A Comparative Analysis of Eye Tracking between Veteran and Novice during Radiological Interpretation

Yuka Naito
Graduate School of Economics, Chuo University, Higashinakano Hachioji-shi, 192-0393, Japan

Jun Nakamura
Faculty of Global Management, Chuo University, Higashinakano Hachioji-shi, 192-0393, Japan

Yoshinobu Ishiwata
Graduate School of Medicine, Yokohama City University, 3-9, Fukura, Yokohama Shi Kanazawa Ku, 236-0004, Japan
Email: a19.3gem@g.chuo-u.ac.jp, jyulis.77f@g.chuo-u.ac.jp, ishi_y@yokohama-cu.ac.jp

Abstract

With the development of AI, AI may substitute for physicians in radiological interpretations in the future. The purpose of this paper is to identify factors that could form the foundation for algorithms enabling AI to explore pathological findings. This study focuses on the "angles of gaze trajectory" and conducts a comparative analysis between veteran and novice. The results indicate commonalities and variances in the angles of gaze trajectory between veteran and novice, particularly 10, 350, and 180 degrees. Both Veteran and Novice have a relatively higher frequency of gaze movement around 10 and 350 degrees compared to other angles. Veteran has a relatively higher frequency of gaze movement around 180 degrees compared to other angles, while novice has a relatively lower frequency around 180 degrees.

Keywords: Eye-tracking, Angles of eye trajectory, Artificial Intelligence (AI)

1. Introduction

Machine learning and deep learning advancements, coupled with high-performance GPUs, have led to a significant breakthrough in the field of artificial intelligence [1]. Particularly in image recognition, AI is considered to surpass human capabilities [2]. In the realm of healthcare, a critical application of AI's image recognition capabilities is evident, with one prominent example being the interpretation of CT images. Given the current shortage of radiologists, AI is expected to achieve a level of expertise in image interpretation that can serve as a viable alternative to human physicians. To attain this capability, various factors contributing to the training of AI in image interpretation must be identified. One such factor is the ocular movement of physicians during image interpretation. This paper aims to discuss the significance of physicians' gaze patterns as one of these factors, emphasizing the need to uncover and understand these aspects to enhance the learning process of AI in image interpretation.

2. Previous Research

Numerous studies have explored gaze measurements of physicians during the interpretation of radiographic images, a certain cue is presented on the screen, and an analysis is conducted on how participants can detect this cue in terms of gaze trajectory and movement velocity [3]. Studies comparing the gaze patterns of veteran and novices are also prevalent. For instance, an analysis of gaze fixation points during chest X-ray image interpretation shows that experts promptly identify lesions and repeatedly confirm their presence while also scanning other areas, whereas novices tend to fixate on structurally complex regions [4]. In research on overlooking and missing findings during medical image interpretation, it has been demonstrated that experts thoroughly observe photographs, strongly focusing on the accurate location of anomalies, while novices exhibit more inconsistent observation patterns, with their gaze often diverted to complex positions where organs overlap [5]. This line of research on tacit knowledge and expertise in skill-demanding scenarios has unveiled that veterans and novices differ in terms of "where to look," influencing their subsequent performance [6]. As a preliminary step, it is necessary to extract and quantitatively analyze the gaze patterns of experts before linguistically formulating such characteristics. Therefore, the purpose of this paper is to conduct a comparative analysis between novices and veterans regarding the angles of gaze trajectories, which could serve as the foundation for algorithms exploring findings in artificial intelligence (AI). Furthermore, the objective is to propose recommendations for AI to learn from the disparities in gaze trajectories between novices and veterans, ultimately enabling more accurate and effective image diagnostics in the future.

3. Experiment

The gaze measurement experiment was carried out as follows.

- Participants: One veteran radiologist (with over 10 years of experience) and one novice radiologist (with 1~3 years of experience).
- Data:15 cases with abnormal findings.
- Experimental method: Tobii Pro Lab eye-tracking software was employed. The camera was fixed. Participants were presented with CT images on a computer screen and performed interpretation of CT images by scrolling through the images using a mouse, following their usual reading methods.

