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Stress Recognition Using Photoplethysmogram Signal

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Abstract

This study proposed a novel method of stress recognition using photopletysmogram (PPG) signal. PPG devices are now widely used because it is convenient, low powered, cheap and also easy to handle due to its small size. A total of 5 subjects were involved in this study. The PPG signals were taken in resting condition using pulse oximetry. The subject then goes through a stressor test in order to record the physiological changes. The data were collected before and after the test was conducted and later extracted. These samples were then categorised using classification techniques to differentiate between normal and stress condition. Based on the experimentation results, the systolic peak value differences of normal and stress conditions are evident.Therefore, the outcome of this study suggest the reliability of implementing PPG signal for stress recognition.

Keywords*: Photoplethysmogram (PPG), stress, systolic peak, stroop, pulse oximetry*

1. Introduction

Stress is crucial in our community nowadays. There are many people who are suffering from stress and unfortunately it has already become part of our life. This problem usually happens to adult because of their high workloads, commitment in life, and also time pressure [1].

Sometimes stress will give a positive impact to some people. However, continuous stress can lead to negative impact especially on health such as hypertension, musculoskeletal disorders, depression, insomnia and heart disease [1, 2].

As stated in [3], stress can affect either psychological or physiological of an individual. Stress can gave a negative impact to a person to accomplish their work such as poor decision making, low motivation, and lack of concentration. These impacts will contribute on poor performance and high absenteeism. While, physiological reaction is referring to internal response of an individual towards the stress. Some people take a stress as a good motivation for them to perform well and to be less fearful. On the other hand, some people may affected by stress in negative side such as having headache, chest pain, indigestion, disturbed sleep etc.

According to European Commission, almost €20 billion a year was spent for work-related stress. This cost is due to the increase of absenteeism and low productivity of the worker [2]. In 2013/2014, the UK Health and Safety Executive stated that there are 487 000 cases or 39% of all work-related illnesses are counted based on stress due to work, depression or anxiety and almost 11.3 million work days is lost due to absenteeism. Besides that, most of the UK university students were also identified to have major psychological problems such as depression [4].

Adult Psychiatric Morbidity Survey 2014 had used the Clinical Interview Schedule (CIS-R) to assess Common Mental Disorder (CMD). The person who has a CSI-R score of 12 above was indicated to have CMD. Figure 1 shows the statistic of person with severe CMD symptoms which score 18 above for the CSI-R from year 1993 to 2014. For instance, rate of CMD for year 1993 is 6.9%, 7.9% in 2000, 8.5% in 2007 and 9.3% in 2014 [5]. Thus, from this survey, it can be concluded that CMD rate were steady increase time to time.

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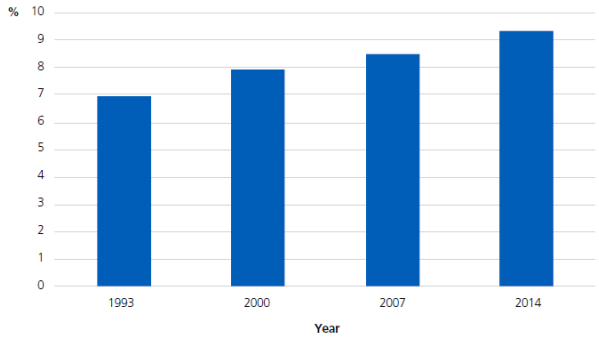

Figure 1. CMD rate based on CSI-R (Score 18+), 1993-2014 [5]

Therefore, there is a need to detect and treat these above mention concerns in an early stage. In this study, the study will focus on the detection of stress using PPG signals. This proposed technique may assist many people from having chronic diseases due to stress. The experimentation results will then be compared to previous researches to determine the accuracy of the proposed method.

2. Literature Review

This section consists of two main parts which are the basic terminologies and related works on the study.

2.1. Basic Terminologies

This sub section consists of fundamental of PPG signal and Stressor test.

