The study of ECG in relation to human emotions

Teo Kah Ming
U049092A
Neurosensors Laboratory, Department of Mechanical Engineering

ABSTRACT:

This study assesses the current progress through literature survey in finding the relationship between emotions, chiefly anxiety, and the different physiological signals with particular focus on the unique patterns of electrocardiogram (ECG) waveform. A pilot study was done to assess which features in ECG waveform may be best associated with anxiety apart from those. It has thus been found that emotion recognition using specific features of ECG is less explored than other physiological responses such as speech signals, facial expression, skin conductance and temperature, heart rate and blood pressure. Through the pilot study, it was also found that the T waves flatten significantly and there is some possibility of P waves.

I. INTRODUCTION

BACKGROUND

Traditionally, electrocardiogram (ECG) has been used to diagnose cardiovascular diseases and cardiac abnormalities clinically (Israel, Irvine, Cheng, Wiederhold, & Wiederhold, 2005). ECG provides a lot of information about the cardiac functions through its patterns. Unlike the past, the use of ECG has become more extensive to include areas like lie detection, stress and emotion measurement and human identification nowadays. This began with William James postulating in 1894 that the afferent signals from our senses resulted in unique physiological responses that are elicited by the stimulus and which in turn cause the associated emotions. (Rainville, Bechara, Naqvi, & Damasio, 2006). This sparked some interest in investigating if a unique combination of physiological responses could reflect a certain emotion, which means if an emotion could be recognized merely seeing the physiological response and mean even the possibility of quantifying emotions by using these bodily signals. Emotion recognition, especially using bio-signals, became en vogue lately as more techniques were invented for measurement of physiological response. Responses that are easily measured, such as blood pressure, skin temperature and heart rate, were common areas to be researched on. Later, greater interest was spurred in researching on the uniqueness of ECG waveform to be one of the biosignals to give us insights into human emotions.

In this study, we strive to assess the current progress, through literature in finding the relationship between emotions, chiefly anxiety, and the different physiological signals with particular focus on the unique patterns of ECG waveform. A pilot study was done to assess which features in ECG waveform may be best associated with anxiety apart from those.

EMOTION

According to American Psychological Association (APA)
dictionary (2006), emotion is defined as "complex reaction pattern, involving experiential, behavioral, and physiological elements, by which the individual attempts to deal with a personally significant matter or event”. There are controversies as to emotions stem from the physiological responses (James-Lange Theory) or physiological responses are elicited simultaneously with emotions by the emotion-arousing stimulus (Cannon-Bard Theory). (Myes, 2001) However, this would not crucial at this phase since in this study, we are merely ascertaining if there is a specific ECG signature to anxiety, be it a cause or an effect.

**ORIGIN AND MECHANISM OF ECG**

ECG is a method which measures the electrical potential and records the electrical activity of the heart over time. These bioelectric potentials are due to electrochemical activity of excitable cells, which are cells that are able to conduct action potential. The muscle fibres (also known as myocytes) of the heart are made of such cells. In addition, the heart has a group of special cells, which can spontaneously generate impulse, at the sino-atrial (SA) node. In a cardiac cycle, the SA node, also the pacemaker, will fire at the myocytes at the atria and spread the impulse to the atrio-ventricular (AV) node. The AV node will then transmit the impulse to the ventricles via Bundle of His and Purkinje fibres and cause the subsequent contraction of the heart muscles. This results in a heartbeat.

![Figure 1: The heart and its pacemaker. SA node is the primary pacemaker. The red line shows the path which the electric impulse takes.](image)

The direction of the spread of electricity is from the atria to the ventricular apex. (Bowbrick & Borg, 2006). To study the patterns, the potential needs to be measured. It is usually assumed to be a net equivalent current dipole at the electrical centre of the heart, which lies within the heart. (Hynes) This could then be found conveniently by giving a vector to the electric current. Each heartbeat consists of P, R and T complexes.

