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Evaluation of Students' Gaze Patterns, Diagnosis Speed and Diagnosis Accuracy When Interpreting Clinical Findings

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ABSTRACT

Time and speed are vital aspects of clinical diagnosis decision-making. This study aimed to investigate the gaze patterns, diagnosis speed and accuracy with and without the assistance of clinical history while interpreting clinical findings. This cross-sectional study employed convenience sampling to recruit 28 normally sighted final year students with ongoing clinical training. Each student was shown six clinical findings, half of which accompanied a brief clinical history in prose, and the other half were not. First, the clinical history was presented to be read by the participants, followed by providing clinical findings regarding fundus picture images. The participants were asked to make a diagnosis based on a clinical finding presented to them. The Dikablis eye tracker was used to record and track the gaze patterns during the treatment. The assessment had no time restriction, and the gaze patterns (number of fixations, fixation duration, number of saccadic, and saccadic angles) were retrieved from the D-Lab software. Diagnostic speed was calculated based on the time taken for the students to provide a clinical diagnosis. Diagnosis accuracy was the score of correct or incorrect of the given diagnosis. Comparison of gaze patterns in interpreting clinical findings with clinical history and without clinical history showed no statistically significant difference for all gaze patterns including the number of fixation ($p=0.20$), fixation durations ($p=0.98$), number of saccadic ($p=0.33$) and saccadic angle ($p=0.77$). There was also no statistically significant difference in both diagnosis accuracy ($p=0.14$) and diagnosis speed ($p= 0.20$) between both conditions. However, there was a strong correlation between the number of fixations and diagnosis speed with ($r = 0.708$, $p < 0.05$) and without ($r = 0.618$, $p < 0.05$) clinical history. A moderate correlation was found between the number of saccades and diagnosis speed with ($r = 0.578$, $p < 0.05$) and without ($r = 0.424$, $p < 0.05$) clinical history. In conclusion, a brief clinical history does not appear to influence the gaze patterns, diagnosis speed and accuracy in evaluating the clinical findings. However, the gaze patterns highly correlated with the diagnosis speed in clinical decision-making. These findings indicate cognitive processing during clinical decision-making, which might benefit clinical educators in enhancing the clinical teaching approach and quality.

Keywords: *gaze patterns; diagnosis speed; diagnosis accuracy; fixations; saccadic*

1. INTRODUCTION

Decision-making is a broad phrase that refers to the process of selecting a plan of action from several possibilities. A clinical decision made by a health practitioner is a more complex

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procedure that requires more individuals to make defined choices from limited options [1]. Clinical decision-making determines who, what, when, and why. Doctors, clinicians, clinical students, nurses, and others usually make clinical decisions, which are influenced by several factors. Examples include practitioner factors such as frames of reference, individual capacities, decision-making experience, and inappropriate work situations [2].

Time and speed are other vital aspects of clinical diagnosis decision-making. These aspects vary depending on the urgency of a particular issue and whether a judgement must be taken urgently or could be delayed [1]. With little time, quick responses and less analysis are adopted. Hence, the clinician has less time to consider analytically, leading to a quick decision [3]. A clinical decision often follows a procedure that begins with acquiring information and ends with the final decision. Cues are employed in the systematic collection and analysis of patient data through direct observations, listening to the patient's major complaints, checking the patient's records, and studying clinical findings [4]. Some eye movements are involved when reviewing the patient’s record and clinical results.

Eye movements are shifts of the eye's position in its orbit, and the specific types of eye movement involved in making clinical decisions are saccades and fixation. Saccades are rapid, ballistic movements of the eyes that abruptly change the fixation point. It ranges in amplitude from the small movements made while reading, for example, to the much larger movements made while gazing around a room [5]. Fixations are the most common feature of looking that are analysed by researchers to make inferences about cognitive processes. Fixations occur when eyes essentially stop scanning about the scene, holding the central foveal vision in place so that the visual system can take in detailed information about what is being looked at. At this particular point, visual information is processed and interpreted [6]. Fixation has characteristics that reveal useful information about attention, visibility, mental processing, and understanding. Overall, eye movements entail sensory-motor connections and higher-order functions like attention and perception. Eye movements thus impact what we perceive, pay attention to, and remember about our surroundings [7]. Thus, eye movement has become an indicator in evaluating the clinical decision-making process.

