Evaluation of Human Stress
Using EEG Power Spectrum

Noor Hayatee Abdul Hamid[1,2], Norizam Sulaiman[1,3], Siti Armiza Mohd Aris [1,4], Zunairah Hj Murat[1,2],
Mohd Nasir Taib[1,2]

[1]Faculty of Electrical Engineering, Universiti Teknologi MARA, 40450 Selangor, Malaysia
[2]Nondestructive Biomedical and Pharmaceutical Research Centre, Universiti Teknologi MARA 40450 Selangor, Malaysia
[3]Faculty of Electrical Engineering & Electronic Engineering, Universiti Malaysia Pahang, 26000 Kuantan, Pahang, Malaysia
\[4]College of Electronics Engineering, Universiti Teknologi Malaysia, 40450 Selangor, Malaysia
nrhayatee@yahoo.com.my, norizam@ump.edu.my

Abstract—**This paper presents an evaluation conducted between human stress questionnaires with EEG Power Spectrum of Beta and Alpha band. Cohen's Perceived Stress Scale (PSS) was used as stress questionnaires to evaluate human stress. The EEG recording of 13 volunteers were carried out immediately after them answering the stress questionnaires. The scores from the stress questionnaires were calculated and used to figure out its relationship with the ratio of EEG Beta and Alpha band power. The results of the study showed the PSS was negatively correlated with the ratio of EEG Power Spectrum. Besides, the study suggested that it was feasible to use PSS and the ratio of EEG Power Spectrum to determine human stress.**

Keywords- Human stress, stress questionnaires; PSS, EEG Power Spectrum

I. INTRODUCTION

Stress is a physical and psychological response to perceived demands and pressures from without and from within. It can be defined as a stimulus or experience that produces a negative emotional reaction or affect, including fear and a sense of loss of control. According to Reisman, stress is a body's reaction with the release of *Cortisol* (stress hormone) due to physical, mental or emotional pressure [1]. Recently, the number of stress victims is growing at an alarming rate with millions of people on stress relief medication [2]. As a result, there is much loss of work time and increasing medical expenses with huge financial losses for individuals as well as for companies.

Stress is not only dependent on the external pressure such as long working hours, many dead lines or a job shift. Most important is it how the persons cope up with stress and the brain responds to it. Stress occurs when a person fails to adapt successfully to changes in the environment that confront him or her with new challenges. Most stress have occurred when we resist mentally or emotionally [2]. Regardless of type of stress, brain's natural response will be indicated by a change in power of brainwaves frequency components [2]. Fatigue, depression, burnout, low job satisfaction, and heart disease are a few of many health consequences of chronic stress. Individuals in high stress occupations, such as law enforcement officers and critical care nurses, need effective methods of coping with stress [3]. It was reported that the stress level of business owners in Malaysia had increased to 65% from 57% than the global average [4].

Nowadays, there are many techniques that been applied to indicate the presence of physiological stress. Recent research had found that stress and relaxation on salivary amylase activity[5]. Based on this finding, a unique tool has been used widely in diagnostic mental condition. A few study of stress had used the Cohen's Perceived Stress Scale (PSS-10) as questionnaires in the experiment to identify the level of stress in human [6]. The PSS-10 measures the degree to which situations in one's life appraised as stressful [7]. Besides, there is significant relationship between PSS-10 with anxiety and depression [8]. The items on the scale asked about the perceived stress felt within the last month and are rated according to a 5-point frequency scale (0 = "never" to 4 = "very often"). This scale was chosen because it has been empirically established and was easy to administer. Furthermore, the PSS-10 was validated in research establishing a link between perceived stress and coronary artery disease [9], predicting negative health outcomes, susceptibility to viral infections [10], and prolonged mood responses [11].

Brainwaves have several rhythmic frequencies that are influenced by physical and emotional states [11]. It can be measured by the device called Electroencephalogram (EEG) which measure the neural electrical activity of the brain recorded using EEG electrodes on the scalp [12, 13]. The recorded signals can be categorized into 4 frequency bands; Delta band (0.5 – 3 Hz), Theta band (4 - 7 Hz), Alpha band (8 – 13 Hz) and Beta band (13 – 30 Hz) [12, 13]. The amplitude of EEG signals is ranging from 2 microvolt to 100 microvolt. The EEG data above 100 microvolt can be considered as the addition of noises or artifacts such as eye movement, power line noise and electrode noise which need to be filtered out to obtain useful EEG data [13].

