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Research Article

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A Study of Gaze Rhythm During the Interpretation of Computed Tomography Images of the Human Head

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Abstract

This study explored the gaze rhythm when reading and examining computed tomography (CT) images of the human head. Fourier analysis of gaze movements showed differences between experienced and entry-level radiographers, particularly at low frequencies. These differences appear to depend on whether a clear policy on CT reading is in place.

Keywords: Gaze Movements, Comparative Analysis, Radiographers, CT Reading

1. Introduction

With the rapid progress in artificial intelligence (AI) in recent years, related techniques are increasingly applied in the medical field, and research and development using supervised learning is progressing in radiological diagnosis, among other areas [1]. However, careful evaluation of the advantages and drawbacks of AI-based diagnosis is required given its reliance on supervised data, where the collection of data from multiple facilities can influence AI decisions depending on the medical equipment used.

In this context, collaboration between AI and physicians is essential, as human judgement is needed to prevent errors that can arise from AI "hallucinations". In this study, we compared the diagnostic methods of experienced and entry-level radiographers, using eye measurement data obtained during computed tomography (CT) reading of human head images.

Our research was conducted in collaboration with Yokohama City University Hospital.

2. Related Research

During product quality inspections, the technician's gaze moves from left to right or exhibits a rectangular, wave-like shape in relation to the object [2,3]. When examining CT images of human heads, the screen displays a planar image with an XY axis. However, the human head is three-dimensional and has multiple cross-sections. The vertical axis between the head and neck is designated the Z-axis, and the planar image is read while moving the Z-axis up and down on the image display device. The purpose of examining a CT image of the head is to identify the presence and location of any notable findings. Therefore, it is necessary to identify XYZ coordinates of interest, such that the viewer's gaze movements may differ from those occurring during simple quality inspection of a product. In this study, we explored left–right, rectangular, or wave-like gaze patterns in the examination of CT images of the head.

An analysis of eye movement during diagnosis based on cumulative eye movement distance (X- and Y-axes) and scrolling speed (Z-axis) showed that experienced radiographers had shorter diagnostic times and shorter eye movement distances on the X- and Y-axes than entry level radiographers. However, the eve movement distance on the Z-axis, which reflects searching for the area of interest, was greater for experienced radiographers [4].

An analysis of the gaze angle on the XY plane of CT images showed that experienced radiographers had a gaze angle near 180° more often than entry-level radiographers [5]. These angles reflect gradual and consistent movement of the gaze to locate the area of interest on the XY plane; this method is effective despite the short movement distances. However, left–right, rectangular, and wave-like gaze patterns should be elucidated in greater detail.

During quality inspections, even unconscious left–right horizontal movements tend to be more common than vertical movements. We focused on gaze movement on the X-axis to fully explore left–right, rectangular, and wave-like gaze patterns.

3. Methods

Gaze movement data were obtained for experienced and entry-level radiographers who examined CT images of 15 heads. X-axis gaze shifts to the right and left were classified as positive and negative, respectively.

Discrete Fourier transformation of the time series data was performed to transform functions in the time domain (waveforms) into functions in the frequency domain (spectra) through signal processing analysis. Because gaze data contain measurement errors and small movements associated with microsaccades, Fourier transform was applied using the Gijutsu Kikaku Seisakujo software to filter the data and extract rough eye movement patterns (i.e., low frequency components). To understand the rhythm and periodicity of the gaze movements, we analysed the frequency components corresponding to changes on the X-axis. We assumed that the gaze movements of experienced radiographers would have a constant rhythm, whereas those of entry-level radiographers would be random, with energy distributed over a wider frequency band.

If the low-frequency component is predominant in extracted features, then eye movements will be smooth and stable, as assumed to be more common in skilled users, whereas if the high-frequency component is predominant, then eye movements will be fine and rapid, as assumed to be more common in novice users.

4. Results

Table 1 lists features of the spectral and time series data. The experimental results of two typical cases are shown in Figures 1 and 2. The amplitude spectra show the amplitude (px) of each frequency component for frequencies up to approximately 15 Hz, and the phase spectrum graph shows the phase shift from –π to +π for the same frequency component. The phase spectrum graph of the experienced radiographer showed that at low frequencies, the phase change was characterized by a repeated rightward shift followed by a sharp drop, which is clearly visible in Figure 2. The graph of the phase spectrum shifts from –π to +π (i.e., upwards and to the right); the direction of the wave is not indicated, but the line of sight moves back and forth from left to right, with a slow and constant rhythm.

