Comparing Novice and Expert Nurses in Analysing Electrocardiographs (ECGs) Containing Critical Diagnostic Information: An Eye Tracking Study of the Development of Complex Nursing Visual Cognitive Skills

Marc Broadbent, Mike Horsley, Melanie Birks and Nayadin Persaud

1 Introduction to Clinical Practice Context

Nurses operate in dynamic health-care environments. They are often in positions where they are required to undertake rapid diagnosis, provide emergency health-care responses and make instant risk assessments. Often, these activities occur in real-time, high-risk health-care environments and emergency situations in conditions that can be characterised as time pressured, complex and ambiguous.

Nurses need to have high levels of understanding of a range of diagnostic patient information, presented in multiple visual formats such as X-ray, electrocardiograph (ECG) and other common diagnostic data presented in specialised diagnostic formats. Analysing ECGs and interpreting their diagnostic information is a highly complex cognitive activity. Significant amounts of physiological data, displayed in ECGs, have to be processed, understood and analysed from complex stimuli, even if these stimuli are presented in static format.

Examining an ECG visual display with a view to understanding the meanings represented in the display is a precursor to correctly interpreting the display and providing an accurate diagnosis of the medical condition presented in the ECG visual display. Nurse education, both in university and field-placement contexts, places high priority on understanding and applying the meaning of diagnostic information conveyed in visual display formats. Understanding the condition of patients revealed by such displays is a critical factor in determining patient outcomes. A promising feature of eye-tracking technologies and methodologies investigating

M. Broadbent (✉)
The University of the Sunshine Coast, Sippy Downs, QLD, Australia
e-mail: mbroadbent@usc.edu.au

M. Birks
James Cook University, Townsville, QLD, Australia

M. Horsley · N. Persaud
Learning & Teaching Education Research Centre, Central Queensland
University, Noosaville, Australia

M. Horsley et al. (eds.), *Current Trends in Eye Tracking Research,*
DOI 10.1007/978-3-319-02868-2_24,

cognitive processes in diagnostic situations is to examine eye movements as nursing students analyse the information provided in real visual displays.

2 Conceptual Background: Understanding Complex Visual Displays

Eye-tracking methodologies provide a method for analysing the way that clinicians view, attend to and process complex visual displays. Gaze plot analysis provides a way of analysing how clinicians direct their view of complex visual displays, such as diagrams, charts, and representations, and their features. Gaze plot analysis allows researchers to understand the sequence of clinicians' visual search, their attention to components in the visual field and the way that an individual clinician's attention is structured. Such aspects of the visual field may then provide a platform for cognitive processing and understanding.

Research on visual attention has explored the processes that determine feature and object selection in the visual field. Current models of visual selection propose that attention is guided by two 'attentional' systems in the guided visual salience model developed by Wolfe (1994). This guided visual search model proposes that a 'bottom-up' visual saliency system guides visual attention to salient regions with high feature contrast, and that a 'top-down' feature-specific visual system based on prior learning and experience (of the visual and cognitive) targets certain features and seeks them out (Folk et al. 1992). In the model proposed by Wolfe (1994) and Navalpakkam and Itti (2007), information from these different 'attentional' systems interacts and is combined to guide attention, the precursor of focus, concentration and the building block of interpretation.

Clinical understanding requires more than attention to components in the visual field. Attention represents the initial step in making sense of complex displays that contain critical clinical information important in patient care. For nurses at different stages of their career, viewing complex diagnostic displays such as ECG and X-ray results, identifying the important features of these displays and interpreting their meaning in the context of patient care can be qualitatively different. This research seeks to analyse these differences using eye-tracking research methodologies. The research will explore the different ways that nurses at different stages of their learning journey attend to complex visual displays.

3 Novice and Expert Gaze Models Applied to Reading Complex Visual Displays

Smul et al. (2009) have proposed a novice expert eye gaze model. This model draws on the visual-salience approach developed by Wolfe (1994). In this model novice gaze patterns are determined by the saliency features of the visual field, termed bottom-up influences, because they reflect the visual field. Novice gaze patterns are believed to reflect the 'visual salience of the stimuli', such as its visual feature or saliency that draws the attention of the viewer. In contrast, experts' gaze patterns are dominated by top-down influences that determine the entire structure of gaze patterns. These top-down influences comprise three prior knowledge structures that determine gaze patterns and gaze pattern structures. These structures include:

a. Experience of the visual stimuli which influence gaze as a result of prior learning
b. Viewers' knowledge of the domain which affects the target of the gaze that exists in wider chunks of information
c. Specific goals of viewing as experts focus their gaze on identifiable components of what they are viewing (in sharp contrast to novices)

Pattern recognition based on experience, domain knowledge and vision goals contribute to wide differences in the gaze patterns of novices and experts.

In relation to the impact of bottom-up novice gaze models, Maljovic and Nakayama (1994, 1996) have suggested that in 'pop-out search' visual saliency, search is fostered when the target repeats. Maljovic and Nakayama (1994), supported by Becker (2008), also proposed a priming effect. In this proposal, 'attentional biases' to select previous target features create a bottom-up or automatic target search for pop-out features that is unaffected by knowledge about the upcoming target (Becker 2008a). 'Pop out does not occur automatically, but depends on repeating the target feature value.' This approach has significant implications for exploring how novice and expert nurses view ECGs because all ECG displays have some familiar features that provide repeated pop-out effects.

Becker, in a number of publications (2008, 2009, 2011), has developed a priming theory that proposes that bottom-up and top-down influences are, in part, due to priming with repeated pop-out effects guiding top-down visual input that feature specific visual effects.

Eye-tracking methodologies provide an opportunity to interpret cognitive processes by analysing eye gaze data.

4 The Research and Study Design

4.1 Description of Study Design

The research used an exploratory design in which participants were asked to view four different 12-lead ECGs. After entering demographic data, the participants were asked to view the four different ECGs at their own pace and answer multiple-choice questions on the medical condition that each ECG and their associated rhythm strips represented.

Each of the four different 12-lead ECGs represented different cardiac conditions. The 12-lead ECG is a critical diagnostic tool for all clinicians to understand and interpret. They form the basis for appropriate cardiac treatment. Each ECG contained a different diagnostic situation that was presented to the participants.