Stress due to tension, anxiety and excitement had high power of Beta band [14]. An increase of Alpha band power will reflect to relax and conscious conditions. Meanwhile, decrease of Alpha band power and increase of Beta band power will indicate that the persons are doing intense activity such as answering examination questions, doing mental arithmetic and so on [15]. Researcher had come out with the ratio of EEG Power Spectrum in term of Alpha and Beta band power on right hemisphere of human brain with left hemisphere of human brain to determine the brain balancing (symmetrical) where the asymmetrical in brain activity may indicate to some chronic health disease such as depression,

mental fatigue, and so on. The ratio is called FBA (Frontal Brain Asymmetry) [15].

The aim of this paper is to determine the correlation between PSS-10 scores with the ratio of EEG Power Spectrum in term of Alpha band power and Beta band power.

II. METHODOLOGY

The block diagram of the study is shown in Fig. 1. In this study, 13 healthy subjects (8 Males and 5 Females) with age ranging from 23 to 39 were voluntarily involved where their EEG data were recorded according to the experiment protocol. Data from one subject was discarded due to corrupted data. Thus data from 12 subjects were analyzed. Prior to the experiment, their consent were obtained by filling the consent form. Besides, participants needed to fill-in their demographic data and then answered the stress questionnaires before their EEG signals were captured for duration of 5 minutes. The EEG signals were captured by using EEG Data Acquisition instruments where the EEG electrodes were placed at Frontal area of human brain (Fp1 and Fp2) as shown in Fig. 2. The sampling frequency is set at 128 Hz. The EEG data then was analyzed in off-line manner. The intelligent signal processing techniques were developed in *MATLAB* to calculate the Alpha and Beta-band power of both right and left hemisphere of human brain in term of Power Spectral Density (PSD). Then, the ratio of PSD from both sides of brain hemisphere was calculated. The ratio then was compared with the scores obtained from stress questionnaires. The artifacts are removed by applying threshold value into the signal analysis program. The results obtained from the PSD are analyzed in term of power band ratio to see any pattern for human stress.
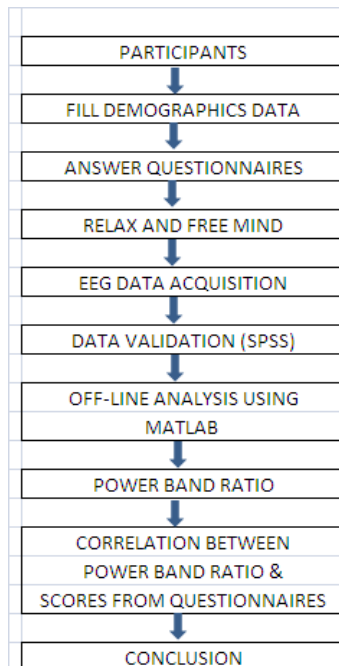

Fig. 1 Research Methodology

The EEG Power Spectrum for Alpha and Beta band was calculated using equation 1 and 2 as stated below.

$$\text{Ratio of Alpha power : } r_\alpha = \frac{\alpha_R - \alpha_L}{\alpha_R + \alpha_L} \qquad (1)$$

$$\text{Ratio of Beta power : } r_\beta = \frac{\beta_R - \beta_L}{\beta_R + \beta_L} \qquad (2)$$

Electrodes placement at point Fp1 and Fp2   EEG Data Acquisition   EEG Signal Processing

Fig. 2 EEG Measurement Set-up

III. RESULTS

The stress scores are shown in Table 1. According to Table 1, there are two subjects who scored higher than others which give negative PSD ratio for both Alpha and Beta band. However, PSD ratio falls on the positive region for both Alpha and Beta band from one subject who scored lower than others. Fig.3 shows the histogram plot of the PSD ratio of Alpha and Beta band. There are five subjects in the negative region that indicate high stress and the rest of subjects in the positive region that point to low stress. The correlation graphs which show the linear regression line between PSS scores and EEG Power Spectrum are shown in Fig.4 and Fig.5. The PSS Score give a negative linear relationship between Alpha and Beta power ratio. The correlation results from SPSS are shown in Table 1. From the correlation results, r values are negative since the linear relationship between the stress scores and PSD ratio is negative. The p value for Alpha and Beta power is 0.296 and 0.141 respectively which are greater than 0.05. This might due to the large variation in the data collection. However, there is a trend in data collection as shown in Fig.3 and the linear regression line as shown in Fig.4 and Fig.5.

