-to-read and hard-to-read texts. Based on past research, under normal conditions it is expected that more fixations and longer total fixation durations would be observed for the hard-to-read text. This is due to the fact that reading difficult text induces more regressions, more fixations and longer reading time (Rayner et al., 2006). The behaviour in the distracting environment seems contrary to this. The distracting environments cause eye movements that deviate from what is normally expected.

Our hypothesis that readers of the easy-to-read text would induce more distractions is therefore not confirmed. This hypothesis 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 (Halin et al., 2014a; Halin et al., 2014b). In this vein we hypothesised that the easy readability text would have a higher amount of distractions, and that L1 readers would be more distracted than L2 readers. This is however not found to be the case for this experiment. Instead what we can conclude is that readers were distracted at a relatively low rate. However, the distractions were enough to cause deviations from normal reading behaviour for both L1 and L2 readers. These deviations are more prominent for L1 readers when they read the easy text. In this case their reading behaviour was similar to the reading behaviour of L1 readers reading the hard text. Additionally, L2 readers reading and eye movements are similar to L1 readers. The result of which is decreased reading comprehension.

There are several differences between this experiment and these studies on auditory distractions (Halin et al., 2014a; Halin et al., 2014b). These being the distraction type and the way in which the text is made difficult to read. Starting with the distraction type, the visual distractions, rather than auditory, may not have been distracting enough. The environment was designed to be highly distracting, so the hypothesis was that participants would be highly distracted and would thus have high, on average, numbers of distractions and fixations in the distraction area of the screen. However, this is not the case. Instead, participants on average fixate about 2% of the time in the distractions area (see Table 3). This is a very small percentage and raises the question of whether the environment is actually "highly" distracting or not. In post experiment discussion many noted that they realised very early on that the experiment was designed to distract them. This is not so far removed from a real life scenario as anytime one works in an electronic environment one becomes susceptible to distractions and is well aware of the fact. However, it does raise the question of whether having a more realistic distracting environment would indeed be more distracting. An example of this would be making the side bar filled with the participants Facebook data, more precisely, embedded the text into a Facebook app.

The visual distractions were an experimental condition and not entirely a realistic situation. However the images rapidly change, which is common for advertising on webpages as well as the rapid changes that occur in social media site such as Facebook. The choice of not using a real scenario, i.e. a webpage with changing adverts, but the objective of the experiment was to control the distraction rate to keep it constant for all participants.

Another, explanation that is that whilst attention grabbing irrelevant images and animations alongside text material have negative effects on learning (Clark & Mayer, 2011; Harp & Mayer, 1998; Mayer et al., 2001; Sung & Mayer, 2012), decorative images have been found to have neither a negative nor positive effect on learning (Sung & Mayer, 2012). The images chosen have only a covert association with the topic in that primarily they are digital images and the topic of the text was on digital images. Given that the images have no overt association to the topic they are perhaps more similar to decorative images rather than seductive images. In either case it would be desirable to redesign of the environment to be more overt in distracting participants would be desirable. Conversely, since the effect of our distractions was to change the way easy-to-read text was read to be statistically indistinguishable from hard-to-read text, perhaps the degree of distraction was sufficient. Even though participants mostly resisted only very rarely at the distracting images there was an effect of eye movements and reading behaviour.

The second difference lies in the fact that task difficulty was altered using the readability of the text rather than by changing the font used. The reason for this is because we are interested in investigating reading behaviour and the effects distractions have on reading. This is different to previous studies where only the outcomes of reading, in terms of comprehension, recall, or time taken, and not the process itself. There is a large body of research on reading behaviour that we can compare against. For these reasons, we decided to change the readability instead of the font.

In the study a sans serif font was used throughout the whole experiment, namely Verdana. However, the hard to read font used by Halin et al. (2014b) was the sans serif font Haettenschweiler. The easy to read font was serif font Times New Roman. In follow-up studies the use of Times New Roman as the font for text display could be tested to see if the font indeed has an effect.

Implications

The implications of the findings from this study are intended to provide insight for designing eLearning environments. Online eLearning allows students to access learning materials from wherever and whenever. Digital environments offer many distractions such as instant messaging, social network sites, email, and the World Wide Web. Teachers' cannot control students' access to such distractions, or whether the student has such sites open whilst they are accessing the learning materials. In this way distracting environments cannot be overcome easily, so it is up to the design of the eLearning environment to mitigate the effects of distractions.

We found that in a distracting environment easy-to-read texts affect eye movements' more than hard-to-read texts. Furthermore, there was no difference in comprehension levels between the easy-to-read and the hard-to-read texts. Consequently, making the text hard to read would therefore be *more* productive for the students.

Additionally, there are differences between L1 and L2 readers in the way that distractions affect their comprehension of text. These differences need to be investigated further, however, the existence of differences means that eLearning environments need to be designed to take into consideration the differences between the two groups. Implications of these difference mean that the same eLearning environment configuration / setup may not be effective for both L1 and L2 readers.

Finally, the use of adaptive eLearning could be used to overcome the effects of distractions. Detection of distractions of readers could be used to control determine whether text should be reshown to students.

CONCLUSIONS AND FURTHER WORK

In this study we considered the effect of text readability on distractions, eye movements and reading comprehension in a visually distracting environment. We compared two texts, one with a readability level aimed at high school level education and the second aimed post-graduate education level. Additionally, we compared L1 and L2 readers to see if they were affected consistently by the distractions.

The results from the study show that text readability does not affect readers' distractions when reading in a distracting environment. However, the results suggest that the distracting environment causes eye movements that deviate from what is normally expected. More precisely, distractions removed the normal significant differences between the eye movements observed for easy and hard text or between L1 and L2 readers. Both of which are contrary to past research findings. This leads to the conclusion that readers are affected more by the distractions when reading easy-to-read text and L2 readers are affected more than L1 readers.

Follow-up experiments are suggested to address certain limitations of the experiments. Namely, to observe the eye movements of readers in the absence of distractions to see if the observed eye movements do indeed deviate when distractions are added. Additionally, some participants may be more easily distracted than others. Using a within-subjects design could control for this.

Furthermore, given a relatively low distraction rate 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 movements and reading comprehension.

Finally, given that distractions have a negative impact on reading it raises the question of whether eye tracking can be used to mitigate such effects. That is whether the eye tracker would be useful to catch distractions and change the display to draw the reader back to the text, as well as perhaps signalling where in the text the reader was up to when they were distracted, thereby potentially reducing the amount of time needed to find the reading start point.

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