![Fig. 2 shows a normal waveform.](image)

Each complex or segment corresponds to different phases of the cardiac cycle. The P-wave is obtained during atrial depolarisation, the QRS-wave is when the ventricles depolarise and the T wave is due to ventricular repolarisation.
II. LITERATURE SURVEY

Hitherto, emotion recognition using physiological responses is a relatively new field which remains less explored. The most common physiological responses that are used to recognise emotions are facial expression and speech signals. (Haag, Goronzy, Schaich, & Williams). Other common ones are skin conductance, skin temperature, respiratory rate, blood pressure and heart rate. (Bauer, 1998). Some of these are also used very often in polygraphs. ECG, if being used in emotion recognition experiments, is usually for the RR interval to calculate the heart rate and also the heart rate variability (HRV). The features of ECG waveform are being researched on but they were mainly for medical uses. Many studies on ECG waveform were to find if any features could tell one’s susceptibility to anxiety disorder or cardiac diseases, or sudden death. Past researches have been done on how the QT dispersion, which is the maximal interlead difference in QT interval 12-lead ECG, correlates positively with the subjects with anxiety symptoms. (Uyarel, Okmen, Cobanoglu, Karabulut, & Cam, 2006). The State-Trait Anxiety Inventory scale was used to measure the anxiety level in the subject’s nature, i.e. the tendency for subject to feel anxious, or at that point of time. Simply put, it is to see if QT dispersion can be a state or trait marker. (Uyarel, Okmen, Cobanoglu, Karabulut, & Cam, 2006) Apparently, the higher the score, the larger the QT interval is even for those without cardiovascular abnormalities. (Piccirillo, et al., 1999). This implies a higher risk of getting sudden or prolonged anxiety. Similar studies on P wave dispersion and maximum P duration have been done by Uyarel and others (2005). These two features were found to correlate significantly with anxiety. While these studies have shown correlation between anxiety and those studied features, nothing was done to subjects to evoke this emotion. For other experiments which involved emotion induction, the features of ECG are still not researched extensively except using its RR intervals and HRV. ECG could also be used to identify individuals. (Israel, Irvine, Cheng, Wiederhold, & Wiederhold, 2005).

III. EXPERIMENT

SUBJECT AND EQUIPMENT

Two healthy subjects with no medical history of coronary diseases or abnormalities, and are not on any medication prior to the experiment, participated in the experiment for the feasibility study. They are females and are of age 22 and 23. Scan NuAmps Express system by Compumedics Neuroscan with Scan 4.3 software are being used to capture ECG data. Gold electrodes were used.

PROCEDURE

Prior to trial, the subjects were required to answer a health screening test to ensure that they are fit enough for the test. Prior warning that the experiment contained shocking parts was given to subjects. They would then be hooked on the Neuroscan machine. Standard Lead II ECG configuration would be used. Two electrodes would be placed on both the collar bones and the ground electrode would be attached to their waists. Subjects would be briefed that an ECG baseline
measurement of ten minutes would be recorded first and after which they would be shown a five-minute video clip which may be shocking. However, before the end of the tenth minute, at the seventh minute, the experimenter would shock the subjects by shouting very loudly behind them. They also would not be shown any film clip at all. Right after the shock, another five minutes of measurement would be recorded. Finally, the subjects would be asked verbally for some feedback on the experiment.

**ANALYSIS**

The results were just being observed and analysed by visual comparison between the baseline ECG and the ECG during the anxiety state. This is just to pick out some of the obvious features which could well be associated with anxiety.

**IV. RESULTS AND DISCUSSION**

Right after shocking, both subjects have an increase in their heart rates. Increase in HR implies a decrease in the time taken for a cycle. One minute after the shocking, the HR starts to decrease to the resting HR.

**Subject 1**

The ECG waves seem noisier than the resting ECG waves. In the waves that we obtained, there are some which resembled P waves but they, at the same time, appear to be like motion artefacts. Hence, it is not conclusive if multiple P waves are found due to the amount of artefacts. The mean P wave amplitude before shocking is -278µV while after shocking, the P wave has an average of -287.81µV. There seem to be greater variance in the P amplitude. Apparently, subject 1, when shocked, has a more negative QRS amplitude. When superimposed the ECG waveform samples, in general, QRS amplitude is more negative. An average of -1520.75µV is obtained from six random samples taken from the minute immediately after the shock whereas the average of the QRS amplitude of her resting ECG baseline is only -1478.74µV. It is also found that there is a greater variance in the amplitude of QRS waves right after shock than before shock. Ten random samples were taken to estimate the P wave amplitude. There is also an increase in the amplitude of T waves right after shocking. It is -49.21µV before the shock while it is -62.30µV right after the shock. A while longer after the shock, the T waves seemed to be smoothed out before returning to the normal. The PR interval before and after shocking is 0.151s and 0.146s. This could be due to the contraction of the whole cycle. The QRS interval remained approximately the same. Interestingly, the QT interval increased despite the decrease in one cycle time. It increases from 0.361s to 0.366s despite the drop in a cycle time from 0.769s to 0.667s. There is also greater variance in PR interval and QT intervals but comparable variance for QRS interval, in ECG waves obtained right after shock and before shock. At least a minute after shock, the variance for ECG waves returned to approximately the same values as before shock.
Figure 3: The superimposition of the ECG waves before and right after shock. The black graph shows the baseline ECG whereas the red graph shows the ECG right after shock.