It was discovered that experienced clinicians were more efficient in their examination method than novices throughout the clinical decision, especially when evaluating anomalies in fundus images [8]. This was supported by a study published in 2017, which found that medical residents were more efficient in solving cases than medical students because they arrived at the correct diagnoses and processed the cases faster and with fewer fixations [9]. Further, both demonstrated different reading patterns regarding which slides they proportionally paid the most attention to. This situation leads to an assumption that a clinician with exposure to the clinical history will often perform better than those who have not seen the patients’ clinical history. The relationships between eye movements and clinical history have received less attention in clinical decision-making. Nevertheless, a study was conducted to assess if the existence of clinical history could impact clinicians' clinical decisions and examine physicians' gaze behaviour when scanning ECG traces to extract meaningful information that supports their diagnostic judgments [10]. Resultantly, experts made more precise and more confident diagnoses and demonstrated a significant difference in visual search behaviour. Peculiarly, experts were significantly faster at fixating on essential and significant information. Expert clinicians were also significantly quicker to diagnose after dwelling on the abnormalities, which allowed them to act with accuracy, speed, and confidence once they had successfully located

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the abnormality [10]. Meanwhile, the presence of clinical history had no significant effect on how quickly the participants focused on the vital information or how fast they were to make a diagnosis once they had focused on the abnormality [10]. The researchers concluded that a brief clinical history does not appear to influence how the reader scans the image or the speed or accuracy of resultant diagnoses. Nonetheless, another study found that the inclusion of clinical history enhanced diagnostic accuracy in ECG interpretation by as much as 4% to 12% when compared to the absence of history [11]. The availability of clinical history in different radiology disciplines has also been associated with improving the reader's perceptual skills, allowing for faster detection of areas of abnormality and improved performance [12]. These findings revealed that exposure to a clinical history would positively impact how a person or a clinician determines a clinical decision accurately compared to when there was no exposure to the clinical history of a patient.

Nevertheless, limited research has been conducted among students on eye movement when analysing clinical findings with and without clinical history, notably among clinical students. This study aimed to investigate the gaze patterns, diagnosis speed and accuracy with and without the assistance of clinical history among final year clinical students. It is hypothesised that the availability of clinical history would influence the speed and accuracy of the diagnosis made.

2. MATERIALS AND METHODS

Ethical approval was obtained from the Research Ethics Committee of the University (IRB/IEC Certification 600-RMI (5/1/6) REC/515/18). This study adhered to the declaration of Helsinki. Written informed consent was obtained before the experiment. A cross-sectional study is well suited to the research question. The aim was to understand the influence of external factors, including clinical history, evaluation of clinical findings, and gaze patterns with diagnosis speed and accuracy. This study was voluntary, and 28 fourth-year Optometry students who underwent clinical training were recruited. The sample size was calculated using Raosoft Sample Size Calculator Online Software with a confidence interval of 95% and a margin of error of 5%, with a total population of 30 clinical Optometry students. The fourth-year Optometry students (who are in semester eight) were chosen since they are currently undergoing clinical training. All subjects successfully completed and passed the preclinical competency courses and they were in the clinical training semester. Thus, they were at a similar level of academic competency. They practise and handle actual patients with various diseases or eye problems under the supervision of a certified optometrist. Potential participants for this study were identified using purposive sampling. All participants had normal or best-corrected to normal distance and near vision (visual acuity (VA) not worse than 6/9 at distance and N6 at near). Participants with binocular vision disorder were excluded.

A collection of patient records from the Optometry clinic database was used to compile the patient's clinical history. The information documented included patients' age and gender, as well as the presenting chief complaint and clinical history. The chief complaints were re-typed and the size of the text used was 12 pt., Times New Roman, justified, with a maximum amount of 100 words and was printed on A4 papers. Six fundus photograph images were saved in high-quality (low-compression) jpg images to give enough simulation trials to the participants. They were standardised in size and magnification and printed on A4 papers using a laser printer to ensure a good resolution of 600 dots per inch. The clinical findings were chosen to represent