The different ECGs and the associated cardiac conditions they represented were:

1. *First-degree atrioventricular (AV) block*: This ECG portrayed a delay in the heart's electrical conduction. This delay in electrical conduction can progress into further electrical conduction issues and cause rhythm disturbances of the heart.
2. *Normal sinus rhythm*: This ECG represented the normal rhythm of a heart.
3. *Anterior myocardial infarction*: This ECG represented muscle (myocardial) damage to the anterior aspect of the heart. In this condition, a coronary artery has become occluded. This condition can cause life-threatening cardiac arrhythmia.
4. *Inferior myocardial infarction*: This ECG represented myocardial damage to the inferior aspect of the heart. In this condition, a coronary artery has become occluded. This condition can cause life-threatening cardiac arrhythmia.

These ECGs were sourced from freely accessible images on the Internet and their veracity and suitability for inclusion in the study were assessed by the principal investigator who has postgraduate qualifications in critical care nursing and 15 years experience in ECG interpretation. The tracings included standard ECGs encountered in clinical practice.

Two types of ECGs were selected for this research. The first described above as (1) and (2) contained diagnostic information that can be evidenced in all 12 leads across the ECG. As these ECGs represent normal rhythm (2) and a rhythm disturbance (1), the diagnosis will conventionally be made using the lead (Ld) II rhythm strip that runs across the width of the ECG and the bottom of the page.

The second type of ECGs used were those with diagnostic criteria found in a specific set of leads. As these ECGs represent damage to a specific area of the heart myocardium, the diagnosis is made through attention to the specific leads that reflect electrical activity of the affected part of the myocardium. However, there is also a requirement to view the Ld II rhythm strip to determine any rhythm disturbance associated with the myocardial damage.

4.2 Data Collection Method

Participants' eye movements were recorded on a Tobii 120 eye tracker, and the data were collected and analysed using Tobii Studio software. The Tobii 120 tracks eye movements at a resolution of 1,280 pixels at a controller refresh rate of 60–75 Hz. The Tobii 120 eye tracker allows 15 ° of head movement 60 cm from the screen and tracks corneal movements to identify gaze focus, fixation and saccade at 15 ms.

4.3 Procedure

Each participant was tested individually. The sequence of the test was:

a. Introduction to the nature of the test
b. Calibration of the Tobii 120 to the participant's gaze (eight participants wore glasses)

c. Testing which included demographic data questions built into the gaze test using Tobii Studio software
d. Gaze testing on 4-, 12-lead ECGs with a multiple-choice question for each ECG
e. Participants viewing their own gaze plots captured by the Tobii 120 Studio software and hardware

The study was conducted in Queensland between April and July 2011 at Central Queensland University, Noosa Campus.

4.4 Participant Sample

The 49 participants comprised three distinct groups:

- Twenty-two undergraduate nursing students recently enrolled in first year of the Bachelor of Nursing (BN). These were students with no prior nursing experiences or study of nursing. These students participated in the study while attending first-year BN study units. These units did not include ECG knowledge or skills.
- Eighteen pre-service nursing students in the final year of their 3-year BN degree. During the BN, these students undertook significant learning experience in ECG recognition, understanding and diagnostics. This included course components focussed on learning to read and interpret ECGs and clinical field experiences that may have included knowledge and skills in interpreting ECGs. In total, the third-year cohort had received information about ECG across three terms with the final unit of study, Critical Care Nursing, having a module on ECG interpretation including the normal ECG, ST segment elevation in infarction and Ld II rhythm strip interpretation.
- Nine expert nurses, clinicians with extensive nursing training and experience, who were employed in clinical settings in areas of nursing requiring continual analysis of ECG data such as intensive care and emergency departments. The experienced clinicians had training similar to the year 3 (Y3) cohort at an undergraduate level, clinical experience, and possibly postgraduate education including ECG interpretation.

5 Data Analysis

Interpretation of an ECG is a critical component for the accurate diagnosis of cardiac disorders, both disorders of rhythm and disorders associated with a reduction or cessation of blood flow to areas of the heart muscle (O'Brien et al. 2009). As noted previously, the ECGs selected for this study comprised two different kinds: those with diagnostic criteria found in a specific set of leads and those with diagnostic criteria that can be evidenced in all leads across the ECG.

The ECGs with diagnostic criteria in a specific set of leads demonstrated an inferior infarction (cell death) pattern (No. 4) and an anterior infarction pattern

(No. 3). The ECGs where the diagnostic criteria can be found in any lead are sinus rhythm (normal health rhythm; No. 2) and first-degree AV block (delayed conduction through the top chambers of the heart; No. 1).

The analysis proceeded in the following way:

Step 1—Gaze plot exploration. A range of gaze plots from participants from each cohort (novice, third-year BN and experienced clinicians) was examined to ascertain the sequence of gaze plots and the areas of highest frequency and visual attention.

Step 2—Area-of-interest analysis was undertaken. For each ECG, an area of interest (AOI) was selected that contained the critical diagnostic information. This AOI was different for each ECG.

Step 3—Area-of-interest data were generated. AOI data were generated to compare the three cohorts in relation to:

a. Time to first fixation on the AOI
b. First fixation duration
c. Fixation count
d. Visit duration

Step 4—Heat map analysis of AOI. A heat map analysis was undertaken to compare the three different groups in terms of the fixation count and frequency of visit to the critical area AOI within the entire ECG.

The following analyses of the data and the findings reflect the steps identified above.

6 Results from the ECGs with Diagnostic Criteria in Specific Leads

6.1 ECG 3—the Anterior Infarction ECG

6.1.1 Selection of AOI

The diagnostic criteria for an anterior infarction are the presence of Q-waves in leads V1–V4 and degrees of ST segment elevation in leads V1–V6. Therefore, the AOI was set in the leads demonstrating the most significant ST segment changes associated with the anterior infarction pattern on this ECG. V2 and V3 demonstrated high ST segment elevation and the development of Q-waves in V3.

