Eye Tracking in the Assessment of Electrocardiogram Interpretation Techniques

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Abstract

Human observers with varying degrees of expertise interpret the 12-lead electrocardiogram (ECG) in different ways. In this work the authors investigate whether eye tracking can be used to gain an insight into how a human observer interprets the 12-lead ECG.

A clinical scientist interpreted 29 ECGs whilst an eye tracking device was used to record eye movement patterns.

The time dedicated to studying each lead across all 29 ECGs was recorded. The observer dedicated 26% of his time to studying the rhythm strip and only 1% of his time to studying lead aVR (t-test: p-value < 0.01).

Eye tracking has the potential to provide an insight into how an individual observer interprets an ECG.

1. Introduction

The 12-lead electrocardiogram (ECG) remains an important tool in detecting cardiac disease. Correct interpretation of the ECG is vitally important to patient diagnosis, and subsequent therapy. However, observers ranging from trainee students to expert clinicians adopt different techniques for ECG interpretation [1]. For example, medical students often adopt a strict protocol and are typically trained to study the rhythm strip before systematically reviewing individual leads and features. Conversely, expert cardiologists are known to adopt an unsystematic approach and observe the entire 12-lead ECG as a single picture. As a result, expert cardiologists can often instantaneously identify any abnormalities on the ECG. In this study, the authors investigate the utility of eye tracking technology as a means of gaining a deeper insight into the process of how a human observer interprets the ECG. Such knowledge could be used to potentially enhance educational practice in electrocardiography.

2. Methods

A human observer (clinical scientist) interpreted 29 ECGs that were preselected from an ECG library available on the Internet [2]. All 29 ECGs, as detailed in Table 1, showed some sign of abnormality. However, the pathology was not disclosed to the clinical scientist prior to the study. All 12-lead ECGs were presented to the observer in the format of 3 rows x 4 columns (+ rhythm strip/s).

Whilst the observer interpreted each of the ECGs, an eye tracking device was used to record his eye movement patterns.

2.1. Protocol

After the study commenced, a short period (<5 minutes) of setup was required to calibrate the device to the eye movements of the observer. Subsequently, the observer viewed and interpreted each of the 29 ECGs. Each ECG was displayed on a high resolution (1440px x 900px) 24” LCD monitor. When the observer completed his interpretation for one ECG, he used the spacebar to proceed to the next ECG. During the ECG interpretation process, the subject was also asked to ‘think-aloud’. Thinking-aloud required the observer to verbally describe his thought process. This included verbalising which ECG features the observer was interpreting/analysing.

Table 1. Details of the 29 12-lead ECGs that were interpreted during the study [2].

Pathology	No. of ECGs
Acute Myocardial Infarction (AMI)	10
Ventricular Hypertrophy (VH)	10
Left Bundle Branch Block (LBBB)	9

2.2. Eye tracking system

A Tobii X60 eye tracking device (Figure 1) and the Tobii Studio 3 software were used to record and analyse the subject’s eye movement patterns [3]. The Tobii X60 is a non-invasive device that records eye movement at a rate of 60Hz. The eye tracker detects eye gaze by reflecting invisible infrared light onto the human eye and uses image processing to transform the recorded data into Cartesian coordinates. These coordinates are subsequently analysed and visualised by the Tobii Studio 3 software.

2.3. Analysis

The Tobii Studio 3 software consists of a number of analytical tools. In this study, the software was used to produce 29 heat maps each corresponding to one of the interpreted ECGs. A heat map shows the distribution of fixations made by the subject. A fixation is when the observer focuses or fixates on a specific location. In the current study this was a lead or a feature on the ECG image. A heat map allows the distribution of all fixations to be viewed in one image. An example heat map is illustrated in Figure 2. The Tobii Studio 3 software also allows areas of interest to be defined. This feature was used to define an area of interest for each lead within each of the 29 ECGs. Using these areas of interest, the software was utilised to generate statistics indicating which leads, across all 29 ECGs, were studied the least and the most.

The Tobii Studio 3 software also produced a video showing each of the ECGs overlaid by a saccade. A saccade is the eye gaze path from one fixation to the next. Thus, the video shows the temporal path of where the observer fixated at each time instant. The video also contained the audio recorded from the observer 'thinking-aloud'. The timestamps from the video were used to measure the time dedicated to interpret each ECG. In summary, the software produced two useful analytical outputs, namely a heat map which can be regarded as an integral visualisation and a video and audio recording, which is particularly useful for detailed temporal analysis.

3. Results

Mean times taken to interpret the different disease groups are presented in Table 2. The overall mean time taken to interpret a single 12-lead ECG was 39.56 seconds (SD=11.56). No statistically significant difference was found between the times taken to interpret ECGs from different disease groups (*t*-test, $p<0.05$).