2.1.1. Fundamental of PPG signal

Photophlethysmographic (PPG) signal is obtained using pulse oximetry. Light absorption from pulse oximetry is used in order to measure arterial blood oxygen saturation (SpO2) and pulse rate (PR) from photoplethysmographic (PPG) signals. Pulse Oximeters will identify a pulsatile signal from the PPG signal which is usually only in a small percentage. Therefore, any movement or motion during the test can cause large noises and artifacts in the signal measurement [6].

PPG signal basically consists of four points which are diastolic points, systolic points, dicrotic notch and dicrotic wave as shown in Figure 2.

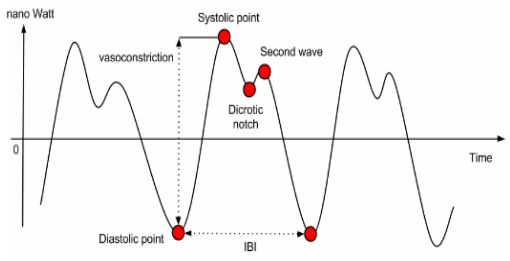

Figure 2. PPG output [7]

The diastolic and systolic points are the important mechanism in PPG signal as it can provide useful information regarding the cardiovascular system. While, the time duration between two consecutive systolic points in the signal determine the instantaneous heart rate of individual.

2.1.2. Stressor Test

The stressor test used for this study is known as the Stroop Test. The Stroop test, named after John Ridley Stroop, is a demonstration of the response time of a task and is often used to illustrate the nature of spontaneous processing versus conscious visual control [8]. It also can be used to induce the stress toward respondent. The example of Stroop test is illustrated as shown in Figure 3. The test consists of two parts which are non-conflict task (Box 1) and conflict task (Box 2).

The outcome of the tests showed that majority of respondent tends to say the colour of each word in Box 1 with less difficulty. However, majority of the respondent's brain were force to work harder and take longer time to say the colour of each word in Box 2. This struggle occurs due to semantic interference.

When the respondents look at the words in the test, they process the colour of each word along with the meaning of each word. If both stimuli (colour and definition) are corresponding or well-matched, they will react with the right answer quickly. This is the reason why majority of the respondents have rapid reaction towards word in Box 1. If there is a direct conflict between the colour and definition of the word then both stimuli are different or do not match. For this situation, a respondent has to make a decision and pay more attention to one stimulus than the other. Usually respondent are attached more significantly to the definition of words rather than the colours that are written in. Reading is spontaneous for most people. Thus, when the respondents are instructed to do the opposite and pay more attention to the colour of the word, conflict happens. They have to consciously adjust their answers as this new test is not as familiar to them as reading is. As a result, the reaction times will be longer with Box 2 as compared to Box 1.

Figure 3. Stroop Test

2.2. Related Works

In recent years, there are many researches on stress recognition based on physiological signal. The information regarding the intensity and quality of a person's internal affect experience can be provided by looking at their physiological signal. There are many methods to measure a physiological signal such as an Electrocardiogram (ECG), Electroencephalogram (EEG), Electromyogram (EMG), Blood Pressure (BP), Skin Temperature (ST) and others. However we choose PPG as our biological signal due to the low cost, low power consumption and small in size. Thus, related literatures on stress recognition are described next.

Garcia-Ceja et al. [9] propose a stress detector using mobile phones. In their study, the accelerometer is used to characterize the subjects' actions using time and frequency domain extraction. Then, in order to measure stress level, the statistical model is build. The study is tested on 30 subjects from two different organizations and the participants are provided with smartphone. From the report, it showed that they recorded their stress levels three times during working hours. Classification accuracies of 71% and 60% were obtained respectively for userspecific models and similar-users models. These results were obtained on data collected from a single accelerometer. However, this study does not focus on specific scenario such as how the person handles the phone which actually can affect the final result.