6.1.2 Heat Map Analysis

The year 1 (Y1) heat map demonstrates a clustering of vision with the most intense gazes being V3, Ld II and the information on the bottom right-hand corner of the ECG that describes the electrical magnitude of the ECG. Another feature of this ECG is that the gaze plots are also generally associated with the changes of rhythm

Fig. 1 Critical diagnosis elements of ECG 3

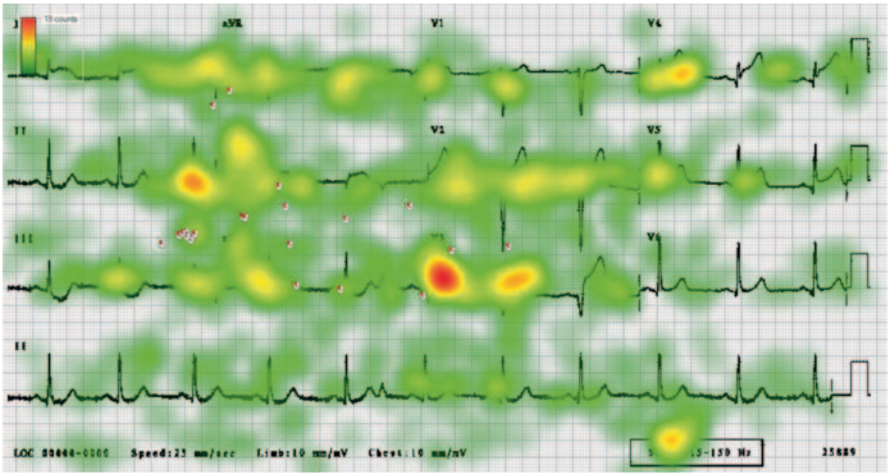

Fig. 2 Year 1 novice heat map anterior infarction

pattern in the various segments of the ECG. The Y1 cohort paid little attention to Ld II for diagnosis of rhythm. This heat map demonstrates the novice identifying the abnormal and also identifying changing patterns and other prominent features within the ECG that result from the bottom-up effects of visual saliency.

The Y3 heat map shows a cluster of vision specifically at the most abnormal leads on the ECG, Lds II and aVL, which are not associated with the diagnostic criteria for this ECG. They did however focus on the AOI to a lesser extent and demonstrated observation of Ld II associated with diagnosis on rhythm. The Y3 cohort demonstrates an awareness of the importance of examining Ld II to determine the

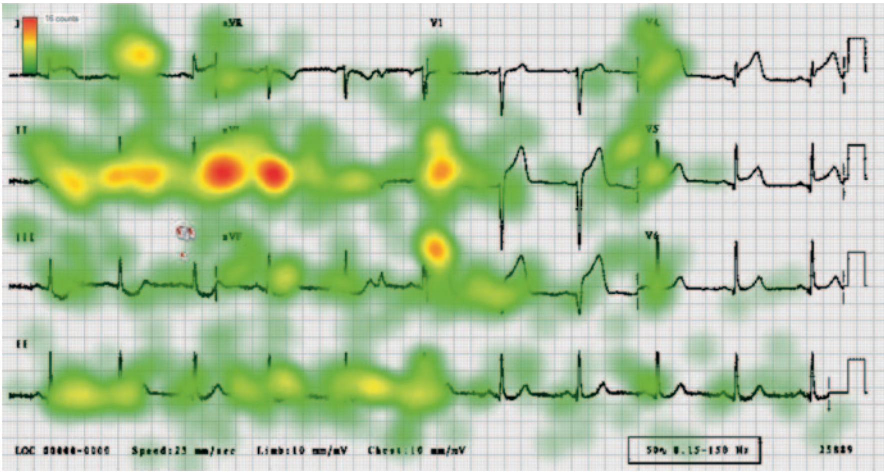

Fig. 3 Year 3 heat map anterior infarction

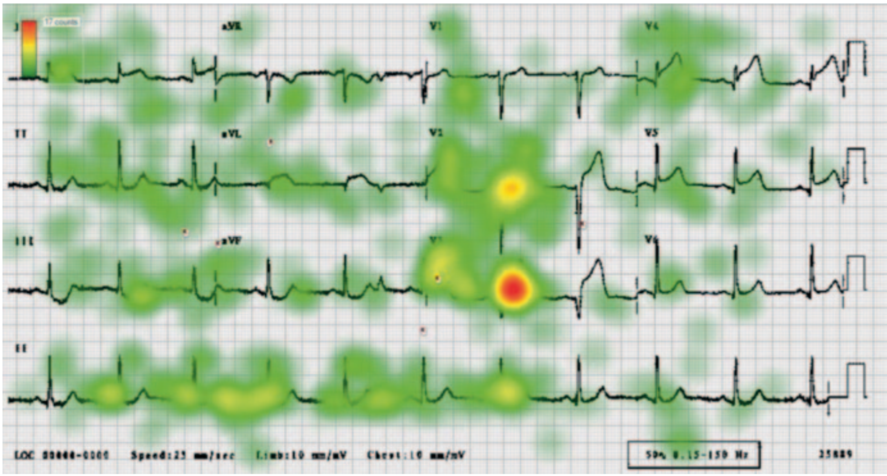

Fig. 4 Experienced clinician anterior infarction heat map

underlying rhythm. This cohort notices the AOI for this ECG but appears distracted by the other non-diagnostic ECG changes in Ld II and aVL.

The experienced cohort has two distinct areas of visual activity. The first being the AOI, and the second being a protracted gaze along Ld II for assessment of the underlying rhythm. The other feature of this heat map is that the entire area of the ECG has been examined, with a focus on the inferolateral leads that show reciprocal changes that are important but not specifically diagnostic. This heat map reflects what would be expected, identification of the significant changes and a focus on them, an examination of the entire ECG and a focus on Ld II for assessment of underlying rhythm.

6.1.3 Analysis of Time to First Duration, Fixation Count, Visit Duration

To build a working model of gaze structure and gaze pattern in each cohort, a comparison of time to first duration, fixation and visit duration for each cohort was undertaken using the Tobii 120 software package.

The AOI for this ECG encompassed the leads demonstrating the most significant ST segment changes associated with the anterior infarction pattern on this ECG. V2 and V3 demonstrated high ST segment elevation and the development of Q-waves in V3.

