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# Assessing computerized eye tracking technology for gaining insight into expert interpretation of the 12-lead electrocardiogram: an objective quantitative approach

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**Abstract**

**Introduction:** It is well known that accurate interpretation of the 12-lead electrocardiogram (ECG) requires a high degree of skill. There is also a moderate degree of variability among those who interpret the ECG. While this is the case, there are no best practice guidelines for the actual ECG interpretation process. Hence, this study adopts computerized eye tracking technology to investigate whether eye-gaze can be used to gain a deeper insight into how expert annotators interpret the ECG. Annotators were recruited in San Jose, California at the 2013 International Society of Computerised Electrocardiology (ISCE).

**Methods:** Each annotator was recruited to interpret a number of 12-lead ECGs ($N = 12$) while their eye gaze was recorded using a Tobii X60 eye tracker. The device is based on corneal reflection and is non-intrusive. With a sampling rate of 60 Hz, eye gaze coordinates were acquired every 16.7 ms. Fixations were determined using a predefined computerized classification algorithm, which was then used to generate heat maps of where the annotators looked. The ECGs used in this study form four groups (3 = ST elevation myocardial infarction [STEMI], 3 = hypertrophy, 3 = arrhythmias and 3 = exhibiting unique artefacts). There was also an equal distribution of difficulty levels (3 = easy to interpret, 3 = average and 3 = difficult). ECGs were displayed using the 4x3 + 1 display format and computerized annotations were concealed.

**Results:** Precisely 252 expert ECG interpretations (21 annotators × 12 ECGs) were recorded. Average duration for ECG interpretation was 58 s (SD = 23). Fleiss' generalized kappa coefficient ($P_a = 0.56$) indicated a moderate inter-rater reliability among the annotators. There was a 79% inter-rater agreement for STEMI cases, 71% agreement for arrhythmia cases, 65% for the lead misplacement and dextrocardia cases and only 37% agreement for the hypertrophy cases. In analyzing the total fixation duration, it was found that on average annotators study lead V1 the most (4.29 s), followed by leads V2 (3.83 s), the rhythm strip (3.47 s), II (2.74 s), V3 (2.63 s), I (2.53 s), aVL (2.45 s), V5 (2.27 s), aVF (1.74 s), aVR (1.63 s), V6 (1.39 s), III (1.32 s) and V4 (1.19 s). It was also found that on average the annotator spends an equal amount of time studying leads in the frontal plane (15.89 s) when compared to leads in the transverse plane (15.70 s). It was found that on average the annotators fixated on lead I first followed by leads V2, aVL, V1, II, aVR, V3, rhythm strip, III, aVF, V5, V4 and V6. We found a strong correlation ($r = 0.67$) between time to first fixation on a lead and the total fixation duration on each lead. This indicates that leads studied first are studied the longest. There was a weak negative correlation between duration and accuracy ($r = -0.2$) and a strong correlation between age and accuracy ($r = 0.67$).

**Conclusions:** Eye tracking facilitated a deeper insight into how expert annotators interpret the 12-lead ECG. As a result, the authors recommend ECG annotators to adopt an initial first impression/pattern

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recognition approach followed by a conventional systematic protocol to ECG interpretation. This recommendation is based on observing misdiagnoses given due to first impression only. In summary, this research presents eye gaze results from expert ECG annotators and provides scope for future work that involves exploiting computerized eye tracking technology to further the science of ECG interpretation.