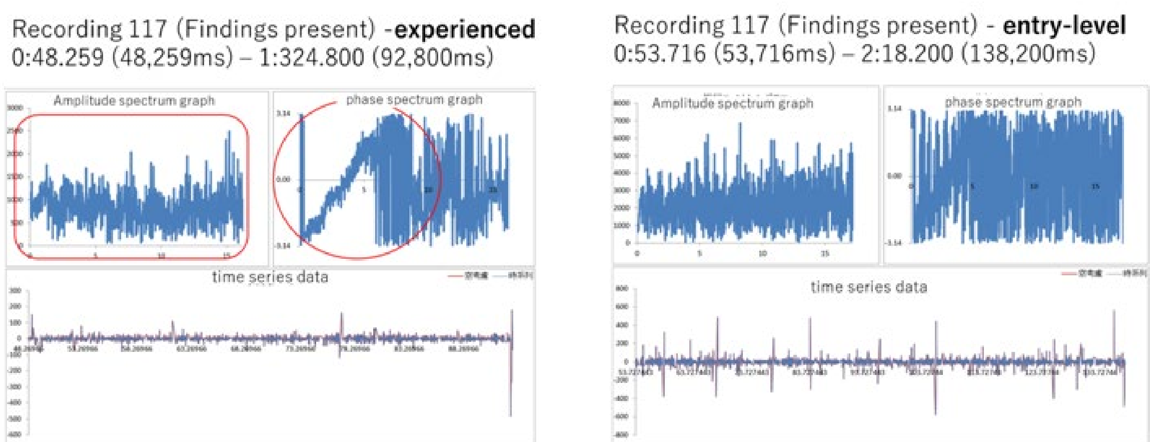

Figure 1: Amplitude Spectrum, Phase Spectrum, and Time Series Analysis of Gaze Movements During Computed Tomography (CT) Reading (Case 1)

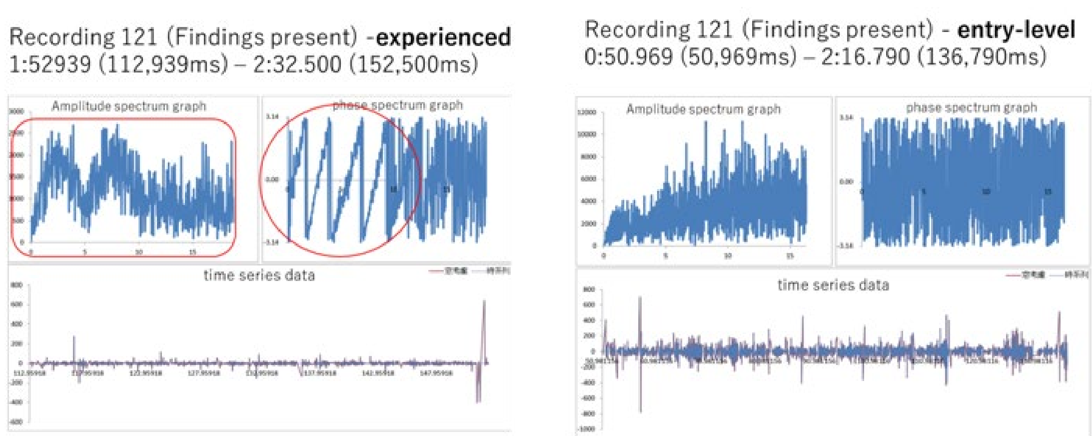

Figure 2: Amplitude Spectrum, Phase Spectrum and Time Series Analysis of Gaze Movements During CT reading (case 2)

	Experienced radiographer	Entry-level radiographer
Maximum amplitude	~3,000 px	8,000–12,000 px
Features of the amplitude spectrum	Comparatively uniform	High energy
Features of the phase spectrum	Smooth with constant periodic phase fluctuations	Low periodicity, many random phase components
Features of time series data	Relatively static signal	More volatile, with more dynamic fluctuations

Table 1: Features of Gaze Data from Experienced and Entry-Level Readers of Computed Tomography Images of Human Heads

5. Discussion

In an interview following the experiment, an experienced radiographer indicated that when reading CT images, he divides the planar image into four sections and carefully observes them along the Z-axis, in the order of upper left, upper right, lower left, and lower right, with the Z-axis moving up and down while moving back and forth between the upper and lower part of the head. Thus, the radiographer unconsciously gazes slowly back and forth along the XY axis, particularly between the left and right sides. This finding is consistent with that of a previous study that reported rectangular wave-like movements during image reading [2].

Experienced radiographers frequently exhibit 180° movements in each of the four image sections, while moving the gaze slowly [5]. Although such movements are referred to as left– right reciprocal movements, they are actually continuous, gradual gaze shifts, such as left→left→left→left→right or right→right→left. This appears to be an aspect of horizontal smooth pursuit, which occurs while moving the gaze along the Z-axis, as might occur when following a moving target [6]. Such movements have not been observed in entry-level radiographers.

Although the main difference between experienced and entry-level radiographers lies in their years of experience, entry-level radiographers are also explicitly instructed to observe an entire image, such that they tend to move their gaze rapidly within the XY plane, which reduces momentum, lessens lesion clarity, and consumes extra time.

6. Conclusion

In this study, left–right gaze movements were explored in radiographers reading planar CT images of the human head. Experienced radiographers performed slow, careful gaze movements, particularly for certain areas of the image, that differed significantly from those entry-level radiographers. Although movement on the Z-axis is key for stereoscopic checking the technique of dividing the image into quadrants along the Z-axis may compromise effective image examination [4].

This study was limited by the inclusion of a very limited number of cases. In future research, we intend to include more cases, analyse these from multiple angles, and study movements along the Y-axis in the XY plane.

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