The Y1 and experienced cohort identified the AOI fairly quickly (Y1 mean = 2.25 s, Y3 = 3.07 s) while the Y3 group took double the time to fix on the AOI (6.23 s). Having identified the AOI, the experienced clinicians remained fixed on it for the first time for longer (0.31 s) compared to the Y1 (0.27 s) and Y3 cohort (0.29 s). The slightly longer first fix duration may indicate an awareness of significance of the finding. This significance is supported by the fact that analysis of the fixation count, the number of times participants fixated on the AOI, demonstrates that the Y1 and Y3 groups went back to the AOI less than half the time of the experienced group, with the Y3 group revisiting the AOI less than the other groups (Y1 = 15 times, Y3 = 11 times and Exp = 30.57 times). This trend is also evident in the total visit duration to the AOI. As well as revisiting the AOI less, the Y3 cohort spent less time observing the AOI (3.39 s) compared to the Y1 cohort (4.63s). The experienced clinician cohort spent more than double the amount of time examining the AOI (9.13 s).

These findings show that the Y1 cohort and the experienced cohort see the AOI in about the same amount of time, possibly because the Y1 cohort respond to the visual salience pop out as they see the changes in rhythm and the amplitude information as being different. They spend about the same amount of time looking at the AOI in the first instance as the other cohorts, revisit and observe the AOI slightly more than the Y3 cohort but significantly less than the experienced group.

The Y3 cohort take more than double the amount of time to identify the AOI than the other groups. The Y3 cohort spend about the same gaze time viewing the AOI but exhibit less visit duration, for less time than the other cohorts—this indicates they are not aware of the significance of the changes in the AOI. This finding is surprising as the Y3 cohort have completed three consecutive terms of study that includes instruction on ECG interpretation.

The experienced cohort identify the AOI relatively quickly and while they do remain fixed on the AOI only slightly longer than the other cohorts, they revisit it and spend longer looking at it than the other groups. This finding would indicate an awareness of the significance of the AOI and possibly demonstrates the cognitive processing required of diagnosis. The Y1 and Y3 cohort both demonstrate a lack of understanding of the significance of data in the AOI and suggest that there has been no net gain in knowledge from the ECG instruction received by the Y3 cohort.

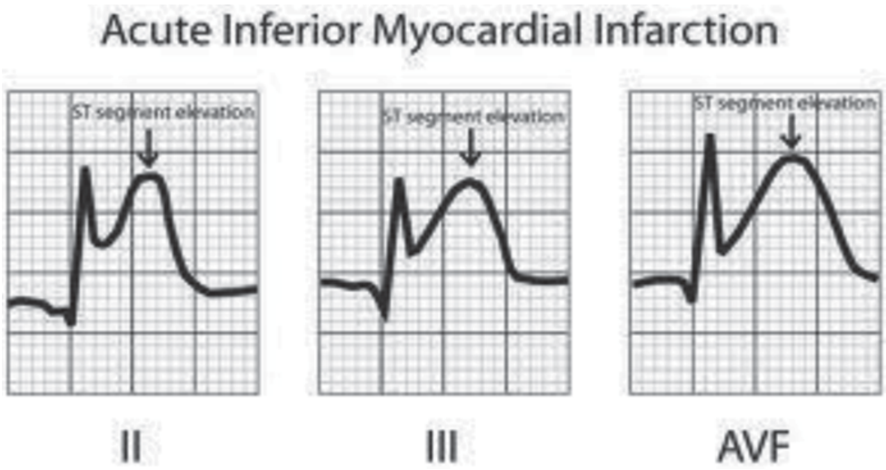

Fig. 5 Critical diagnosis elements of ECG 4

6.2 ECG 4: the Inferior Infarction ECG

6.2.1 Selection of AOI

The diagnostic criteria for an inferior infarction are the presence of Q-waves in Ld II, III and AVF and degrees of ST segment elevation in the same leads. Therefore, the AOI was set in those leads on this ECG.

6.2.2 Heat Map Analysis

The Y1 heat map indicates widespread viewing over the entire surface of the ECG. The areas of most and longest viewing duration were related to non-clinical information. This includes superfluous material on the tracing such as the letters aVF, V3, V2 and AVL and information that relates to the speed the ECG was recorded at and the voltage associated with rhythm amplitude. The viewing of clinically significant information is varied across the ECG and similar time is spent on the AOI as is spent on ECG changes across the entire ECG, including V1–V6 where there are both clinically significant changes and changes associated with the tracing of the ECG. The concentration on the extraneous information represents the visual saliency of pop out.

The Y3 heat map demonstrates a more ordered approach to viewing with clusters of activity in the AOI and above and below it. While the Y3 cohort focussed on the clinically significant components (ST segments), there was an equal amount of interest in the labels of the ECG components II, III, aVF suggesting students may have been drawing a correlation between the leads and the changes within them. This phenomenon is also observed in Ld I and on the rhythm strip across the bottom

