ORIGINAL ARTICLE

Comparing Eye Tracking Technology in Reading Performance Assessment with Conventional Method

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Keywords:
reading performance; reading speed; fixation duration; eye tracking

ABSTRACT

Background: Reading is one of the most essential skills for academic and social development. It greatly affects one's quality of life, making the assessment of reading performance essential and should be considered in clinical practice. The purpose of this study was to compare the reading speed recorded using eye tracking technology (Tobii Pro Fusion 120-Hz eye tracker and Tobii Pro Lab software) with the reading speed measured using conventional evaluation method. The number of fixations and total fixation duration acquired from the eye tracking data were analysed as potential indicators for reading performance. **Methods:** Seventeen healthy participants (aged 21 to 38) with optimum vision were recruited in this study. All participants were instructed to read aloud from two different reading materials, which were selected in random sequences. During the reading task, the eye tracker automatically captured and computed the reading duration, number of fixations and total fixation duration. As for the conventional evaluation method, the time taken to complete the reading task was manually measured for each participant using a stopwatch. Reading speed was quantified as words per minute (wpm). **Results:** The paired t-test revealed no significant difference in reading speed measurement between conventional evaluation method and eye tracking recording (p=0.986). The Bland-Altman plot demonstrated good agreement between the reading speed measured using the two methods. Regarding the analysis of fixation data, the Pearson correlation showed a negative correlation between reading speed and both total fixation duration (r=-0.515, p=0.035) and number of fixations (r=-0.585, p=0.014), suggesting that participants with lower reading speed (slow reader) tended to have higher number of fixations and longer total fixation duration. These findings imply that fixation data may be a useful measure for assessing reading performance. **Conclusion:** This study highlights the potential of Tobii Pro Fusion 120-Hz eye tracker as a valuable tool for enhancing the assessment of reading performance as it offers a more precise and dynamic approach to assess reading performance compared to conventional methods.

INTRODUCTION

Reading is a fundamental skill involving the ability to understand any information from written or printed stimuli (Frey, 2020). Proficient and efficient reading involves multiple factors including linguistic and cognitive skills such as understanding the auditory and visual elements of word and the meaning of the word itself (McBride et al., 2022). Reading proficiency is a critical skill and significantly affects individual's quality of life especially in term of academic achievement and cognitive development (Kelly et al., 2017; Kugathasan et al., 2019; Narayanasamy et al., 2015).

Traditionally, reading performance usually being evaluated by measuring the reading speed, accuracy and comprehension (Buczkowska & Miskowiak, 2017; Lee et al., 2020). However, the disadvantage of these convensional methods is that these approaches mainly focused on outcome-based assessment, without accounting for the detailed process involved in reading which possibly affect the reading performance such as eye movements, specifically saccades and fixations. These components are critical in understanding the visuomotor behaviour during reading and information processing, especially among individuals with specific visual conditions such as amblyopia and anisometropia (Niechwiej-szwedo et al., 2019; Quaid & Simpson, 2013; Vinuela-Navarro et al., 2017).

One of the promising tools for investigating eye movement behavior during reading tasks is eye tracking technology. Eye tracking is a method used to investigate eye movements by analysing participants' visual attention, cognitive processes and visual behavior. It has been widely used in various research fields including reading and language, psychology, neuroscience, and is currently of great interest for exploring biomarkers in clinical research

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Journal homepage: https://journals.iium.edu.my/ijahs/index.php/IJAHS
EISSN NO 2600-8491

(Holmqvist et al., 2023).

In reading research, other than offering detailed analysis of visual performance during reading, eye tracking provides objective measurements of reading behavior such as text processing and duration of visual attention at specific phrase, word or even character level (Tobii AB, 2022). In contrast to conventional methods, eye tracker records the eye movement in real time throughout the reading task, which reflects the way readers engage with the text. This information provides better knowledge on reading behaviors, especially in terms of visual attention and fixation, instead of examining the common elements of reading assessments.

As eye tracker has emerged as a promising tool for analysing eye movement, this study aimed to explore the potential of eye tracking technology in enhancing the assessment of reading performance, offering potential benefits through its objective outcome measures. Specifically, this study aimed to compare the reading speed recorded using Tobii Pro Fusion 120-Hz eye tracker, with the reading speed obtained through conventional evaluation method in order to ensure the accuracy of the eye tracker for clinical applications. Besides, the total fixation duration and the number of fixations obtained from Tobii Pro Lab software were analysed as potential indicators for reading performance.