According to Munla et al. in [10], the stress level can be measured using the ECG signal based on the Heart Rate Variability (HRV). The aim of the study is to predict the stress level of the drivers and also provide a warning for safety purpose. In order to analyse the HRV, the ECG signal needs to be initially extracted and pre-processed. This analysis can be done using time, frequency, time-frequency domains or nonlinear methods such as Wavelet and Short Time Fourier Transform (STFT). The study used 16 subjects from Stress Recognition in Automobile Driver database (DRIVERDB) to perform this experiment. The result shows that 83% of

accuracy in stress detection is achieved by using Support Vector Machine with Radial Basis Function (SVM-RBF) technique. However, this study cannot classify the levels of the stress such as low, medium or high level. This method is also less practical because the electrodes of the ECG need to be in contact with the skin of the user.

Hou et al. in [11] used EEG as algorithm to monitor stress level. In order to proof this algorithm, an experiment using 9 subjects was carried out to classify four levels of stress. A Stroop colour-word test acts as the stressor in this experiment. The stress level can identified using two combining features which are fractal dimension (FD) and statistical and then classify using SVM. The result shows that the average accuracy is 67.07%, the accuracy for three levels of stress is 75.22% and for two level stress the accuracy is 85.17%. Then, the proposed algorithm is implemented in real life using the CogniMeter system for monitoring the stress level. However, this method is not convenient to use and require accurate skin preparation in order to get a good result.

Although there are many techniques that have been implemented in order to recognize stress, however, little has been said about stress recognition using the PPG signal. This type of bio-signal is more preferred because it is a low cost solution with low power consumption, easily available and simpler to use. Therefore, this study will further investigate the effectiveness of stress recognition technique using PPG signal.

3. Research Method

This section discuss on the proposed system to recognize stress based on PPG signal. In order to recognize the signal, we propose 4 steps which are signal acquisition, pre-processing, feature extraction and classification as summarizes in Figure 4.

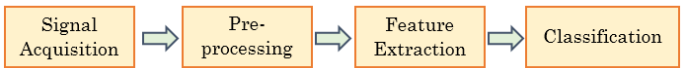

Figure 4. Proposed system for stress recognition using PPG signal

In the first step, the raw data as shown in Figure 5 will be acquired from 5 respondents using Easy Pulse hardware as illustrated in Figure 6. This process is done where the respondent undergoes two conditions which are normal and stress conditions. The PPG signal under stress condition is collected during the Stroop test. Whereas the normal PPG signal is collected before the respondent performs the Stroop test in a relax state. Then, these raw data will go through preprocessing steps which will eliminate external noise, outliers or artifacts in the PPG signal. Later, feature extraction will take place in order to extract the distinguished feature. This step will show the difference in terms of its signal between normal and stress conditions. Lastly, classification will be done using the selected algorithm to classify the data and evaluate the performance of the system.

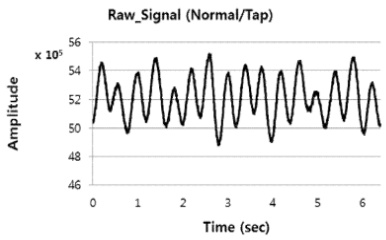

Figure 5. Raw data of PPG signal [12]

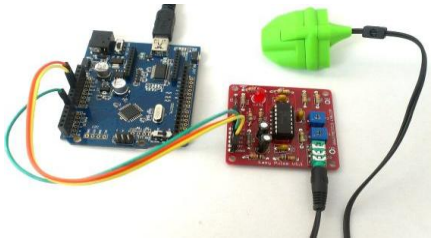

Figure 6. Easy Pulse hardware [13]

This study involved two techniques which are stimulation and analytical. For stimulation technique, it consists of collection of raw data, removing noise, extraction of distinguished

features and lastly the classification of the signal. The second technique which is analytical is used to analyze the existing methods of stress recognition and to find the suitable mechanism that can be applied to PPG signal.