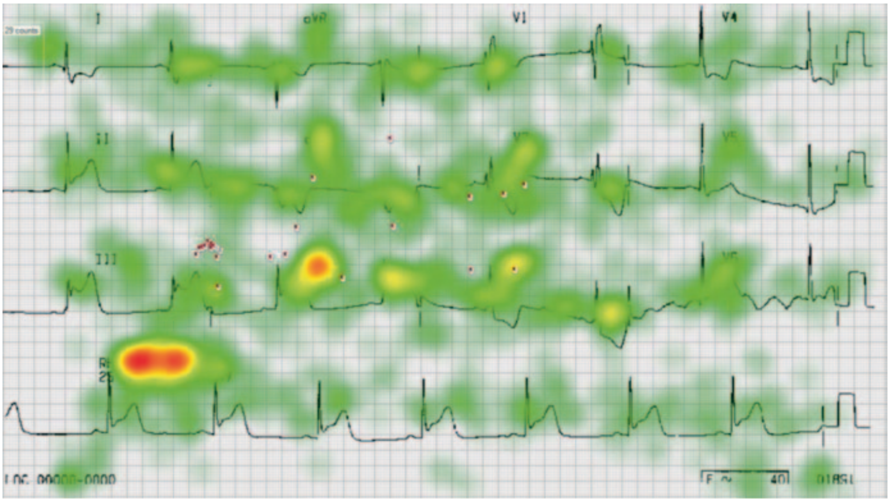

Fig. 6 Year 1 cohort heat map

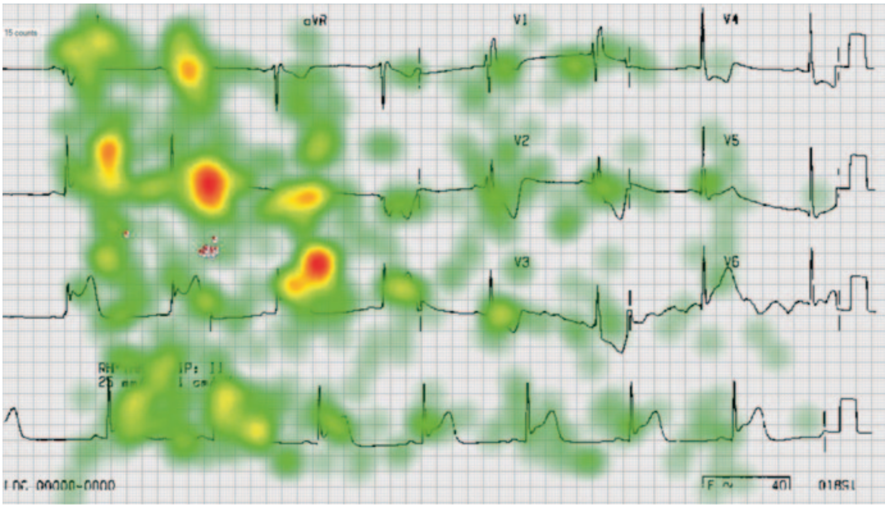

Fig. 7 Year 3 cohort heat map

of the ECG where their attention is also drawn to the information on the ECG that relates to the speed the ECG was recorded at and the voltage associated with rhythm amplitude as were the Y1 group. The Y3 cohort spent very little time viewing V1–V6 where evidence of other significant ECG changes are obvious.

The heat map of the experienced clinician cohort demonstrates prolonged viewing across the ECG. There is a concentration of activity in the AOI, which includes time

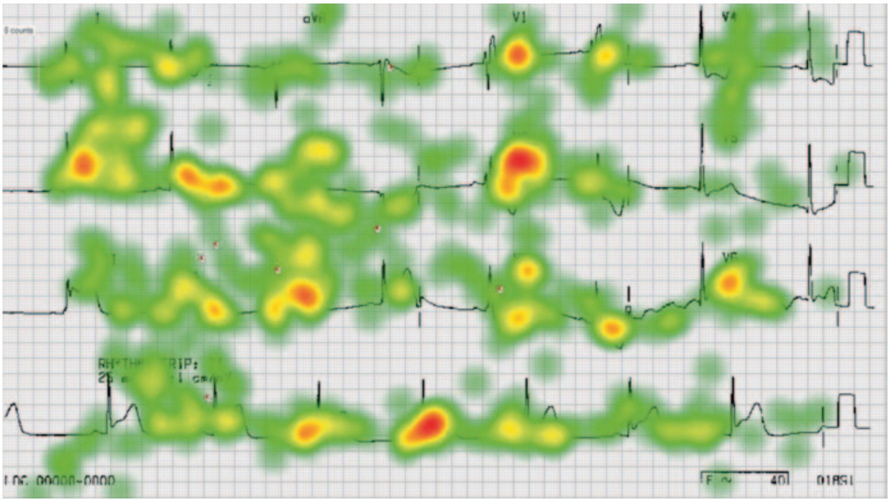

Fig. 8 Experienced clinician heat map

spent viewing the lettering identifying the leads. There is also a significant amount of time focussed on the other clinically significant information in leads V1–V6 and Ld I, aVL. This finding may suggest that the experienced clinicians are as interested in the non-significant information, including the wandering tracing in V6, as they are in the AOI that contains the diagnostic leads for this ECG. Of note is the greater observation of Ld II rhythm strip by the experienced cohort than the Y1 and Y3 cohorts. The experienced clinicians examined the entire length of the tracing. This heat map clearly shows the experienced clinicians observing both the area of the P–R interval, essential for determining the underlying rhythm and the ST segment elevation present as part of the inferior infarction. The experienced cohort place as much emphasis on the diagnostic AOI as they do to the other non-diagnostic, but significant, changes on this ECG that must be examined in order to correctly understand the ECG.

6.2.3 Analysis of Time to First Duration, Fixation Count, Visit Duration

The Y1 and experienced cohorts first viewed the AOI in much the same time (Y1 = 1.75 s, Exp = 1.82 s). However, the Y3 cohort viewed the AOI first but viewed the AOI in shorter periods of time—1.11 s. All three groups viewed the AOI for about the same amount of time on the first view (Y1 = 0.23 s, Y3 = 0.22 s, Exp 0.27 s). Similar to the results of the previous ECG, the experienced cohort viewed the AOI a larger number of times, 17.33, compared to the Y1 and Y3 cohorts, 11.88 and 12.35 times, respectively. Again, the experienced cohort spent longer viewing the AOI (5.09 s) compared to the Y1 cohort (3.90 s) and the Y3 cohort (3.90 s). This result may signify the experienced cohort recognising the significance of the AOI and focussing on these features of the AOI to confirm the diagnosis.