MATERIALS AND METHODS

This study adhered to the tenets of the Declaration of Helsinki and the study protocols were approved by the International Islamic University Malaysia (IIUM) Research Ethics Committee (IREC 2023-144). Seventeen participants aged between 21 and 38 years volunteered to participate in this study. The number of participants was determined based on previous eye movement study by Shafee (2021). Besides, as this study fall under psychophysics experiment involving the relationship between stimuli and perception among normal population, small sample size was acceptable considering the adequate control of external factors (Marszalek et al., 2011). Written consent was obtained from all participants prior to study procedures.

Participants

All participants underwent a comprehensive eye examination before the data collection process and the participants who met the inclusion criteria were included for data collection. The inclusion criteria for this study were good ocular and general health, age between 20-40 years old, distance best corrected visual acuity of 0.00 logMAR or better in each eye, near best corrected visual acuity of 0.00 logMAR in each eye, able to fluently read Malay reading material and have no known metabolic disorders or serious medical conditions that could affect eye movement.

Reading materials

Two sets of validated reading materials (Omar et al., 2015) were utilized in this study. Both reading materials consist of 50 words, with 6 sentences for each text. As for conventional method, the reading materials were printed in 100% contrast on A4-sized white paper. The font typeface used was 'Arial' as the font was easier to read (Taylor et al., 2020) and made of straight, simple lines without any serifs, which could minimise the crowding effect to the readers (Beier & Oderkerk, 2021). Meanwhile for eye tracker recording, the letter sizes in the reading materials were precisely calculated for 600mm viewing distance, ensuring the visual angle matched that of the conventional method (Eq. 1). Figure 1 illustrates the differences in letter sizes for both conventional method and eye tracking.

$$\text{Visual angle } (\theta) = 2 \cdot \tan^{-1}\left(\frac{S}{2D}\right) \quad (1)$$

where, θ = visual angle
S = height of letter in reading material for conventional method
D = distance between participant's eyes and reading material

Visual angle (ϑ) for conventional reading material

$$\Theta = 2 \cdot \tan^{-1}\left(\frac{5}{2(400)}\right)$$
$$= 2 \cdot \tan^{-1}(0.00625)$$
$$= 0.72°$$

Letter height for eye tracking reading material

$$0.72° = 2 \cdot \tan^{-1}\left(\frac{S}{2(600)}\right)$$
$$S = 2 \cdot 600 \cdot \tan^{-1}\left(\frac{0.72}{2}\right)$$
$$= 7.5\text{mm}$$

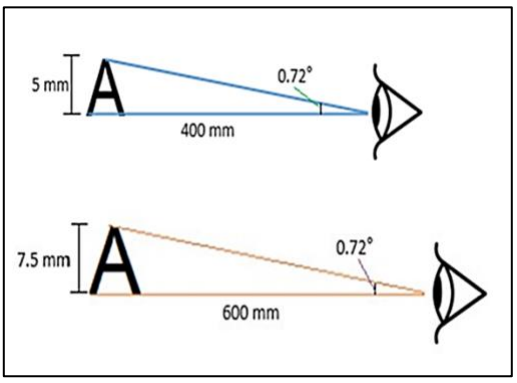

Figure 1: Letter height for conventional method (top) and eye

tracking (bottom).

Reading assessment using conventional method

With their best-corrected visual acuity, the participants were instructed to read the sentences on the Malay reading material (randomly chosen) aloud, as accurately as possible, with the speed as they normally read any reading materials. The reading material was placed 400mm from the participants' eyes. Time taken to complete the reading task was manually timed for each participant using a stopwatch and recorded to the nearest 0.1s (Buari et al., 2015). Reading speed was then calculated in words per minute (wpm), as shown in Eq. (2).

$$\text{Reading speed} = \frac{Number\ of\ words\ in\ text}{Time\ taken\ to\ read\ all\ the\ words\ (\text{sec})} \quad (2)$$

Reading assessment using eye tracking (Tobii Pro Lab Software)

Reading assessment was conducted using Tobii Pro Fusion 120-Hz eye tracker, which mounted on a display monitor positioned 600mm from the participant (Figure 2). During the reading task, all data were recorded on a HP Pavilion laptop equipped with Tobii Pro Lab Software.