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anomalies that all clinical optometry students should be familiar with. Two experienced Optometrists verified the correct diagnosis of the presented clinical findings. Fundus photograph images with three or more abnormalities were excluded. The patient's information was removed for confidentiality purposes. Figure 1 shows a sample of clinical findings and a clinical history employed in this study. Participants were fitted with a head-mounted Dikablis Eye Tracking system (Ergoneer, Germany), which required the participants to wear a glasses-like frame with three miniature cameras. The technical specifications of Dikablis Eye Tracker system consisted of 60Hz eye cameras tracking frequency, 648 x 488 pixels eye cameras resolution and 1920 x 1080 @ 30 fps field camera resolution. Two small cameras were facing in front of the eye and another miniature camera was situated on the nasal part of the glasses to record the participant's viewing scene. The scene camera records the field of vision in front of the tested person. As the Dikablis Eye tracker is wireless, the participant can move freely without being bound by wires. It can also be worn over the participant's spectacles or polarised glasses. Calibration was performed before every experiment began to set the baseline fixation, and it was used as the reference point. The eyes camera and the scene camera recorded the eye of the test person throughout the experiment. Recorded videos were sent to a computer, and D-Lab Software interpreted all data.

(a)

A 38/M/M patient who is a spectacle wearer came with complaint of seeing green halos and pain which located around the eye and at the back of the head. His VA was reduced on the RE > LE. The IOP reading was

OD: 11mmHg/11.45am/16.10.18

OS: 14mmHg/11.45am/16.10.18

(b)

Figure 1: Sample of (a) clinical findings, (b) clinical history

Participants were attended individually, and the experiment took place in a quiet room with ambient room lighting. Initially, the participants were prescreened for their habitual distance

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visual acuity (VA) using the Snellen chart at 6 meters and their near VA with Snellen N-notation. The participants were also screened using the cover test, near the point of accommodation (NPA), near the point of convergence (NPC), and a colour vision test using the Ishihara. Those who passed the screening proceeded to the actual experiment procedures. The participants were positioned at 50 cm in front of the reading stand as shown in Figure 2. Standardised five-point calibration on the Dikablis eye tracker was performed. Each participant was given verbal instruction about the experimental procedures before the assessment.

A sample clinical finding was first shown to familiarise the participants with the clinical diagnosis-making process based on demonstrated fundus image before the actual experiment. Each participant was presented with six clinical findings, where half included a brief clinical history regarding the age, gender, and presenting complaint. The remaining half was presented without clinical history. All clinical findings were introduced one at a time to the participants randomly. First, the clinical history was shown to be read by participants. The participants were then allocated time to read the clinical history record. Thereafter, clinical findings in terms of fundus photograph images were presented. Once the participants were ready, they were asked to diagnose the given clinical findings. Their diagnoses were recorded at the end of the session. There was no time limit on evaluation, and the eye movements were recorded and tracked throughout the procedure. This procedure was repeated with other clinical findings until all six clinical findings were completed. During this experiment, when participants read the clinical history and evaluated clinical findings, the Dikablis Eye Tracker was automatically generated and measured the eye movements, which consisted of fixation and saccades. Diagnosis speed was defined as the time taken from the presentation of clinical findings to the diagnosis reported by the participants. It was measured using the Dikablis Eye Tracker, the first dwell fixation on the presented image. The diagnosis accuracy was marked based on the correct or wrong diagnosis. The diagnosis accuracy was recorded as a score of correct diagnosis.

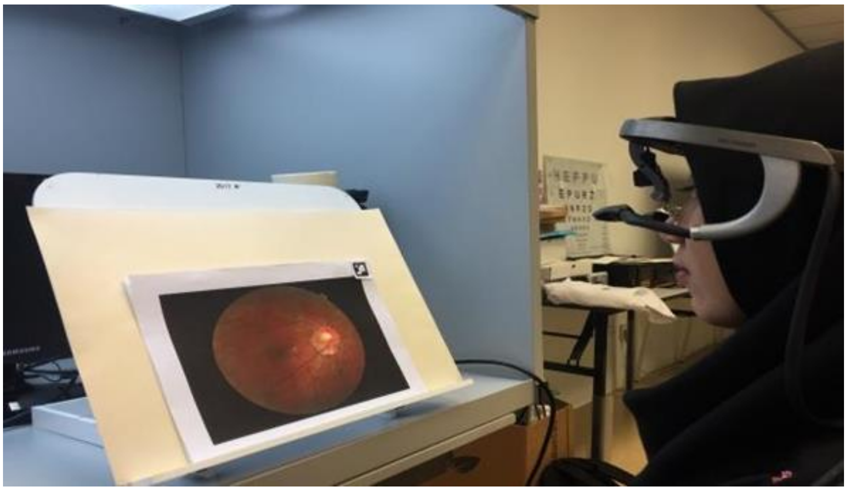

Figure 2: Example of a participant wearing a Dikablis eye tracker while viewing clinical findings.