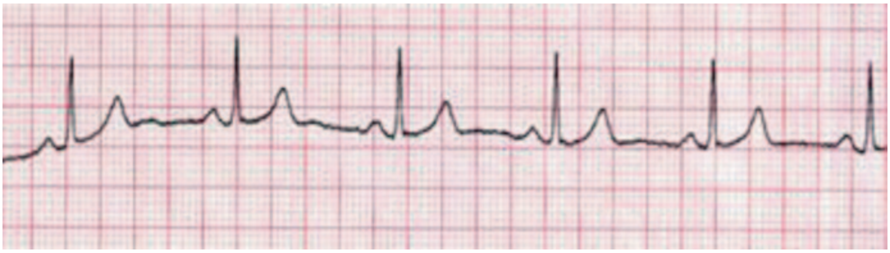

Fig. 9 Area of interest (AOI) of sinus rhythm strip

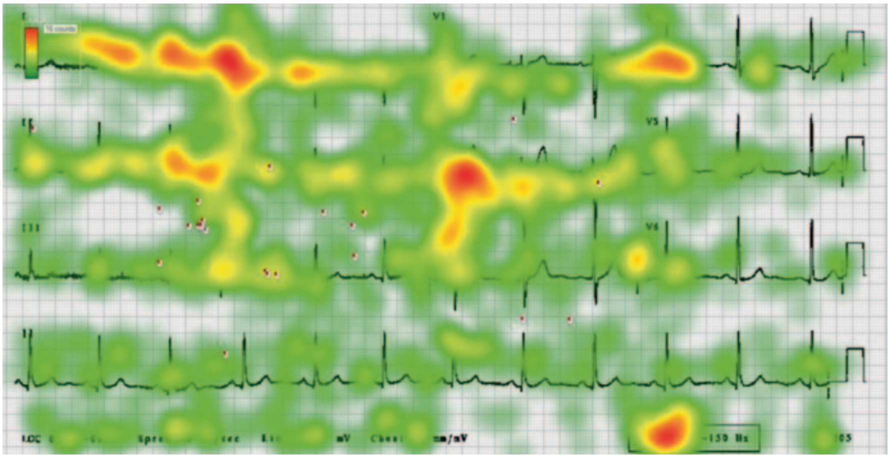

Fig. 10 Year 1 cohort map

7 Results from the ECGs with Diagnostic Criteria that can be Evidenced in All Leads Across the ECG

7.1 ECG: the Normal Sinus Rhythm ECG 2

7.1.1 Selection of AOI

The normal ECG is characterised by the complete lack of any abnormalities. Due to the highly complex nature of ECGs, and the ability to determine sinus rhythm in any part of the ECG, the AOI was set across the first half of the Ld II rhythm strip. This is the rhythm strip that is used to determine underlying rhythm in the absence of any abnormalities.

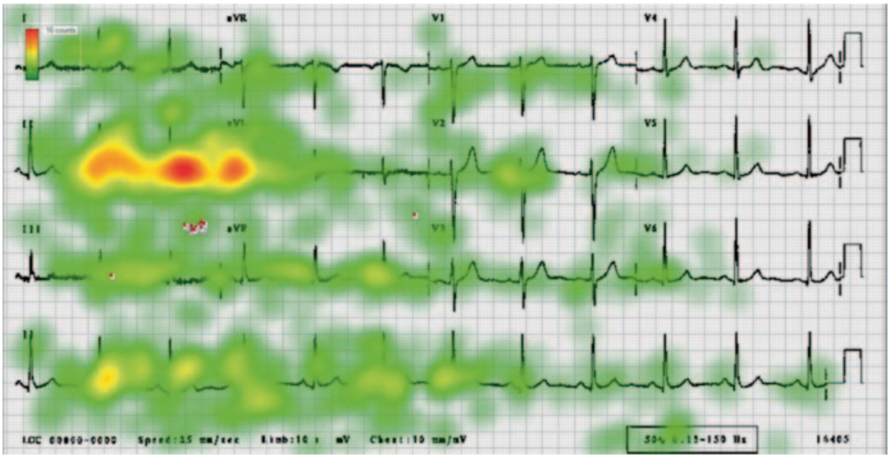

Fig. 11 Year 3 cohort heat map

7.1.2 Heat Map Analysis

The Y1 cohort heat map demonstrates widespread viewing of all elements of the ECG including the data along the bottom of the page indicating the speed, voltage and other technical information about the ECG. Prolonged visualisations are found across the ECG where the changes in the lead, and therefore the rhythm, are evident. This demonstrates the pop-out effect—where patterns are repeated. There is scant visual activity in the Ld II rhythm strip.

The Y3 heat map shows visual activity predominantly across the first half of the ECG and in the Ld II rhythm strip. There is a focus on leads II and aVL.

By contrast, the experienced cohort demonstrate widespread viewing of the ECG with a focus on Ld II and aVF, as did the Y3 cohort, yet the reason for this is uncertain. The two important features of this ECG are that there is extensive viewing of the Ld II rhythm strip, particularly in the first half where the main visualisation has occurred, and there are areas of extended gaze over the T-waves in V1, V2 and V3. This is likely due to the unusual elevation of the T-waves indicating that the experienced cohort is viewing these to rule out abnormalities.

The similar pattern of viewing between the Y3 cohort and the experienced cohort suggests the Y3 cohort is familiar with the importance of the Ld II rhythm strip.

7.1.3 Analysis of Time to First Duration, Fixation Count, Visit Duration

The Y1 cohort took more than twice as long (8.49 s) as the experienced cohort (3.66 s) and nearly twice as long as the third-year cohort (4.88 s) to view the AOI. All three groups viewed the AOI for about the same amount of time (Y1 and Y3 = 0.27 s, Exp = 0.3 s). The Y3 and experienced cohort viewed the AOI a similar number of times (Y3 = 8.22, Exp = 9.33) compared to the Y1 cohort who only viewed the AOI 4.86 times. Similarly, the Y3 and experienced cohorts spent longer