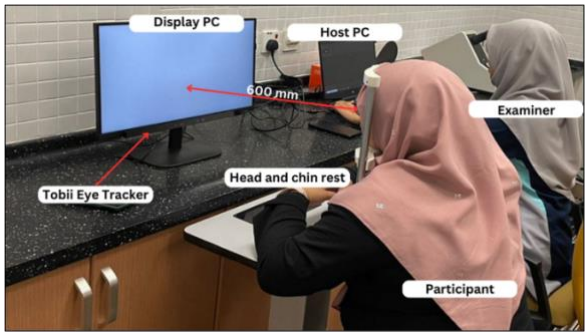

Figure 2: Participant set-up during reading assessment

Prior to reading assessment, eye tracking calibration using a 5-point calibration technique was conducted (Ozer & Ozdemir, 2021). The calibration accuracy and precision thresholds were set at 0.5° and 0.2°, respectively, as recommended by the manufacturer (Tobii AB, 2022). After a successful calibration, reading material (different set as the one used for conventional method) was presented on the display monitor. The participants were instructed to read the reading material and the eye tracker automatically recorded and calculated reading duration, total fixation duration (duration of the eyes fixate inside the texts during the recording period) and number of fixations (the number of fixations occurring within the texts during the recording period) during the reading task.

Data analysis

Statistical analysis was conducted using the Statistical Package for Social Science Software (version 28, Statistical Package for Social Sciences; SPSS Inc., IBM Corp., Armonk, NY, USA). Normality testing was examined using the skewness and kurtosis tests (Kim, 2013). A paired sample t-test was employed to compare the reading speed measured using conventional method and eye tracking technology. Bland Altman analysis was tested to evaluate the limit of agreement between the two methods in assessing the reading speed. Besides, the correlation between; (1) reading speed (measured using eye tracking) and total fixation duration, and (2) reading speed (measured using eye tracking) and number of fixations during reading task were examined using the Pearson correlation .

RESULTS

Reading speed measured using conventional method vs. eye tracking

As presented in Table 1, the paired sample t-test analysis showed a non-significant difference (p=0.986) in reading speed measured using conventional method and eye tracking. The result showed that the Tobii Pro Fusion 120-Hz eye tracker is an accurate device for assessing reading performance, as it produced results comparable to the conventional method.

Table 1: Comparing the mean of reading speed measured using conventional method and eye tracking technology

Parameter	Conventional method Mean ± SD	Eye tracking Mean ± SD	p-value*
Reading speed (wpm)[†]	135.68 ± 11.02	135.69 ± 11.87	0.986

[†] wpm= words per minute
*p-value analysed using Paired sample *t*-test

Furthermore, by using the eye tracker, additional parameters (i.e. total fixation duration and number of fixations) were measured to provide a more comprehensive assessment of reading performance, as shown in Figure 3 and 4.

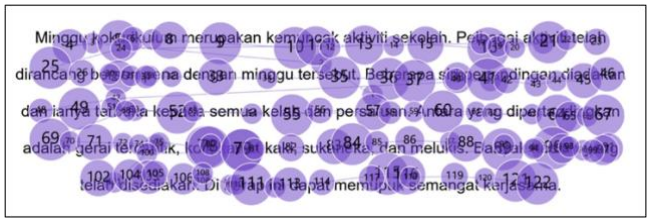

Figure 3: Participant's gaze pattern during the reading experiment. The size of the circle corresponds to the fixation duration. The number in the circle is the rank of fixation. The

lines represent saccades.

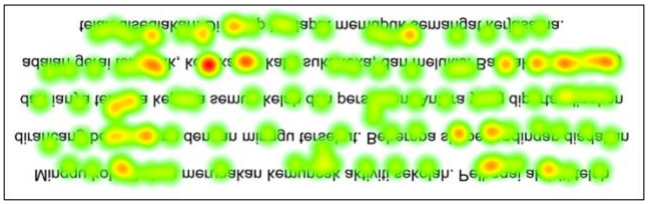

Figure 4: Heat maps visualization of reading material. Red/dark shade indicates high density of fixations and green/light shade indicates low density of fixation.

Agreement of reading speed measured using conventional method vs. eye tracking

The Bland-Altman test showed a bias of -0.01 (95% CI: -0.96 to 0.95) with all data occupied the upper and lower limit of agreement (3.93,-3.95) as illustrated in Figure 5, indicating no proposional bias. The results suggested that while there was a small average difference in reading speed measurement, the two methods were comparable to be used in clinical applications.