Each participant's gaze patterns were studied. The Dikablis Eye Tracker was used to extract gaze patterns such as the number of fixations, fixation duration, number of saccades, and saccadic angles. As the gaze patterns of the right and left eyes showed no significant difference ($p > 0.05$), only the right eyes' gaze patterns were selected for further analysis. The gaze patterns, diagnosis speed and diagnosis accuracy were compared between clinical findings with

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clinical history and clinical findings without clinical history using Wilcoxon Signed Ranks Test since the data was not normally distributed (Shapiro-Wilk $p < 0.05$). The correlation between the gaze patterns with diagnosis speed was analysed using Spearman's correlation coefficient test. All data were analysed using the Statistical Package for Social Science version 21.0.

3. RESULTS AND DISCUSSION

A total of 28 fourth-year Optometry students with ongoing clinical practices participated in this study, comprising of five males and 23 females. They all had best-corrected distance visual acuity (VA) of not worse than 6/9 and with a near VA of N6. A cover test was performed to measure for any gross binocular vision problem. Six (6) participants were exophoric at near and three (3) exophoric at distance. There was also one participant with esophoria near and one with esophoria at distance. However, phoria was categorised as an insignificant binocular vision problem as the results were within the normal values. Colour vision was also performed to screen for any colour vision anomaly. All participants passed the colour vision test with Ishihara. Gross binocular vision tests with NPA (10.58 ± 1.17 D) and NPC (5.99 ± 1.20 cm) revealed no abnormality.

Comparison of gaze patterns, diagnosis accuracy and diagnosis speed in evaluating clinical findings with clinical history and evaluating clinical findings without clinical history were analysed using Wilcoxon signed-rank test. The test showed that all the gaze patterns including the number of fixations, fixation durations, number of saccadic and saccadic angles, between evaluating clinical findings with clinical history and evaluating clinical findings without clinical history did not elicit a statistically significant difference ($p > 0.05$). There was also no statistically difference in both diagnosis speed and accuracy ($p > 0.05$) in evaluating clinical findings with clinical history and clinical findings without clinical history (Table 1).

Table 1: The gaze patterns, diagnosis speed and accuracy in evaluating clinical findings with and without clinical history.

Variables	With clinical history	Without clinical history	Statistical analysis
	Median (CI)	Median (CI)	Z, p-value
Gaze patterns			
No. of fixations (n)	47.83 (68.21, 42.15)	49.0 (61.07, 39. 71)	-1.29, 0.20
Fixation duration (ms)	614.84 (854.26, 556.89)	666.35 (823.72, 555.26)	-0.02, 0.98
No. of saccadic (n)	32.83 (50.04, 30.17)	34.67 (45.90, 28,20)	-0.97, 0.33
Saccadic angle (deg)	4.35 (5.63, 4.03)	4.25 (5.64, 4.01)	-0.30, 0.76
Diagnosis speed (s)	41.0 (57.73, 38.70)	37.33 (52.59, 32.55)	-1.28, 0.20
Diagnosis accuracy (score)	1 (1.52, 0.98)	1 (1.52, 0.98)	-1.50, 0.14

A Spearman's rank-order correlation was conducted to determine the relationship between the gaze patterns and diagnosis speed with (Figure 3a and 3b) and without clinical history (Figure 3c and 3d). The scattered graph revealed a positive, strong, significant correlation between the number of fixation and diagnosis speed with ($r = 0.708$, $p < 0.05$) and without ($r = 0.618$, $p < 0.05$) clinical history. There was also a positive and moderate statistically significant correlation between the number of saccades and diagnosis speed with ($r = 0.578$, $p = 0.001$) and without ($r = 0.424$, $p = 0.024$) clinical history. However, the fixation duration and saccadic angle showed an insignificant correlation with diagnosis speed for both with and without clinical history.