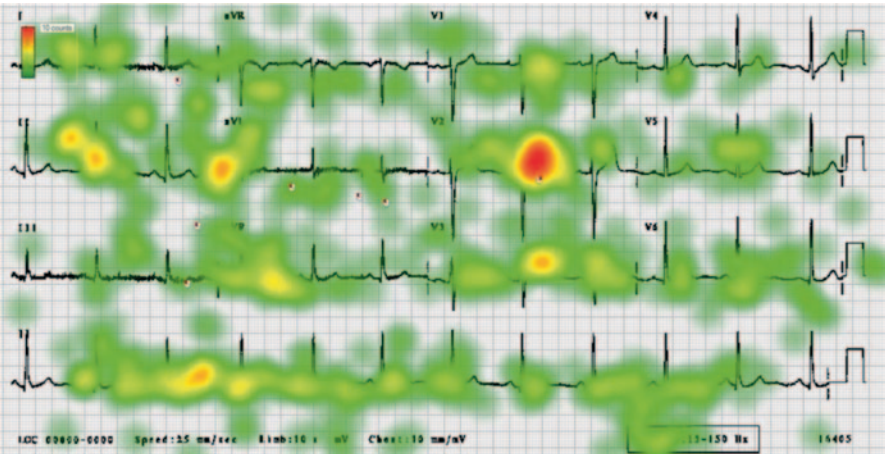

Fig. 12 Experienced clinician cohort heat map

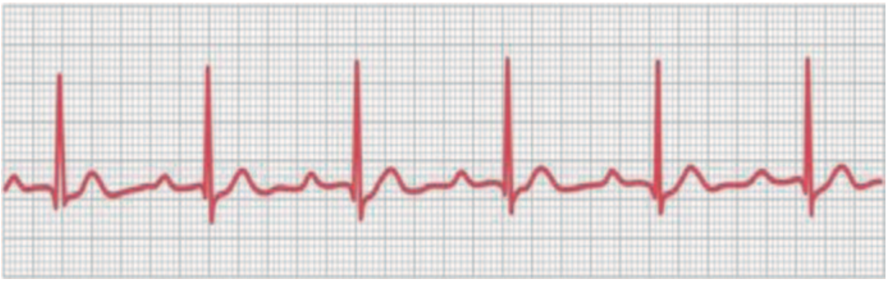

Fig. 13 Area of interest (AOI) of the first-degree AV block

viewing the AOI (Y3 = 0.95 s, Exp = 1.20 s) than the Y1 cohort (0.53 s). These data reinforce what has been determined for the heat map that the Y1 cohort are not aware of the importance of Ld II and while the Y3 cohort are, but that they are not viewing it for as long or as repeatedly as the experienced cohort. This finding has significant implications for instruction and education in relation to developing ECG clinical knowledge and skills.

7.2 ECG—the First-Degree AV Block ECG 1

7.2.1 Selection of AOI

This ECG is very similar to the normal sinus rhythm ECG in that diagnosis can be made in any lead; however, the focus should be on the Ld II rhythm strip. The diagnostic criterion for this ECG is a prolonged P–R interval. Therefore, the AOI was set across the first half of the Ld II rhythm strip.

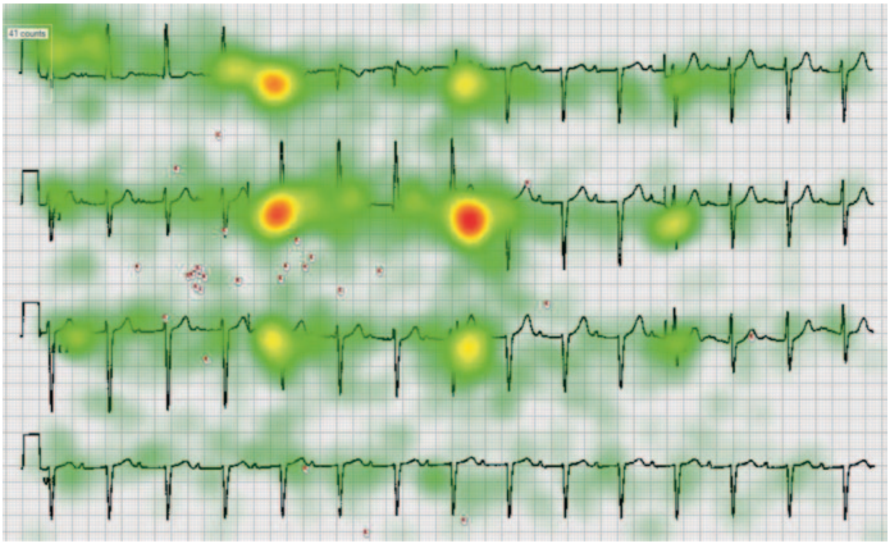

Fig. 14 Year 1 cohort heat map

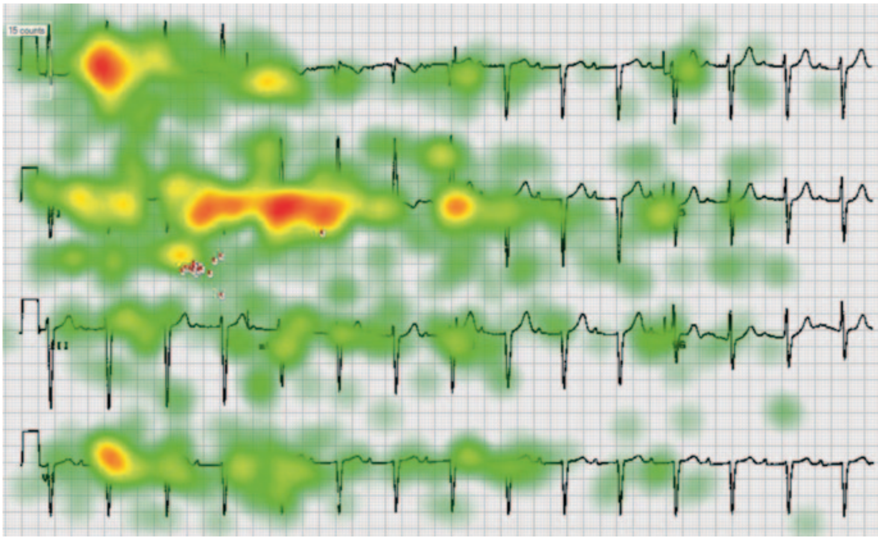

Fig. 15 Year 3 cohort heat map

7.2.2 Heat Map Analysis

Similar to the sinus rhythm ECG, the Y1 cohort heat map demonstrates prolonged visualisations across the ECG where the lead, and therefore the rhythm, changes. In particular, the Y1 cohort visualise the lettering at these points. This finding suggests

