RESEARCH ARTICLE

Preliminary investigation of digital reading techniques and their impact on eye movement and blinking rate

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Abstract:

This preliminary study investigates the effect of four digital reading techniques on eye movement and blinking rate. A total of ten young adults (aged 18-26 years) were recruited in this preliminary investigation about the ocular impact of digital reading techniques. The inclusion criteria were best-corrected visual acuity of 6/6 and N5 (6/9 Snellen equivalent) or better for far and near, respectively. The exclusion criteria were any known vision problems and ocular diseases. Four types of digital reading techniques were studied: (1) skimming, (2) scanning, (3) intensive reading and (4) extensive reading. The ocular parameters encompass eye movements (fixation and saccadic) and blinking rate. The measurements were recorded using a Dikablis™ eye tracker. There was no significant difference among the four types of digital reading techniques in all eye movement investigations ($p>0.05$). However, the blinking rate was the lowest during 'scanning technique' (average of 10.90 blinks per minute) and the highest during 'extensive reading' (average of 26.95 blinks per minute) (Friedman ANOVA Test =11.35, $p=0.03$). The eye movement patterns remain the same regardless of the types of digital reading techniques may indicate the robustness of individual visual search capability. The significant variation in blinking rate might be associated with the cognitive demand of the reading techniques. It will be interesting to investigate the ocular impact of these different digital reading techniques among school children due to the digital shift in our education system.

Keywords: scanning, skimming, extensive reading, intensive reading, eye movement, blinking

1. INTRODUCTION

There is an uprising trend in the amount of exposure time for digital engagements (Bandura, 2002). Literature has consistently highlighted the negative impact of prolonged digital usage on the visual health (Adams, 2017; Atella et al., 2019; Chen & Rosli, 2022; Chindamo et al., 2019; Clark et al., 2018; Owen et al., 2010; Peper & Harvey, 2018; Rosella et al., 2019). Blue light from electronics has been linked to multiple ocular complications such as blurry vision, eyestrain, dry eye, macular degeneration, and cataracts (Bauer et al., 2013; Clark et al., 2018; Jaiswal et al., 2019). Compromised binocularity and the ocular surface are among the main visual problems associated with digital usage (Collier & Rosenfield, 2011; Golebiowski et al., 2020; Hue et al., 2014; Kwon et al., 2012; Park et al., 2014; Park et al., 2012; Phamonvaechavan, 2017; Seo, 2012). In contrast, O'Hagan et al. (2016) presented an interesting view after conducting a blue light exposure comparison study between artificial blue light exposure emitted from digital devices (computer screens, tablet computers, laptops, and smartphones) and blue light exposures under natural environment. The blue light exposure conditions were also compared with international exposure limits. None of the digital devices assessed approached the exposure limits, even for extended viewing times. O'Hagan et al. (2016) concluded that blue light emitted from digital devices should not be a concern for public health even under extreme long-term viewing conditions. Nevertheless, they also alluded the age influence on the transmission of blue light from the cornea to the retina. They also emphasised the possibility of distress discrepancy between adults and children due to the higher transmission in children (O'Hagan et al., 2016).

Human eyes react differently to electronic and non-electronic activities (Arunthavaraja et al., 2010; Ciuffreda & Vasudevan, 2008; Lin et al., 2013). Mixed findings of accommodation adaptation were reported after electronic and non-electronic near work (Pandian et al., 2006; Radhakrishnan et al., 2007; Cufflin & Mallen, 2008). The amplitude accommodation was unfailingly reduced after electronic tasks despite mixed outcome after printed materials. The accommodation lag surged but the accommodation facility worsened after both types of near work. Reduction in positive and negative relative accommodation was unswervingly found after electronic near task compared to mixed outcomes in printed materials. Thinning of choroidal was reported during electronic task but not in non-electronic task (Ghosh et al., 2014; Hoseini-Yazdi et al., 2021; Woodman-Pieterse et al., 2015).

Many health issues regarding electronic usage have prompted questions about the 'what-how-why' of the electronic device differed from the traditional printed hardcopy (Harasim, 2000; Prien et al., 2009). There is concern about the deterioration of functional vision due to near extensive work, especially in the electronic interface (Chang et al., 2015; Chu et al., 2014; Zambarbieri & Carniglia, 2012). It is interesting to examine how digital reading affects the eyes.

Reading, as one of the important skills for all ages in obtaining knowledge and learning, has an impact on the quality of life (Rayner et al., 2001). Reading requires complex coordination of interrelated information to construct meaning from written texts (Pearson & Anderson, 1985). Reading activity can be affected by several factors such as font size, font type, field size, contrast, eye movement, and age (Chen et al., 2019). Reading involves a visual-motor system and visual information processing system (Garzia et al., 1990). The reading activity engages the processes of decoding and linguistic comprehension (Hoover & Gough, 1990; Rayner et al., 2003). When retrieving information from a text, the reader can adopt different reading techniques depending on the purposes, such as searching for information (scanning), extracting detailed information (skimming), reading for leisure (extensive) or deep comprehension (intensive). Scanning is a reading technique that quickly searches for specific information in a text (Fisher, 2016). The scanning reader needs to immerse or deeply comprehend the text thoroughly. Skimming evaluates the text for complexity, interest, and general storyline rather than searching for specific facts (Barral et al., 2014). Skimming usually looks for summaries, first and last sentences of paragraphs, bold words or stands-out text features. Skimming reader deliberately skips text that provides details, stories, data, or other elaboration. Extensive reading generally involves a rapid reading of large quantities of material or extended readings (Bell, 2001). Extensive reading aims to obtain new information with no time constraints. Intensive reading refers to thoroughly and profoundly reading through every word of a text from beginning to end (Koay, 2015). Intensive reading requires a lot of focus and great mental efforts (Macalister, 2011).