Table 3 provides a ranked list of the time dedicated to looking at each lead over all 29 ECGs. It can be seen that the observer dedicated the plurality (26%) of his total time to studying the rhythm strip whilst dedicating the least time to studying lead aVR (*t*-test, *p*-value<0.01). Nevertheless, in general, more time was given to studying the precordial leads when compared to the limb leads (*t*-test, *p*-value=0.002).

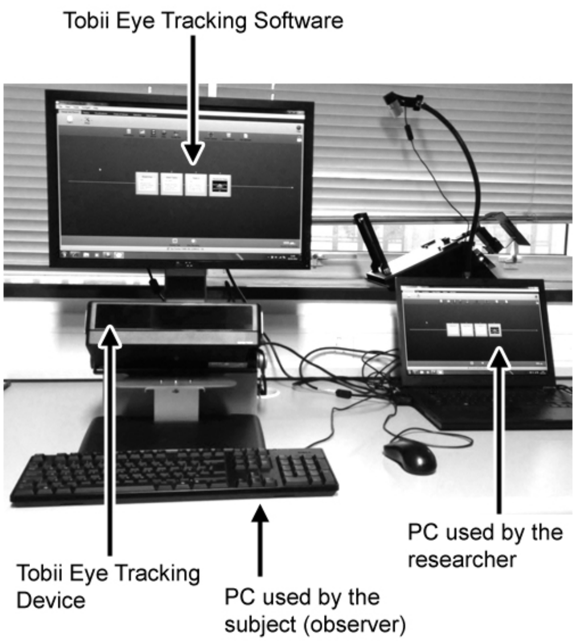

Figure 1. The Tobii X60 and Tobii Studio 3 eye tracking system.

Figure 2. Heat map showing the distribution of fixations over the time taken to interpret the ECG. Red represents the highest number of fixations and green represents the least number of fixations.

Table 2. Times taken to interpret ECGs from different disease groups.

Disease group	ECG Interpretation duration (seconds)
AMI	$\bar{x}$=39.36 (SD=13.49)
VH	$\bar{x}$=41.56 (SD=9.67)
LBBB	$\bar{x}$=37.56 (SD=12.84)
All groups	$\bar{x}$=39.56 (SD=11.56)

From visual analysis of the recorded data (video and audio recording), it was possible to verify that the observer did use a systematic approach to ECG interpretation. For example, in the majority of cases, the rhythm strip was studied before any other lead. This remained true even when prominent features, such as very obvious ST segment changes were present in a number of precordial leads. An example of this is shown in Figure 3 where a heat map representing the first 10 seconds of interpretation is illustrated. In this case, whilst there are obvious signs of AMI, the observer still devoted most of the initial period to inspecting the less revealing rhythm strip.

Table 3. Total duration of individual lead fixations over 29 12-lead ECGs. Organised in descending order of duration.

ECG Lead	Total duration of lead fixations (seconds)	Percentage of time dedicated to each lead (%)
Rhythm strip	162	26
V1	85	13
V2	71	11
V6	52	8
V3	50	8
V5	50	8
II	37	6
V4	31	5
I	26	4
aVF	24	4
aVL	21	3
III	12	2
aVR	7	1

Figure 3. Heat map showing the distribution of fixations in the first 10 seconds of ECG interpretation. This ECG is from a patient experiencing AMI.

4. Discussion

Although the proposed use of eye tracking in electrocardiology is novel, it has been used in other medical domains for similar purposes. For example, eye tracking has been used to assess the clinical interpretation of radiographic images. This type of research is often regarded as the science of medical image perception [4]. In 2010, Matsumoto *et al.* [5] used eye tracking technology to gain an insight into how expert neurologists interpret Computed Tomography images of the brain, when compared to a control group consisting of nurses and medical students. Given the large rate of iatrogenic errors, Wetzel *et al*. [6], in 2009, proposed that eye tracking be used for competency testing in the interpretation of radiographic images. Nevertheless, it was thought that the proposal made by Wetzel *et al*. could be applied to other medical domains such as electrocardiography.

Sustaining medical education research has some importance. For example, enhancing the education of medical students and clinical personnel can result in improved decision making, which will eventually have a positive impact on patient outcomes.

Although this study is limited (i.e. with only one subject), we speculate that this research could be used as part of a much larger study to inform and enhance educational practice. Currently, within the classroom, medical students are often given ECGs to interpret and subsequently receive binary feedback (i.e. whether their diagnosis was right or wrong). However, the use of eye tracking technology would allow instructors to gain detailed data on where, how and why an individual gave a correct or incorrect diagnosis. This would allow for richer and more objective tailored feedback.

5. Conclusion

It is envisaged that eye tracking technology can provide two benefits, namely (a) an insight into how different observers ranging from a trainee student to an expert clinician interpret the 12-lead ECG; and (b) the profiling and assessment of how individuals perform in interpreting different ECGs. This data would allow an instructor to provide objective tailored feedback to that individual. Although these benefits are speculative, this study provides a foundation for further research in this area.

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