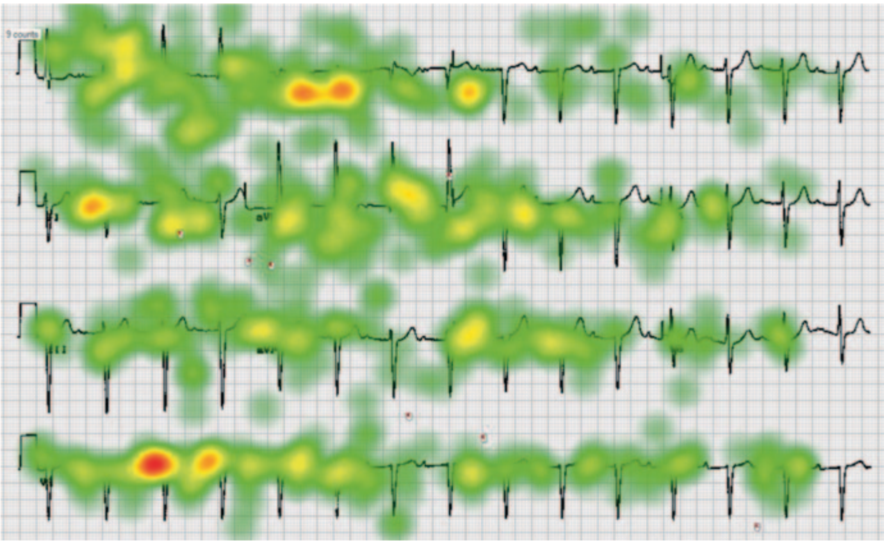

Fig. 16 Experienced clinician cohort

that the students are responding to visually salient aspects of the ECG display. There is little visual activity and focus in the critical Ld II rhythm strip.

There are similarities between the Y3 heat map for this ECG and the sinus rhythm ECG in that the visualisations are predominant across the first half of the ECG; particular attention is paid to Ld I and aVL and the Ld II rhythm strip is visualised.

The experienced cohort visualise the entire ECG. There are areas of visual concentration over the inverted T-waves in aVR. Again, the experienced cohort visualise the Ld II rhythm strip as would be expected. Of note are the prolonged visualisations over the extended P–R interval, i.e. the gaze is to the left of the R-wave, whereas in the Y3 cohort the gaze is to the right of the R-wave suggesting that while the Y3 cohort have examined the Ld II rhythm strip they are not aware of the abnormalities.

7.2.3 Analysis of Time to First Duration, Fixation Count, Visit Duration

The Y1 cohort took 16.41 s to first visualise the AOI, Y3 9.49 s and the experienced cohort 11.32 s. Having visualised the AOI, the experienced cohort observed the AOI for 0.62 s compared to the Y3 and Y1 cohorts who visualised the AOI for less than half that time (Y3 = 0.37 s, Y1 = 0.29 s). The Y3 and experienced cohort return to the AOI repeatedly (Y3 = 3.30, exp = 4.67 times) while the Y1 cohort only revisit the AOI 1.64 times. The overall time spent at the AOI is 1.49 s by the experienced cohort compared to 0.65 s by the Y1 cohort and 0.34 s by the Y3 cohort.

8 Discussion

The results of this study provide an interesting perspective on cognitive processes that occur in reading ECG tracings. There are clear distinctions between the way in which year 1, year 3 students and experienced nurses approach the identification and assessment of AOIs on ECGs. While it is clear that the Y1 and Y3 cohorts do not appreciate the significance of abnormalities in the ECG, what is surprising is that the Y3 cohort do not appear to have advanced in their ability to interpret ECGs in spite of three terms of study that include ECG interpretation. The data from these ECGs indicate that the Y3 cohort are aware of the importance of Ld II rhythm strip but they do not revisit this as frequently or focus on it as long as the experienced cohort. This is seen across all the AOIs suggesting that the experienced cohort will dwell on areas of significance in order to decipher and recognise the important data on the ECG. Wolfe (1994) suggests that 'bottom-up' gaze models use high feature contrast regions as a point of interest. Consistent with Smut et al.'s (2009) assertion that such a gaze pattern is usually employed by novices, Y1 participants in this study tended to be attracted to extraneous data on the ECG, such as letters or numbers, or areas where there is a distinctive pattern, such as where lead changes occur.

While the experienced cohort do not necessarily visualise the AOIs in more or less time, they do focus on them for longer periods and return to them more frequently than the other groups. This would be consistent with them having the knowledge to identify abnormalities and also the need to focus on these abnormalities to confirm details important for interpreting the diagnostic information provided. The experienced cohort, therefore, tend to target specific visual effects, suggesting a 'top-down' gaze model characteristic of experts (Wolfe 1994; Smut et al. 2009).

The Y3 cohort appear to be aware of the significance of viewing the Ld II rhythm strip yet are not aware of the clinical significance of the information there as evidenced by the findings of the first-degree AV block ECG. This outcome is reflected throughout the findings where the Y3 cohort appear to know what they need to find but are unsure of what the finding indicates. There is evidence, therefore, of 'attentional biases' (Maljovic and Nakayama 1994) in this cohort. Consistent with Becker's (2008) priming theory, third-year students appear to be primed by exposure to 'pop-out' features, possibly as a result of instruction on ECG interpretation, that enable identification of specific visual effects, yet they are unable to interpret their significance. It is evident that the Y3 cohort fall between novice and expert and behave accordingly in combining characteristics of both top-down and bottom-up systems of viewing the ECG tracing.

The findings of this study have implications for nursing practice, education and research, specifically in the design of instruction in reading complex diagnostic displays.

References

Ariasi, N., & Mason, L. (2011). Uncovering the effect of text structure in learning from a science text: An eye-tracking study. *Instructional Science, 39*(5), 581–601.
Becker, S. I. (2011). Determinants of dwell time in visual search: Similarity or perceptual difficulty? *PLoS ONE*, Vol. 6, No. 3.
Becker, S. I., Folk, C. L., & Remington, R. (2009). The role of relational information in contingent capture. *Journal of Experimental Psychology: Human Perception and Performance*.
Duchowski, A. (2002). A breadth-first survey of eye tracking applications. *Behavior Research Methods, Instruments, and Computers, 34*(4), 455–470.
Navalpakkam, V., & Itti, L. (2007). Search goal tunes visual features optimally. *Neuron, 53*(4), 605–617.
O'Brien, K., Cannarozzi, M., Torre, D., Mechaber, A., & During, S. (2009). Training and assessment of ECG interpretation skills: Results from the 2005 CDIM survey. *Teaching and Learning in Medicine, 21*(2), 111–115.
Wolfe, J. M. (1994). Guided search 2.0: A revised model of visual search. *Psychonomic Bulletin & Review, 1*(2), 202–238.
Wolfe, J. M. (1998). Visual search. In Pashler, H. (Ed.), *Attention*. London: University College London Press.