Tracing texts during reading is essential to repossess information (Tabrett & Latham, 2011; Whittaker & Lovie-Kitchin, 1993). Reading involves the visual-spatial capability to locate words, visually identify text, and visually encode typo scripts (Pammer et al., 2004; Singleton, 2008). Eye movements help to position the eyes to text location during reading (Altangerel et al., 2006; Ishii et al., 2013). Saccades is a rapid eye movement that shifts from one point to another during reading (Millodot, 2017; Rowe, 2012). Fixation refers to several eyes paused during reading for the information processing (Ciuffreda & Tannen, 1995). Visual information originated from fixation but was incorporated spatially and temporally by the movement of saccades to form a visual perception (Schütz & Souto, 2011; Solan, 1985). Readers barely note discontinuities as the eye moves from one spot to another (Burton et al., 2015; Krieber et al., 2016). The parafoveal information from the initial fixation is unified with information from the fovea of the following fixation (Ishida & Ikeda, 1989). Previous studies on eye movement and reading techniques exhibited increased saccades and shorter fixation duration during the skimming, scanning, and extensive reading compared to the intensive reading (Loberg et al., 2019). However, the disparity was reported among those good readers. People with good reading skills reported shorter fixation durations than an average skilled reader (Ashby & Clifton Jr, 2005).

The blinking rate is closely linked to reading. Visual and ocular symptoms experienced by digital users have been reported to associate with changes in the quality of blinking and tear break-up to ensure the maintenance of the normal optical integrity (Emina, 2003; Himebaugh et al., 2009; Patel et al., 1991). Symptomatic digital users showed a reduced blinking rate (Emina, 2003; Jaiswal et al., 2019; Patel et al., 1991). In a well-controlled laboratory set-up, a significant reduction in the blinking rate was reported in the letter tracking task compared to watching movies (Himebaugh et al., 2009). The blink rate decreased in a visually demanding task (Baumstimler & Parrot, 1971; Drew, 1951; Stern & Skelly, 1984). This inverse relationship between the blink rate and the task criteria can be due to efforts to reduce the risk of losing essential information (Baumstimler & Parrot, 1971). Electronic reading has been associated with increased burning sensation, tearing, and blinking (Argilés et al., 2015; Prabhasawat et al., 2019).

The present study aimed to directly compare the four different reading techniques (scanning, skimming, intensive and extensive reading) using eye movement and blinking rate. Our study design controlled the screen luminance and text structure consistency. Eye movement and blinking rate were measured using one piece of equipment to control the time variation.

2. MATERIALS AND METHODS

Ethical approval was obtained from the UiTM Research Ethics Committee [REC/01/2020 (UG/MR/17)]. This cross-section study adhered to the declaration of Helsinki. Written informed consent was obtained prior to data collection. In this preliminary study, ten young adults were recruited using convenient sampling. The inclusion criteria were best-corrected visual acuity of 6/6 and N5 (6/9 Snellen equivalent) or better for far and near, respectively. The exclusion criteria were any known vision problems and ocular diseases.

The data collection was done in a room size of 3x4 meters. The subject was seated on a chair, and a table was used. The chair and table height was 45 cm and 75 cm, respectively. Four types of digital reading techniques were studied under standard room illumination (400 to 500 lux) at 40cm working distance: (1) skimming, (2) scanning, (3) intensive reading and (4) extensive reading. The sequence of the four techniques was randomly determined for each subject. The washout period was 30 minutes between techniques.

The reading materials were presented in black text on a white background on a laptop [MacBook Pro Retinal Display 13.3 inch]. The contrast is about 80% quantified by luminance meter LS110 [Konica Minolta, Japan]. The luminance from the laptop was the highest setting in the display option. The ambient illumination was the standard office lighting, ranging from 400 to 500 lux, measured by Illuminance Spectrophotometer, CL-500A [Konica Minolta, Japan]. All reading materials for each reading technique were specially engendered for this research. They were prepared in Arial font type of N12 (6/24 Snellen equivalent) font size, single line spacing, the same number of sentences, approximately 500 words per page and justified alignment of the paragraphs. N12 was selected because it was commonly used in books.