4. Results and Analysis

As a preliminary study, PPG signals were taken using Easy Pulse Oximetry under normal and stress conditions. The subjects will go through a Stroop Test to record the physiological change. A total of 5 subjects which is the range of 20-29 years old were selected. All subjects will be asked to rest for 1 minute before taking their signal. After taking their signal in normal state, the subjects were instructed to do the Stroop test. At the same time, their signal were collected and recorded to observe the effect of the test to their biological signal.

In order to evaluate this study, the PPG signal were constructed in Figures 7 to 11 using MATLAB. The figures below show the graph pattern of normal and stress state of Subject 1, 2, 3, 4 and 5.

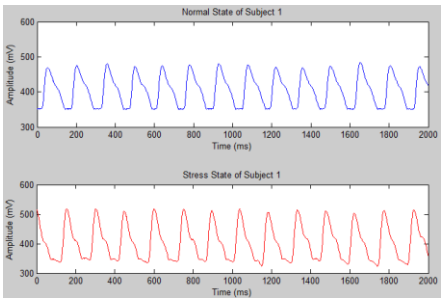

Figure 7. Normal and Stress State of Subject 1

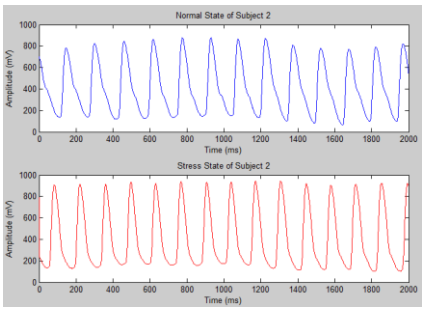

Figure 8. Normal and Stress State of Subject 2

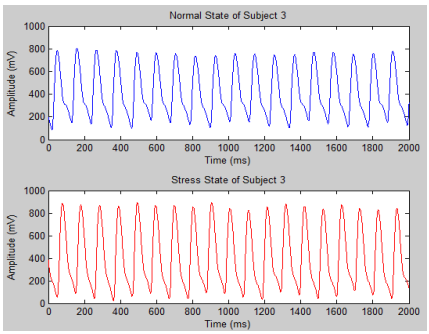

Figure 9. Normal and Stress State of Subject 3

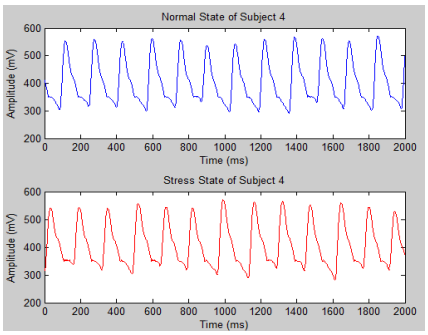

Figure 10. Normal and Stress State of Subject 4

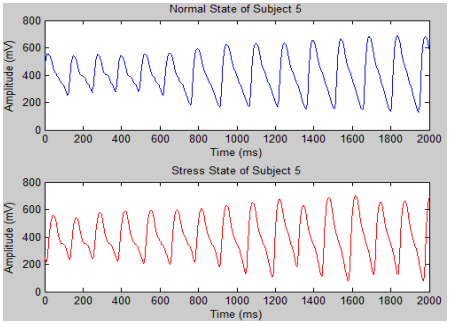

Figure 11. Normal and Stress State of Subject 5

Even though the signal pattern looks similar, the signal amplitude is not the same. The heart rate of subjects varies according to physiological changes. These data will help to us to detect the difference between normal and stress condition of the individual in our study.