Table 1: Stress Scores, Alpha and Beta Power Ratio

Subjects	Scores	PSD Ratio (Beta Band)	PSD Ratio (Alpha Band)
1	10	0.5873	0.3927
2	13	0.4619	0.4891
3	13	0.8975	0.9509
4	15	-0.3630	-0.1913
5	14	-0.5805	-0.6227
6	12	0.4619	0.4891
7	14	0.1975	0.3985
8	11	0.3137	0.1005
9	11	-0.0679	-0.0774
10	13	-0.0877	-0.1786
11	13	0.7456	0.6977
12	15	-0.0724	-0.3618

Table 2: SPSS Results

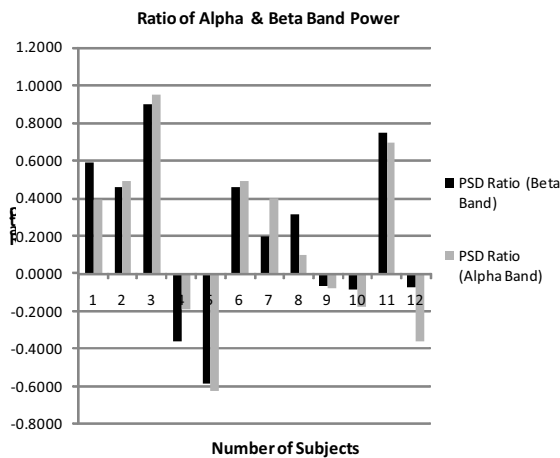| Band	r	r²	F	Sig
Alpha	-0.329	0.109	1.218	0.296
Beta	-0.451	0.204	2.556	0.141

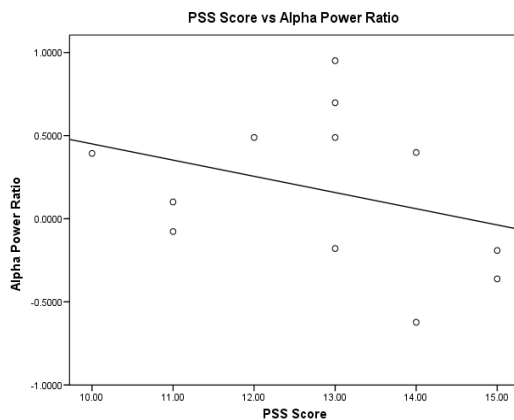Fig. 3 PSD ratio for Alpha and Beta band

Fig. 4 Correlation results between PSS Score and Alpha Power Ratio
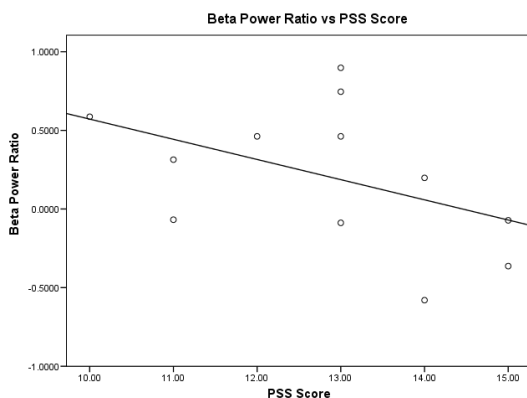

Fig. 5 Correlation results between PSS Score and Beta Power Ratio

IV. ANALYSIS OF DATA

Based on the plot of Power ratio for all subjects, it indicates that the participants who obtained high stress scores will have negative PSD ratio and vice versa. Besides, the plot from SPSS shows that there are negative correlation between Alpha and Beta power versus PSS Score. Even though the correlation coefficient and significant value from SPSS results are not convincing, there are significant trend shown by the graph of PSD ratio versus PSS scores.

V. CONCLUSIONS

From the results of the experiment, there is a negative linear relationship between the scores and power ratio of Beta and Alpha band. When the subjects obtained high score of PSS, the subject might obtain negative ratio. Meanwhile, when the subjects obtained low score of PSS-10, the subject might obtain positive ratio of Beta and Alpha power. Thus, it can be concluded that, there is negative correlation between Stress Scores with the ratio of EEG Power Spectrum. The PSS can be used to determine the level of human stress. The future experiment will cover bigger subjects hence improve correlation coefficient in order to provide a firm relationship between PSS-10 scores and EEG Power Spectrum. Thus, this might lead to a clearer direction in searching for the human stress pattern or level using EEG signals.

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