Specific instruction was given to the subject for each reading technique. Each subject was given a single paragraph of text on one page for the scanning technique. All texts were in English. The subject was instructed to read the words starting with capital letters. For the skimming technique, the subject was given a collection of articles, and they were instructed to sort them out according to categories such as health, sports, history, and food. For the intensive reading investigation, the subject was given a text to read, and they needed to answer some questions about the test. For the extensive reading probe, the subject was given a few short stories (in a single paragraph on each page). The subject was instructed to read for 5 minutes at leisure.

The eye movements (fixation and saccadic) and blinking rate were recorded using a Dikablis™ eye tracker for five minutes during each type of reading technique. The eye tracker was calibrated for each reading technique to get an accurate reading. Calibration was performed before taking any measurement by adjusting the eye camera, pupil detection configuration, and calibrating the eye motion. Dikablis™ eye tracker is a head-mounted eye-tracking system used to track and experimentally analyse the glance direction and the eye movement of the subject being tested. Dikabilis™ incorporates live view in the recording software and allows the recording of the blinking rate.

Statistical data analysis was performed with statistical software (SPSS software 26.0 for Windows; IBM Corp., Armonk, NY, USA). The Friedman ANOVA test was used to compare the mean score of parameters such as fixation, saccades, and blinking rate to measure the effect on visual function for each reading technique.

3. RESULTS AND DISCUSSION

The age range of the subjects was between 18 and 26 years old. Gender composition consisted of seven female and three male. All of them were university students.

The effect of digital reading techniques on fixation, saccades, and blink rate were summarised in Table 1. There was no significant difference among the four types of digital reading techniques in fixation and saccadic eye movement investigations ($p>0.05$). However, the blinking rate was the lowest during ‘scanning technique’ (an average of 10.90 blinks per minute) and the highest during ‘extensive reading’ (an average of 26.95 blinks per minute) (Friedman ANOVA Test =11.35, $p=0.03$).

Table 1. The Effect of Four Reading Techniques on Eye Movements and Blinking Rate

Reading techniques	**Eye movements, counts (n)**		**Blinking rate (Blinks per minute)**
	Fixation	**Saccadic**	
Scanning	22.30	26.90	10.90
Skimming	21.30	20.30	22.40
Intensive	17.40	19.10	21.75
Extensive	21.00	15.70	26.95
Friedman Test	2.34	6.85	11.35
p-value	0.93	0.24	0.03

Fixation in reading is the point at which the eyes rest when reading. To measure the effectiveness of reading performance, the total number of eye fixes during the reading of the complete text was counted in this study. Less eye fixation during reading was suggested to result in a greater word intake per fixation (Vitu et al., 2001). A previous study suggested that the number of fixations is closely related to the difficulty of the reading task (Krieber et al., 2016). Reading for comprehension should require more cognitive processing and be considered more incredible difficulty. However, our findings on fixation and saccade patterns remain the same regardless of the types of digital reading techniques, which may indicate the robustness of individual visual search capability. Therefore, the characteristics of the reading texts used became really crucial. To repeatedly use the same text might help to standardize the consistency of text difficulty level across techniques. However, it might introduce other limitations such as learning effect and boredom to subjects in four experimental sessions. Our experimental settings were devised as close as possible to the typical expected reading environments that stipulated scanning, skimming, intensive and extensive techniques. We assembled variety of texts that matched the cognitive level of our subjects. Text of equivalent length was also premeditated to reduce variant.

Our findings partially supported the previous research that reported an inverse relationship between the blink rate and the task demand (Abusharha, 2017; Baumstimler & Parrot, 1971). The blink rate concerns maintaining the normal integrity of the ocular surface (Golebiowski et al., 2020; Kim et al., 2017). Most blinks originate a cycle of secretion, dispersal evaporation, and drainage of tears (Fenga et al., 2008; Himebaugh et al., 2009), duly associated with dry eye symptoms. Surprisingly, the highest blinking rate was extensive and not intensive reading in our study. Intensive reading should give more cognitive demand than the extensive reading technique that was associated with blink inhibition (Golebiowski et al., 2020; Nakamura et al., 2010). One possible explanation is the reading passage used in our intensive task was not challenging enough to trigger more blinking. While for scanning reading, the low legibility perceived by the retinal image might influence the lower blinking rate (Golebiowski et al., 2020), which sees high eye movement counts on fixation and saccadic.

The small sample size of this preliminary study may limit the inference of the findings to the general population. A larger sample size with more complex reading passages for intensive reading technique investigation should be used in future research. Another limitation of this preliminary study was the absence of reading skill information of the participants. Longer fixation duration on low-frequency words was found in average-skilled readers compared to high-skilled readers (Ashby et al., 2005). A skilled reader showed fewer fixations per word and a total number of saccades and reduced jump distances than low-skilled readers (Krieber et al., 2016). However, our cross-over design minimised the bias. Our recommendation for future design should include reading performance evaluation of subjects. In addition, it will be interesting to investigate the ocular impact of these different digital reading techniques among school children due to the digital shift in our education system.

4. CONCLUSION

The eye movement patterns remain the same regardless of the types of digital reading techniques may indicate the robustness of individual visual search capability. The significant variation in blinking rate might be associated with the cognitive demand of the reading techniques.

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