Visualization of the Skilled Physician's Gaze characteristic during Diagnosis

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Abstract

This study examines gaze movement differences in diagnosis between skilled and beginner physicians, aiming to identify factors influencing diagnostic speed and developing human resource and enhance artificial intelligence's diagnostic capabilities. Results reveal that experienced physicians, on average, spent 61% less diagnostic time than beginners, covering 49% of the gaze distance on the X and Y-axes. (comparison of the cumulative distance of gaze on the screen). Despite increased movement on the Z-axis (comparison of the scrolling speed of the CT scan results), skilled physicians moved 2-3 times faster, effectively narrowing attention and identifying specific areas.

Keywords: Experimental Economics, Eye-tracking, Cognitive Science, Artificial Intelligence (AI)

1. Introduction

Examination work in the medical industry is generally considered time-consuming and highly labor-intensive to train one CT service technician to acquire the knowledge necessary to prepare interpretation reports [1]. In addition, a nationwide survey of the actual status of the reading system for chest interpretation of radiograms for medical examinations, based on a questionnaire targeting 239 radiologists in 2018 [2], also indicated that it is difficult to train radiologists in a short period of time and requires a certain level of clinical and reading experience. In addition, the results of the survey indicated that the burden on radiologists is increasing due to the aging of the workforce and that the spread of CT scans will further reduce the manpower needed for the interpretation of radiograms, which may lead to the breakdown of the current radiogram system.

This has led to increased awareness of human resource development and medical AI development. Medical AI is being developed using deep learning. However, because deep learning has a black box problem in which the decision-making process cannot be identified by humans, the development of medical AI that can explain the process is being explored in the medical field, where safety is a high priority [3].

Considering the above issues, this study does not aim to contribute to the development of medical AI based on deep learning. This study aims to understand humans through the diagnosis of skilled physicians, and based on the understanding, aims to contribute to the realization of diagnosis like that of skilled physicians by beginner physicians and AI.

Diagnosis using imaging test results requires time and effort to master, resulting in a difference in the speed at which skilled physicians and beginner physicians can make a diagnosis. This is thought to be due to the difference in knowledge and experience between skilled and beginner physicians based on previous research [2]. This paper visualizes and analyzes the eye movement of both physicians resulting from the difference in knowledge and experience.

Humans are thought to possess the property of being able to make automatic inferences about stimuli with which they have frequent contact through practice, and this process of developing automaticity in judgment through practice is called procedural processing [4]. Procedural processing has been found to enable quicker decisions, improve reaction speed, and emphasize rational and practiced judgment [5]. It is thought that such procedural judgment is also made by experienced physicians when they use imaging test results to make diagnoses.

It is difficult to verbalize and provide effective guidance for diagnoses that are made unconsciously using such procedural judgments. Therefore, in this paper, by using a method [6] to visualize the eye movements of experienced physicians and beginner physicians during diagnosis by measuring eye gaze and to analyze the differences from a cognitive perspective, this paper aims to clarify the factors that lead to the speed with which

experienced physicians make diagnoses.

2. Purpose

The purpose of this paper is to contribute to human resource development and Medical AI development by clarifying factors that lead to the speed of making a diagnosis through a cognitive approach, such as measuring the eye movement of experienced physicians and beginner physicians during the interpretation of radiograms.

This paper is a study of novelty and academic significance. Conventional economics has focused on the results of decision-making and attempted to understand human behavior through mathematical decision-making models. However, this paper attempts to understand human behavior through a cognitive approach such as eye measurement by visualizing and analyzing the diagnostic process during the interpretation of a radiogram by using imaging tests. In addition, unlike previous studies that analyzed decision-making by comparison, this paper is unique in that it analyzes decision-making in the process of developing automaticity [4] as mentioned above.

This paper has social significance in that it aims to contribute to the development of beginner physician and development of medical AI by making the gaze at the time of diagnosis visible and clarifying factors that lead to the speed of giving a diagnosis.

3. Hypothesis

The hypothesis was developed as differences in the way experienced physicians and beginner physicians move their gaze during the interpretation of radiograms.

Experienced physicians have a narrower range of eye movement when searching for the presence or absence of symptoms/points of symptoms compared to beginner physicians. Since both interpretations of radiograms by experienced physicians and batting by experienced hitters have in common that they are performed using procedural judgment [4], a process in which the aforementioned automaticity of judgment has developed, previous studies [7] in which the gaze of experienced hitters while batting was studied were consulted. The results showed that experienced batters fix their gaze on the entire pitcher in their peripheral vision, fixing their gaze by on the point of attention prediction, rather than on a wide area as beginner batters gaze at a wide range. Based on this finding, it was hypothesized that the gaze movements of experienced physicians would be narrower than those of beginner physicians.

4. Methods

In this paper, experiments were conducted under the following conditions.

Yokohama City University Hospitals

- Experienced (more than 10 years career) 1 person
- Beginner (1~3 years of career) 1 person

With the cooperation of 2 physicians

- Abnormal findings 15 people (cases)
- No findings 15 people (cases)

A total of 30 people (cases) were tested for interpretation of head CT scan results, and eye gaze was measured using Tobii Pro Lab Screen Edition.