4. Analysis Methods

Duchowski provides guidelines regarding data collection and interpretation in the context of eye tracking. The book introduces applications and instances of success in fields such as medicine, psychology, and human factors engineering, underscoring the effectiveness of employing eye tracking in the medical domain [7]. Furthermore, Holmqvist et al. offer an in-depth exposition of data analysis methods in eye tracking research. Of particular note, fixation points serve as a frequently employed metric [8]. However, the analyzed metric in this paper is the angle of the gaze movement as it sequentially moves from one fixation point to the next in succession. (Henceforth, this shall be referred to as the angle of eye movement.) The reason for this is to confirm whether the direction of eye movement, namely the trajectory of the gaze, when radiologists interpret CT images is consistent with the characteristics of everyday human gaze as elucidated in previous research [9]. The characteristics of human eye movement elucidated in this previous research are detailed in the subsequent discussion section. The employed eye-tracking software in this study automatically aggregates parameters such as fixation points, fixation counts, fixation duration, and coordinates of fixation points, subsequently generating this information as output data. The trajectories connecting successive fixation points (hereinafter referred to as gaze trajectories) are visually indicated by red lines, enabling direct observation.

The angles of gaze movement were defined based on the eye-tracking data obtained using Tobii Pro Lab and analyzed using a custom-developed program. In this context, angles of gaze movement refer to the direction changes of gaze trajectories as it progresses across different fixation points. The concept is illustrated in the Fig. 1, where black circles represent fixation points (pixel), and connecting lines depict the gaze trajectory between these points. When the coordinate shifts from (971, 810) to (988, 867), and subsequently to (974, 816), the angle of gaze movement is denoted by Angle 1 in Fig. 1. The directional movement is measured clockwise. Similarly, when moving from (988, 867) to (974, 816) and further to (1013, 837), the angle of gaze movement is represented as Angle 2 in Fig. 1.

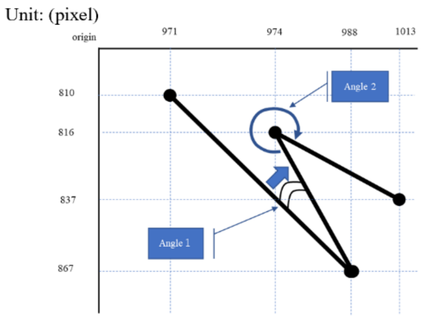

Fig.1 Angles of gaze movement

5. Results

The results of the measured angles of gaze movement, as captured by the software, are presented in Fig. 2 and Fig. 3.

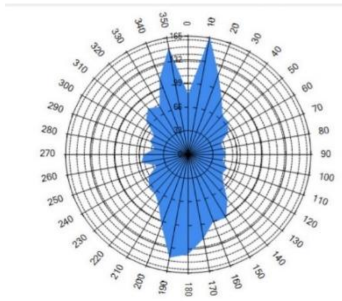
Fig.2 Angles of gaze movement in veteran (with abnormal findings)

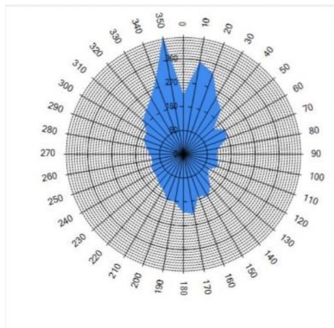
Fig.3 Angles of gaze movement in novice (with abnormal findings)

A comparison between veteran and novice revealed notable differences in angles of gaze movement. In the graphs, the numbers displayed on the outer circumference represent the angles, while the numbers within the circumference, namely the radii, indicate the frequency of the corresponding angles. Skilled practitioners exhibited a higher frequency of gaze movement angles around 180 degrees within the 360-degree spectrum. This is demonstrated in Fig. 2. In Fig. 2, angles such as 10 degrees, 350 degrees, 190 degrees, and 180 degrees were observed with higher frequencies. When examining the results for novice, as shown in Fig. 3, angles such as 350 degrees and 10 degrees were more pronounced in their gaze movement. Comparing the results presented in Fig. 2 and Fig. 3, it is evident that veteran frequently exhibit gaze movement angles near 180 degrees, a pattern not as pronounced in novice practitioners. This suggests that veteran tend to pause and carefully observe between fixation points when shifting their gaze, while novice appear to transition their gaze more promptly from one point to another.