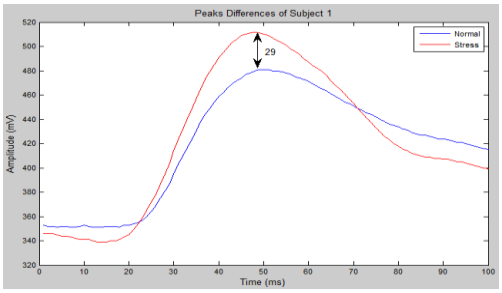

Figure 12. Peaks Difference of Subject 1

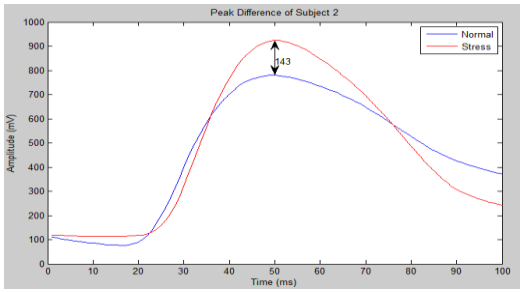

Figure 13. Peaks Difference of Subject 2

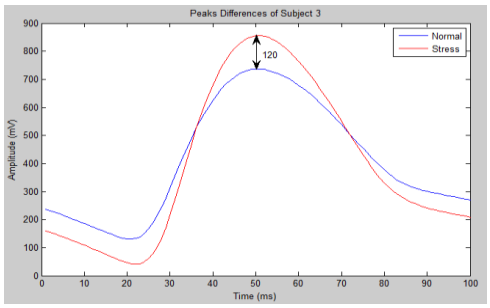

Figure 14. Peaks Difference of Subject 3

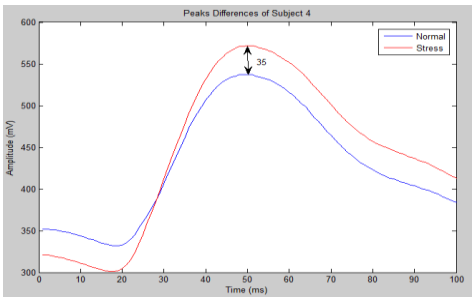

Figure 15. Peaks Difference of Subject 4

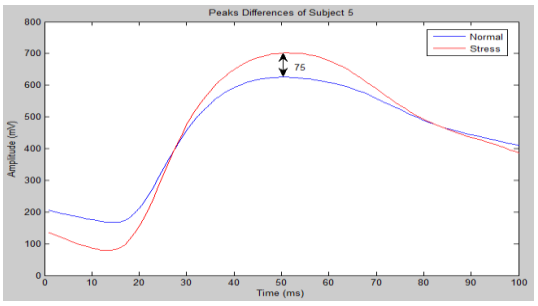

Figure 16. Peaks Difference of Subject 5

In order to gain more information, the systolic peaks of normal and stress condition were drawn in Figure 10, Figure11 and Figure 12. Based on the PPG signal seen in Figure 12 to 16, it can be seen that there are slight difference between normal and stress state. The value of systolic peak of stress signal is much higher as compared to normal state. Table 1 summarizes the difference of systolic peak between normal and stress state.

Table 1. Difference of Systolic Peak of Normal and Stress State

Subject	Stress Peak (mV)	Normal Peak (mV)	Difference of Systolic Peak* (mV)
1	510	481	29
2	923	780	143
3	856	736	120
4	572	537	35
5	701	626	75

*Difference of Systolic Peak = Stress Peak – Normal Peak

Based on the results, it shows that the pattern of the results obtained is almost the same for all 5 subjects where the systolic peak for the stress condition is much higher as compared to normal condition. Therefore, it can be assumed that the objectives of this study can be achieved by using the proposed method.

5. Conclusion

As a conclusion, the objectives of this study have been well achieved. Based on the results obtained, PPG is seen as an alternative method to recognize stress. The results show that the pattern of PPG signal for stress and normal conditions differs from each other where the systolic peak of stress signal is much higher as compared to normal signal. Thus, this result proved that PPG signal can be used to identify the stress condition of an individual.

However, there are some improvement can be made in the future. Currently, this study was conducted by using a random subject regardless their age, gender or races. In the future, this study should consider important conditions such as age and gender factors to make the study more reliable. As a proof of concept, this study was capable of detecting stress using PPG signals with the aim to consider age and gender influences. In addition, the study only considered 5 subjects where to obtain more accurate results, the number of subjects should be increase.

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