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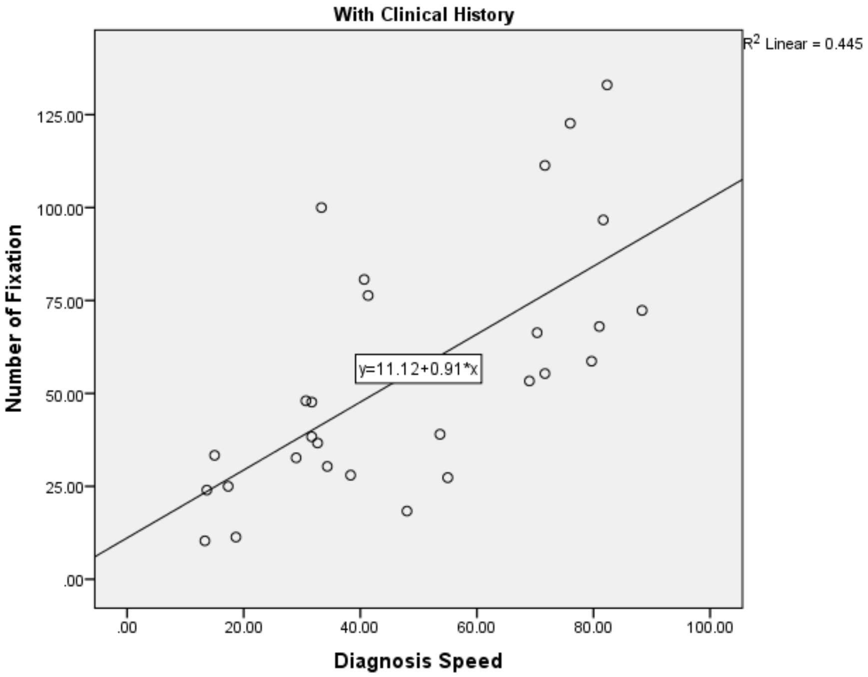
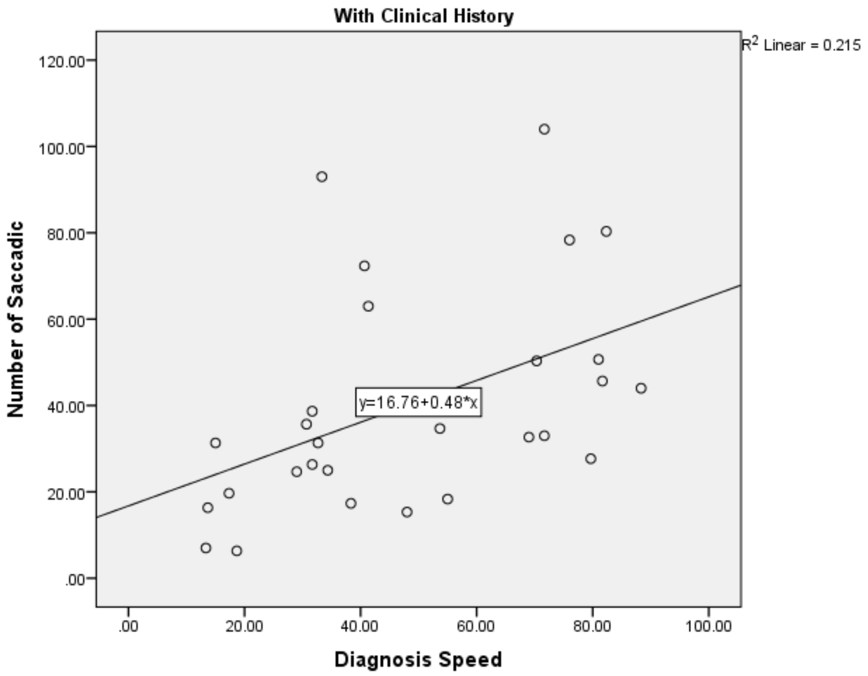


(a)



(b)