6. Discussion

The paper highlighted differences in gaze movement between veteran and novice during interpretation. The analysis of angles of gaze movement, a hypothesis was formulated. The hypothesis suggests that skilled practitioners pause for careful observation between fixation points when shifting their gaze, whereas novices shift their gaze more promptly from one point to another, lacking this intermediate pause.

Considering that novices possess less experience than skilled practitioners, they might find it challenging to predict the location of anomalies. This could potentially explain why novices tend to survey the entire CT images thoroughly and quickly. In contrast, veteran can infer the approximate location of anomalies, allowing them to concentrate on specific areas. Interviews with experienced practitioners aligned with this explanation. Inexperienced individuals may have attempted to observe a broad area as much as possible. As a result, the gaze of novice may have exhibited movements along the Z-axis (the head-foot direction in CT images), while simultaneously surveying the XY plane comprehensively. Conversely, veteran tend to direct their gaze along the Z-axis (head-foot direction). Therefore, in a series of similar CT images, should an anomaly be detected, it could be recognized as a flicker. According to the previous research [9], the characteristics of human gaze encompass distinct roles for central vision and peripheral vision, where grasping stimuli occurs through peripheral vision and subsequently confirming details via central vision constitutes a fundamental process. Veterans shift their gaze along the Z-axis (head-foot direction) with peripheral vision, and subsequently enhance the resolution with their central vision when anomalies are detected. This phenomenon aligns with the description provided by adept physicians as "recognizing anomalies as flickers."

Additionally, the gaze patterns of veteran revealed repeated back-and-forth movements along lines near 180 and 360 degrees. Similar repetitive movements along horizontal and vertical lines have been observed in previous studies [9]. The research has been elucidated that repetitive movements along horizontal lines are more frequent than those along vertical lines. In other previous research [10], it has revealed that the capability to accurately perceive information is higher in the horizontal direction of eye movements compared to the vertical direction. This paper also found that novice exhibited more frequent back-and-forth movements along horizontal lines than vertical ones. This phenomenon can be attributed to reasons such as the relatively easier execution of horizontal movements compared to vertical ones, as well as the cautious tendency of novices due to the difficulty in anticipating the location of abnormal findings. Consequently, novices may opt to observe a broader scope of the CT image.

7. Conclusions

The purpose of this paper is to conduct a comparative analysis between novices and veterans regarding the angles of gaze trajectories, which could serve as the foundation for algorithms exploring findings in artificial intelligence (AI). Furthermore, the objective is to propose recommendations for AI to learn from the disparities in gaze trajectories between novices and veterans, ultimately enabling more accurate and effective image diagnostics in the future. This paper specifically analyzed the angles of gaze movement and speed of veteran and novice radiologists. However, it is important to note that this research had limitations in terms of a limited number of participants and sample size. Future studies should involve a larger sample size to further investigate the elements of algorithms during radiological interpretation.

8. Acknowledgements

The development of a program for analyzing gaze movement angles in this study was made possible through the support of Focus Systems Corporation. The authors express their deep gratitude for their assistance.

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Authors Introduction

Ms. Yuka Naito

She is a 1st year graduate student at the faculty of Economics, Chuo University, Japan. The areas of his research interest are Experimental Economics, Behavioral Economics, Cognitive Psychology, and Artificial Intelligence.

Dr. Jun Nakamura

He is a professor at the Faculty of Global Management, Chuo University, Japan. Previously he was working as a professor at the Graduate School of Engineering Management, Shibaura Institute of Technology. His main research areas are Cognitive Science and Humanities.