Figure 2: The smoothing out of T waves after shock which occurred seconds after fig 1.
Subject 2

At the point of shock, there is a presence of multiple P waves. The ECG waves right after shock have not become noisier like what had occurred for the first subject. There is also the phenomenon of smoothing out of T waves which would not occur right after shock, but seconds after shock. The amplitude of the QRS waves, unlike those of the first subject, it decreased from 1307.5μV to 1288.7μV. The P waves decreased from -98.61μV to -21.86μV. However, there is something noteworthy about the results obtained from this subject is that the ECG waves seem to be oscillating in a sinusoidal wave. It compared by superimposing. The amplitudes are comparable for before and after shock.

Figure 3: The superimposition of the ECG waves before and right after shock for subject 2. The red ECG waves are observed 20 seconds after the shock and lower T wave and the dip between the T and P waves are smoothed out.

Figure 4: Multiple P waves were observed at the point of shocking.
DISCUSSION

The results obtained for multiple P waves were not conclusive due to the presence of high amount of artefacts right after shock which could be due to motion. However, it is strange that artifacts only occur for subject 1 even when through our observation, it was clear that subject 2 had more movement at the point of shock when subject 1 was much more still. This was unlikely to be due to her electrodes being more loosely as the artifacts only occurred right after shock not throughout the whole ECG recording.

The ECG of the two subjects deviate from the normal ECG, especially subject 2, despite not indicating of any heart abnormalities in the health screening questionnaire.

There is an increase in QT interval and also the QT dispersion, which is the difference between the maximum and minimum QT interval. This is already supported by existing studies such as Uyagel et al (2005) which showed that an increased QT dispersion can indicate higher level of anxiety. According to Ishida, it was also found that QT dispersion was positively correlated with increased sympathetic and/or vagal modulations. However, there is some inaccuracy involved during reading the exact onset and offset times.

As for P wave, there is a decrease in the time for P wave which is due to the increase in heart rate and therefore, decrease in the time taken for one complete cycle. There is also a slight increase in the P dispersion. However, this is as dubious as the QT dispersion due to the errors in reading off the exact times.

LIMITATIONS

Errors could be resulted from the following sources:

1) Unavoidable motions made by subject when in shock
2) Health screening questionnaire may be inadequate to screen out people with heart abnormalities since many of such health conditions went undetected.
3) Events should be properly marked. Currently, the timing for the events is approximate.
4) Protocol should be standardised. The shouting of the experimenter may vary in volume.
5) It is difficult to identify exactly the onset of a certain wave and thus, the difference in time might be due to human errors.

RECOMMENDATION

Recommendations for the respective errors abovementioned:

1) Use shoulder bands to secure the electrodes to the body
2) Conduct proper health check-up before allowing one to participate in the experiment.
3) Have some buttons to press to mark the point of shock in the ECG recordings
4) A constant audio clip should be used or other means of shocking subject which could be standardised should be used.

V. CONCLUSION

Emotion recognition using more specific features of ECG is found to be a rather unexplored area so it is worth investigating. There are some interesting features about the results found in this
experiment. There is no concrete evidence that there are multiple P waves due to the amount of errors present. Other than the possibility of multiple P waves, a possibility to look at is also the flattening of T waves. Despite having a lot of limitations and errors, the results that we obtained are still fairly reliable since the other aspect of waveforms - the QT interval, which existing studies have looked into before, are as what is expected. However, the difference in QT and P interval could be due to human error in reading off the onset time. Further experiments with better protocols should be carried out to test. The study that follows would be more comprehensive covering more features that could not be detected through visual comparison.

References