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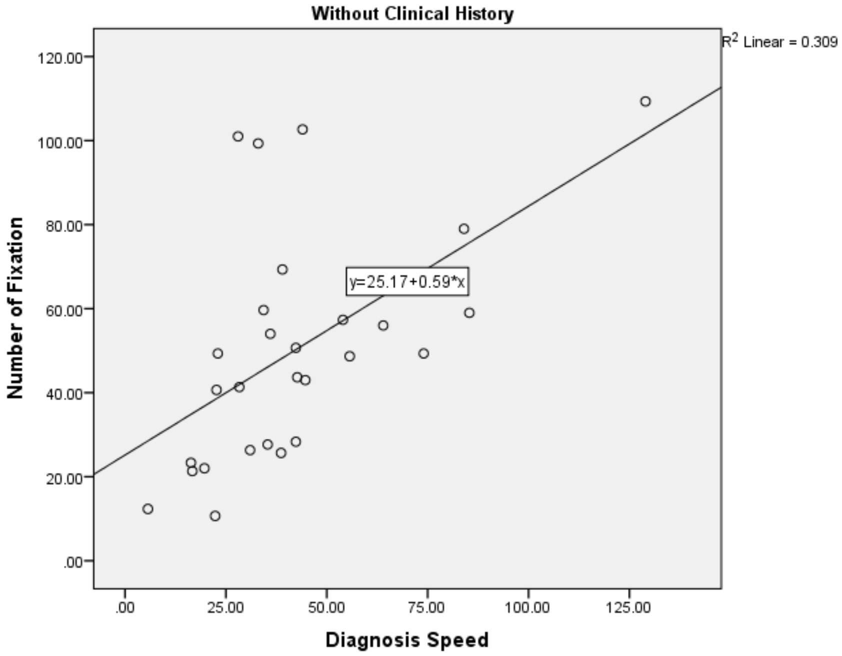
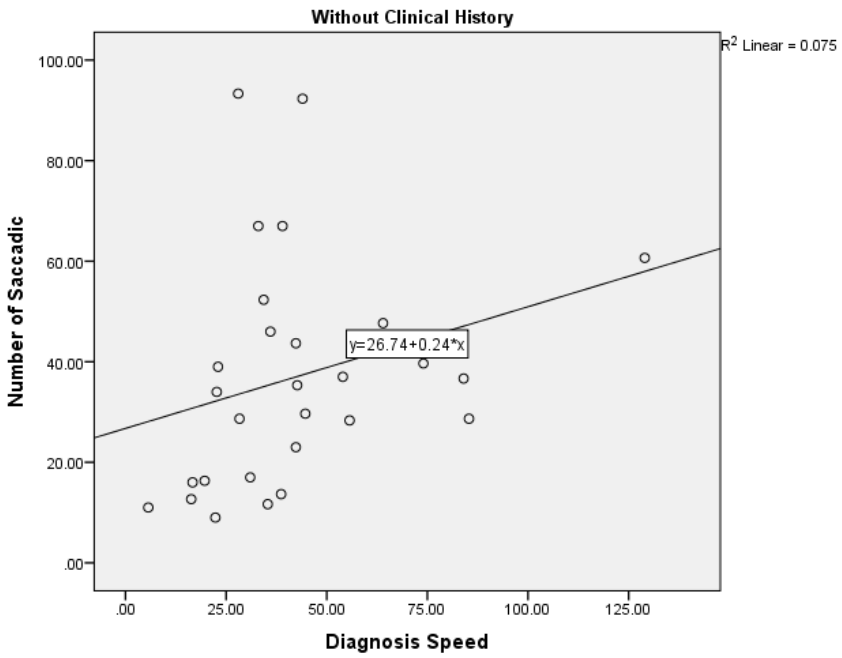


(c)



(d)

Figure 3: Correlation of gaze patterns with diagnosis speed in clinical findings with clinical history, (a) number of fixations, (b) the number of saccadic and clinical findings without clinical history (c) number of fixation, and (d) number of saccadic.

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The aim of this study was to investigate the gaze patterns, diagnosis speed and accuracy with and without the assistance of clinical history. The eye movements were compared between evaluating clinical findings with clinical history and evaluating clinical findings without clinical history. The result showed that the eye movements which consist of the number of fixation, fixation durations, number of saccadic and saccadic angles in evaluating clinical findings with and without clinical history were not statistically significant. This could be because a very brief clinical history was provided. Some of the clinical histories did not give much clue to the participants in order for them to evaluate the clinical findings which were the fundus photograph images. This result was supported by a study done by Wood et al. in 2014 which concluded that the presence of clinical history had no significant effect and did not influence the way in which the reader scans the image [10]. An explanation for this finding could be that the brief history provided in the study was less comprehensive than the clinical history provided in some real-world scenarios.