When interpreting the 30 cases, both physicians were not informed of the findings, the examination images were random, and both physicians diagnosed the cases in the same order, beginning and ending the diagnosis of each case at the physician's own discretion.

In comparing the experienced physician and beginner physician in this paper, the following two types of analyses were conducted.

- Comparison of the cumulative distance of gaze on the screen (X-axis and Y-axis movement): Abnormal findings - 15 cases.
- Comparison of the scrolling speed (Z-axis movement) of CT scan results: Abnormal findings - 3 cases.

The cumulative distance of the gaze (movement of the X-axis and Y-axis) was performed with reference to the velocity-detection method [6], which measures the distance of gaze movement on the screen. In addition, in this paper only analyzed abnormal findings (15 cases) from 30 cases.

The scrolling speed of the imaging test results (movement of the Z-axis) is an analysis unique to this paper; the movement of the Z-axis is an expression also used in the interpretation of radiogram and corresponds to the scrolling speed (diagnostic time and movement) between images of CT test results that capture cross sections. In the analysis, the diagnostic time for each image was recorded at the time the examination images were switched. The recording was done manually, and the error in the timing of when the physician switched images was kept within a range of 0 microseconds to 4 microseconds or less. If the physician did not change the scroll direction within 5 images, the time was recorded at intervals of 5 images, and if the physician did change the scroll direction within 5 images, the time was recorded each time an image was switched.

Both analyses were conducted with the purpose of focusing on gaze movements in the X-axis, Y-axis, and Z-axis to investigate whether the range of gaze movements of the hypothesized experienced physician's eye would be narrower than the range of gaze movements of the beginner physician's eye.

5. Results

Comparison of cumulative distance of gaze (X-axis and Y-axis movements)

Fig.1, Fig.2 below shows a comparison of the cumulative distance of gaze when the same case was diagnosed by an experienced physician and a beginner physician. Due to space limitations, the figures for each case are not shown here, but rather the total cumulative distance and the total normalized diagnosis time for all

cases, table summarizing their sum, mean, and variance, and figure showing the mean cumulative distance for the cases with findings (15 cases). The horizontal axis represents the time of diagnosis.

Table 1. X-axis and Y-axis movement in Abnormal Finding cases.

	Experienced_normalized time	Experienced_cumulative distance of gaze	Beginner_normalized time	Beginner_cumulative distance of gaze
Case1	66.99	31042.43	100	100626.18
Case4	84.16	99326.15	100	87496.00
Case5	57.23	115339.97	100	128587.59
Case6	43.91	66014.34	100	180581.15
Case10	70.13	63618.04	100	112969.58
Case13	64.24	42570.61	100	73038.85
Case14	55.58	43520.29	100	90969.10
Case15	58.08	44683.93	100	96657.33
Case17	52.90	40321.40	100	84090.70
Case18	39.92	27541.30	100	173406.17
Case19	77.37	52913.18	100	85824.34
Case20	61.02	34938.71	100	134411.07
Case21	46.54	34720.16	100	168388.14
Case24	83.93	66331.85	100	154028.48
Case27	86.07	76429.26	100	166290.33
SUM	948.07	839311.63	1500	1837364.99
AVERAGE	63.20	55954.11	100	122491.00
VARIANCE	205.25	608630602.91	0	1325636396.42

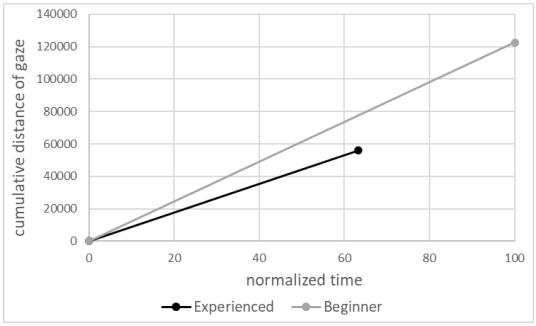

Fig.1. Average of X-axis and Y-axis movement

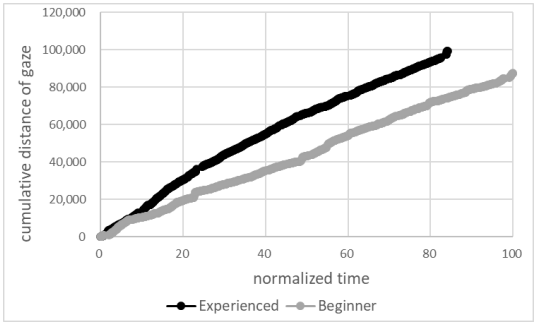

Fig.2. Case 4 X-axis and Y-axis movement

The horizontal axis represents diagnostic time. Among the diagnoses made by experienced physician and beginner physician diagnosticians, the diagnosis completion time of the one with the longest diagnosis time was set to 100 and normalized. The vertical axis represents the cumulative distance of eye movements until the end of the diagnosis, calculated by dividing all eye movements in the screen where the examination image is displayed in Tobii Pro Lab by the coordinates of the X-axis and Y-axis.