*Keywords:* eye-tracking; ECG interpretation

## Introduction

The 12-lead electrocardiogram (ECG) requires a high degree of skill to accurately interpret [1]. Moreover, accurate interpretation of the ECG is imperative to clinical decision-making and subsequent patient therapy. Unfortunately, annotators (i.e. physicians and other readers of the ECG) do not always have a high degree of intra and inter-rater reliability [2]. In addition while this is the case there remains a lack of best practice guidelines for the actual ECG interpretation process [1]. Numerous institutions and universities teach ECG interpretation using their own protocols and techniques. In addition, different annotators do adopt various interpretation techniques. For example, experienced interpreters are known to adopt their own unique approach (usually based on first impression and pattern recognition) whereas novices will adopt a strict protocol to interpretation (which frequently involves studying specific leads and deflections in a particular sequence [3]. In the past, qualitative efforts [4] have been used to better understand various aspects of ECG interpretation but very little quantitative research has been done [5]. However, eye tracking has been used as an objective quantitative measure in other medical disciplines [6–8]. For example, researchers have used eye tracking technology to gain a better understanding of the clinical interpretation of radiographic images [7]. This has often been referred to as the science of medical image perception [6]. Matsumoto et al. [7] in 2010 adopted eye tracking technology to enhance the understanding of how expert neurologists interpret computed tomography images of the brain, when compared to a control group consisting of nurses and medical students. In addition Wetzel et al. [8], in 2009, proposed the use of eye tracking for regular competency testing of clinical personnel who interpret radiographic images. Perhaps Wetzel's suggestion could be applied to other medical disciplines such as electrocardiography. Nevertheless, in an attempt to influence the development of best practice guidelines, this study adopts eye tracking technology to investigate whether eye-gaze can be used to gain a deeper understanding into how expert annotators interpret the 12-lead ECG. Expert ECG annotators were recruited at the 2013 International Society of Computerised Electrcardiology (ISCE). ISCE has been established since 1984 and is known to attract world leading expert electrocardiographers [9]. In addition, members of ISCE play a major role in developing recommendations for ECG diagnostic criteria [10].

## Methods

A general overview of the study protocol has been illustrated in Fig. 1. Step 1 involved the dissemination of information sheets, which were made available at the conference registration desk (the actual information sheet can be viewed on the Internet [11]). Each subject who inquired was subsequently profiled using a questionnaire [12] (step 2). Inclusion criteria required each annotator to have considerable experience in 12-lead ECG interpretation. Annotators who were recruited gave informed signed consent (step 4). The eye tracker was then calibrated to each annotator to ensure optimal accurate recordings (step 5). They were then asked to think-aloud while interpreting twelve individual ECGs and while the eye tracker recorded their eye gaze patterns (step 6). It was emphasized that they should interpret each ECG as they would in the normal healthcare setting. The ECGs were presented in a randomized order. Finally, each annotator completed a post-test questionnaire (step 7), which has also been made available on the Internet [12].

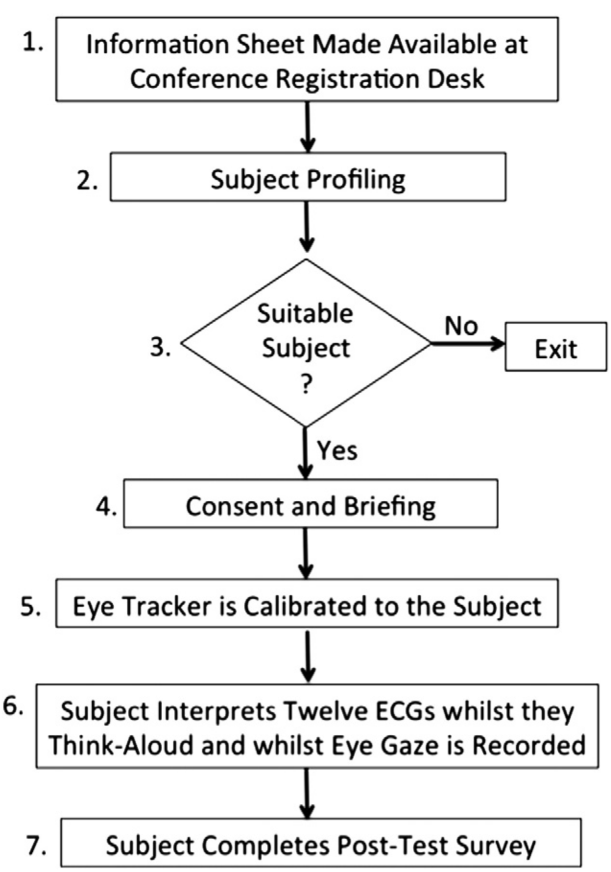


Fig. 1. A general flow diagram illustrating the protocol of each session in the study.