Secondly, we would like to identify whether reading a clinical history affects diagnosis accuracy in evaluating clinical findings. We had anticipated that clinical history would influence the participant's interpretation of clinical findings. However, this study has not demonstrated such an effect. The result showed no statistically significant difference between the diagnosis accuracy with the clinical history provided and the diagnosis accuracy without clinical history provided. This might be due to the same reason as before which was because of a brief clinical history being provided. According to the study done by Wood et al. in 2014, they concluded that the presence of clinical history does not affect the diagnostic accuracy of clinicians in ECG interpretation [10]. Another factor that may have contributed to our results found in this study was that the participants might have failed to incorporate previous knowledge that they had learned from the previous class theoretically into a clinical setting. This might be due to insufficient clinical experience of the participants as they were still students with ongoing clinical training. This was supported by a previous study done by Vilppu et al., in 2017 which had demonstrated that the residents showed a higher level of accuracy in their diagnosis compared to the students after reading the patient case text [9].

Further correlation analyses were performed to investigate the relationship between gaze patterns and diagnosis speed. Comparisons of clinical findings with and without clinical history demonstrated a substantial and strong correlation between the number of fixations and diagnosis speed. A significant and moderate correlation was also found in the number of saccadic and diagnosis speeds. As the number of fixation and the number of saccadic increases, the time spent to make a diagnosis also increases. However, this is only notable with the presence of clinical history. The possible explanations behind the finding might be because with the presence of clinical finding, the students tend to look at the notes frequently to seek for cues, as compared to without clinical finding; hence it might take longer time to reach the diagnosis. This situation might be due to insufficient knowledge among the participants as reported in a previous study where a novice spent more time performing clinical decisions or diagnoses compared to experts [13]. Experts have demonstrated shorter overall viewing times or time-on-task compared to novices in most studies utilising eye tracking in examining medical visualisations [13-15]. This result was also supported by a previous study in which a software infrastructure was created that tracks viewed whole slide images (WSI) areas. The software was also employed to discover students' viewing behaviour during a practical exam in oral pathology [16]. Resultantly, students who answered incorrectly tended to view the slides longer, went through more view fields and were more dispersed than students who answered correctly.

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The information-processing theory provides the basis for the current interpretations of visual search data on decision making. According to image processing theory, the extraction of feature information from an image relies on two processes. When the picture is initially viewed, the viewer gets a general idea of the content, such as anatomy, symmetry, colour, and grayscale. The information received in this global impression contrasts with information stored in long-term memory, which shapes the viewer's cognitive schema (or expectations) of what information is contained in a photo fundus image. In other circumstances, the search objective "pops out" from the overall impression, prompting the viewer to make a quick decision [14]. The application of gaze pattern data could analyse students' achievement in the educational setting. Students who efficiently view slides and give accurate answers may score higher than students who provide correct answers, but whose viewing style suggests they are unprepared for the question.

Similarly, tracking the learning process could assist in shaping the future of digital education. How students learn and acquire knowledge through digital technology might facilitate the smooth delivery of courses. Real-world contexts are often dynamic and it is evident that a combination of bottom-up and top-down information is employed to maximise the possibility of attaining the task's objectives by optimising the allocation of visual attention by minimising uncertainty [17]. How students extract information and obtain visual attention might facilitate the smooth delivery of courses. Theoretically, both low-level (stimulus-based) and high-level (knowledge-based) conceptual aspects of the scene percept affect how visual attention is distributed [17]. Depending on the type of task performed, visual attention might rely more on stimulus- or knowledge-based features [18]. Immersive educational applications that provide students with immediate feedback could be developed using real-time data collection and analysis. These solutions are scalable and could be used for conventional and online classes.

4. CONCLUSION

In conclusion, a brief clinical history does not appear to influence the gaze patterns, improve diagnosis accuracy and diagnosis speed in evaluating the clinical findings. However, the gaze patterns are correlated with the diagnosis speed in clinical decision-making among Optometry students either with or without clinical history. More eye movements were made, and students took a long time to make a clinical diagnosis and fixated more on the clinical findings to find more information. The limitation of this study was that the brief clinical history provided might not influence how participants evaluate the clinical findings. The research that has been undertaken for this study has highlighted a number of topics on which further research would be beneficial. This includes a deeper examination of student knowledge as a potential contributory factor in the speed of diagnosis. In addition, future research is warranted to explore how Optometry students can best be educated to prepare them for decision-making in clinical training and practice, as well as to explore factors impacting the quality of decision-making. Research to identify the differences in visual search characteristics between Optometry students and experienced Optometrists could be made to provide an insight into the improvement of students' clinical training and continuous quality improvement in teaching and learning.

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CONFLICT OF INTEREST

The authors declare no conflict of interest in this study.

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