A comparison of the results for 15 cases revealed the following three points.

- Experienced physician require an average of 61% of the diagnostic time of beginner physician for all 15 cases. (Table 1, Fig.1).
- Experienced physician will require an average of 49% of the cumulative gaze distance of the beginner physician for all 15 cases except Case 4 (Fig.2).
- Experienced physician never exceeded the cumulative distance of the beginner physician's gaze for more than half of the diagnostic time in all 15 cases except Case 4 (Fig.2).

Comparison of scrolling speed (Z-axis movement) of imaging test results

Fig.3 below is representative Figure that shows a comparison of the representative Z-axis gaze shift of the gaze when the same case was diagnosed by an experienced physician and a beginner physician.

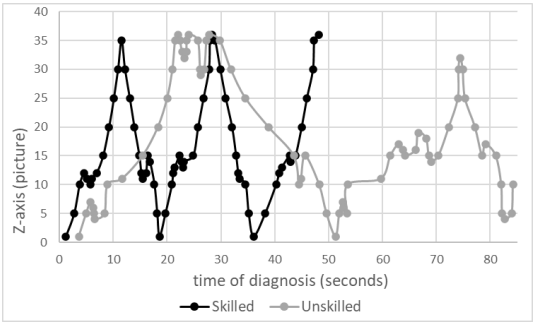

Fig. 3. Z-axis movement

The following two points were clarified.

- Experienced Physician move back and forth 1~1.5 times between imaging test results until beginner physician confirm all imaging test results (Fig.3).
- Compared to the Beginner Physician, who tended to move back and forth along the Z-axis at many points and was not able to narrow down the range of attention, the Experienced Physician tended to identify the points of attention and gradually narrow down the range of attention along the Z-axis (Fig.3).

6. Discussion

The purpose of this paper is to contribute to human resource development and medical AI development by clarifying factors that lead to the speed of making a diagnosis through a cognitive approach, such as measuring the eye movement of experienced physicians and beginner physicians during the interpretation of radiograms.

In analyzing the gaze, this paper hypothesized that Experienced physicians would have a narrower range of eye movement when searching for the presence or absence of symptoms and the location of symptoms than beginner physicians.

As a result of the analysis, it can be said that the hypothesis is valid according to the following two analysis results for the movement of the X-axis and Y-axis.

- Experienced physician will require an average of 49% of the cumulative gaze distance of the beginner physician for all 15 cases except Case 4 (Fig.2).

- Experienced physician never exceeded the cumulative distance of the beginner physician's gaze for more than half of the diagnostic time in all 15 cases except Case 4 (Fig.2).

In addition, about Z-axis,

- Compared to the Beginner Physician, who tended to move back and forth along the Z-axis at many points and was not able to narrow down the range of attention, the Experienced Physician tended to identify the points of attention and gradually narrow down the range of attention along the Z-axis (Fig.3).

This is related to the hypothesis that the range of eye movement of Experienced physicians is narrower than the range of eye movement of beginner physicians.

However, in all the cases investigated in this paper, the number of eye movements back and forth on the Z-axis for Experienced physicians was greater than that for beginner physicians Thus, in addition to substantiating the hypothesis, the experienced physicians made fewer eye movements between the X-axis and Y-axis than the beginner physicians, but made more eye movements in the Z-axis, suggesting that the experienced physician may perceive and diagnose imaging test results in a three-dimensional rather than a planar manner.

These findings and discussions in this paper will lead to human understanding through the skilled physician's diagnosis and contribute to the future development of human resource training and medical AI.

7. Conclusions

The purpose of this paper was to contribute to human resource development and medical AI development by focusing on the differences in eye movement between experienced physicians and beginner physicians during diagnosis and to identify factors that lead to the speed at which they make a diagnosis.

As a result of analyzing eye movement during diagnosis in two ways: cumulative distance of eye movement (movement on the X-axis and Y-axis) and scrolling speed of imaging test results (movement on the Z-axis), it was found that experienced physician was faster than beginner physician in making a diagnosis, moving less distance on the X and Y axes, and usually moving less than the distance of beginner physician. On the Z-axis, however, they tended to identify the area of focus and gradually narrow the range of attention but traveled more distance and in a shorter time than the beginner physician.

Next, the limitations of this paper are discussed. Due to technical problems, this paper has not been able to analyze the Z-axis shift of all cases. Besides improving the reliability of the analysis results, it would be desirable to continue analyzing the Z-axis shift, which may lead to new discoveries. In addition, this paper only compares one experienced physician and one beginner physician each. In the future, it is desired to increase the number of subjects and to include intermediate physicians who are between the levels of the two physicians in this paper to increase the reliability of the results.

Finally, in terms of future prospects, this paper will share the results of this analysis with physicians, and by deepening the discussion, explore effective human resource development methods and way of developing medical AI.

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