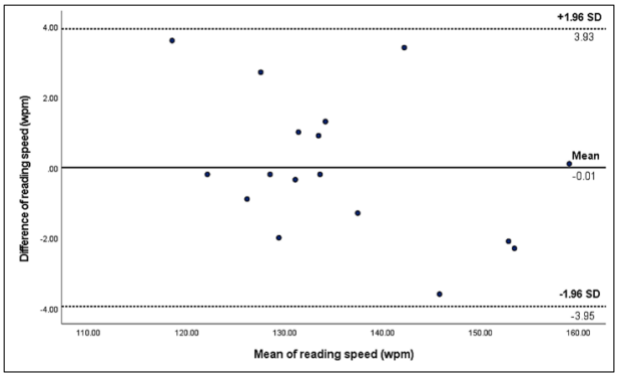

Figure 5: Limit of Agreement (LoA) of reading speed measured using conventional and eye tracking method.

Correlation between reading speed and fixation data during the reading task

The Pearson's correlation analysis showed a negative correlation between reading speed and both total fixation duration and number of fixations, suggesting that as the reading speed increases (in the case of fluent reader), both total fixation duration and number of fixations tend to decrease. Table 2 specifies the Pearson's correlation coefficient (r) and statistical significance for each pair of variables.

Table 2: Correlation between reading speed measured using eye tracker and total fixation duration, and number of fixations during reading task

Variables	r	p-value*
Reading speed (wpm)ᵻ Total fixation duration (ms)#	-0.515	0.035
Reading speed (wpm) Number of fixations	-0.585	0.014

ᵻwpm= words per minute, #ms= milliseconds
*p-value analysed using Pearson correlation

DISCUSSION

The findings suggested that the eye tracking method produced valid measurements regarding reading speed, comparable to those measured using conventional method. Insignificant difference in reading speed measurements (p=0.986) with good agreement between the two methods suggested that eye tracker technology provides comparable and reliable results in assessing reading speed.

As eye tracking technology enables a more detailed analysis on reading assessment, this study included another two parameters for reading performance indicators: total fixation duration and number of fixations. Fixation in reading experiment can be defined as a small pause between saccades, occurred in order to gather sufficient information in analysing the text viewed during reading (Dambacher et al., 2013; Justino & Kolinsky, 2023).Previous studies have reported that eye movement behavior, including fixations were differ between proficient and novice readers (Justino & Kolinsky, 2023; Vinuela-Navarro et al., 2017), indicating the advantages of including these parameters to be included during the assessment.

In this study, the analysis of fixation data revealed a negative correlation between reading speed and both total fixation duration and number of fixations. It can be inferred that slower readers may make a greater number of fixations and have longer fixation durations to gather the necessary information and process the text they are reading. These findings were in line with previous literature which reported higher reading rate resulted in fewer and shorter fixation when measured using Visagraph software (Spichtig et al., 2017).

The consistency in results between the current study and previous research indicates that the eye tracker, specifically Tobii Pro Fusion 120-Hz is a viable tool for assessing reading performance in clinical practice. The potential implications of this study extend beyond the scope of healthy individuals, as it may benefit future investigations, especially among children with learning disabilities. This is because children with visual dysfunction were reported to underperform in academics due to deficits in reading ability, resulting in poorer overall academic outcomes (Kugathasan et al., 2019; McBride et al., 2022).

Thus, it is recommended for future study to evaluate the

effectiveness of eye tracking technology as an early diagnostic tool for children with learning literacy. Besides, it is also highly recommended for future study to explore on other reading metrics available in Tobii Pro Lab software, such as saccades, progression-regression and re-reading duration to provide more comprehensive evaluation of the reading performance using the eye tracking.

CONCLUSION

Eye tracking technology can accurately analysing participants' reading performance in terms of reading speed, total fixation duration and number of fixations, making it a potential alternative to conventional evaluation method. Although conventional evaluation method remains relevant for their cost-effectiveness, incorporating eye tracking technology enhances accuracy and provide valuable insights into reading behavior through the fixation data analysis, leading to better diagnostic and therapeutic approaches.

ACKNOWLEDGEMENT

Special thanks to the participants involved in this study, as well as to all the staff from the Department of Optometry and Visual Science (KAHS) for their support and encouragement during the data collection process. This study has been presented at International Virtual Medical Research Symposium 2023 on 7th and 8th December 2023. The symposium was organised by International Islamic University Malaysia (IIUM).

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