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THE EFFECT OF ALPHA BINAURAL BEAT ON FRONTAL ESD ALPHA ASYMMETRY ON DIFFERENT GENDER

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ABSTRACT

This paper describes the study of the effect of Binaural Beats tone on Alpha and Beta sub bands of different gender in three situations namely Doing Nothing, Listen to Noise and Post Binaural Beats. Binaural beats has been renowned worldwide for its ability to entrain our brainwaves into desired state i.e. relax state. In this research, the frequency of the Binaural Beats tone used is Alpha 9 Hz and the EEG feature, Energy Spectral Density (ESD) is utilized. ESD provides information on distribution of energy of an energy signal per unit bandwidth as a function of frequency. ESD is derived from the power spectral density or PSD. The ESD feature is used to compute the Frontal ESD Alpha Asymmetry. Hence, the ESD pattern is observed in both genders in the three said conditions. 39 subjects consists of 17 males and 22 females involved in the research. From Shapiro-Wilk Normality Test, the box plot showed that females are easier to be effected by the noise with the percentage decrement in the Frontal ESD Alpha Asymmetry value is 4.2% as compared to only 1.9% in male. However, emotionally, female shows that they are easier to be alleviated from stress as the percentage of Frontal ESD Alpha Asymmetry value increases 6.5% as compared to male 4.7%.

Keywords: frontal asymmetry, binaural beat, eeg, emotion, stress, ESD, FFT, box plot, male, female.

INTRODUCTION

For more than 35 years, researches on the alpha frontal asymmetry have been embarked and linked to emotion, behaviour and psychopathology. How was it supposed to be? Numerous electroencephalographic (EEG) studies have shown that there is a connection between hemispheric asymmetry in frontal regions of the cortex and depressive indications. Even though it is not always, naturally at rest in depression, there were reduced left frontal and/or increased right frontal activity [1]. Expression of positive emotions or approach motivation have been corresponded to the activation of the left hemisphere while expression of negative emotions or withdrawal motivation have been associated to the activation of the right hemisphere [2] .

This paper focuses on the effect of Frontal ESD Alpha Asymmetry on different gender when they are in three different conditions, i) Doing Nothing, ii) Listening To Noise (Stress Induced) iii) Post Binaural Beat (Stress Alleviated). Frontal alpha asymmetry is highly associated with emotion [3-5], however there was not many research done on frontal asymmetry and its relation with gender.

The main objective of this research is to investigate and distinguish the pattern of the Frontal ESD Alpha Asymmetry on different genders in three different conditions as mentioned earlier. The stress inducer used in this study is the sound of traffic noise [6, 7]. Such noise is believed able to induce stress in our daily routine as we franticly go through our fast paced life. For the stress alleviation part, we utilize binaural beats tone as a mean to stimulate relaxation in the subjects as an alternative method to meditation [8, 9].

We would like to observe if there are any changes on Frontal ESD Alpha Asymmetry of both genders during the three different conditions and if there is any difference between them. We would also like to observe between these two genders, who are more emotionally stable when come to stress situation and who are easier to be entrained to be calmer.

MATERIALS AND METHODS

Subjects

A total of 39 right handed and healthy subjects comprising of 17 males and 22 females were involved in this study. All of them are free from any centrally acting medication and negative history of any psychiatric and neurological disorders.

EEG

EMOTIV EPOC, as shown in Figure-1 below is a wireless EEG equipment that consists of 14 channels and followed the International 10/20 System of Electrode Placement was utilized. However, only eight electrodes located on the frontal part were being elected for the analysis. They were AF3, AF4, F3, F4, F7, F8, FC5 and FC6, in which each four of them represent each hemisphere. The selection of these electrodes is due to the fact that the frontal part of the brain is involve in the process related to emotion as shown in several studies [10, 11]. The sampling frequency for this equipment is 128 Hz.

Figure-1. The EMOTIV equipment used which is connected to the lap top wirelessly.

PROCEDURE

In order for the subjects to be acclimatized to the EEG recording session, they attended a laboratory session to get some briefings on the procedure they will go through and also to complete and sign the consent form. Beforehand, they were reminded not to consume any drug, alcohol and caffeine before having their EEG reading recorded. The caffeine is believed to have the ability in increasing the level of attentiveness and to constrain tiredness [12]. Nevertheless, the subjects were allowed to leave the experiment whenever they felt uneasy. The summary of the experiment procedure is shown in the Figure-2 below.

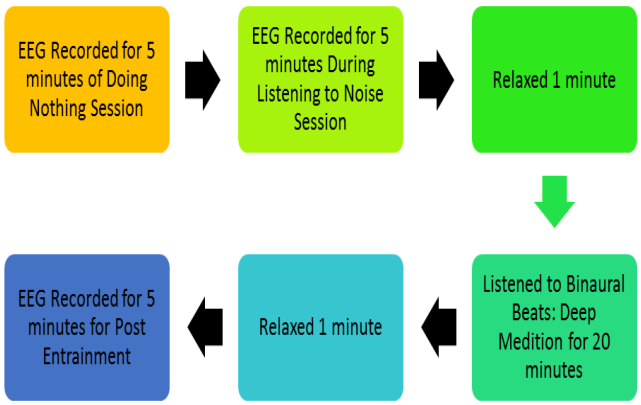

Figure-2. The procedure of EEG recording.

There were three sessions of EEG signal being recorded. They were: a) Doing nothing (relax), b) Listened to noise (stress), c) After listened to binaural beat (brainwave entrainment to mediate calmness).

The sound of traffic noise had been chosen to stimulate stress in the subjects due to the fact that many people are not only infuriated by this noise, but have further psychological disturbances such as headache, nervousness, fatigue, feeling depression and difficulties in falling asleep [7, 13]. The traffic sound was generated by the laptop with the volume of the sound being regulated for each subject.

Once the stress was induced, the subject's brain would then be entrained for 20 minutes by listening to binaural beats deep meditation pre-set tone. Brainwave generator software, installed on the laptop has been used to produce the binaural beats tone, which had also been applied by other researchers [14, 15]. Estimating the effect of brainwave entrainment could persist even after the session, we took the EEG recording for five minutes after the entrainment session.

EEG SIGNAL PROCESSING

Figure-3 shows the sequence of steps taken in processing the recorded EEG signals. The process was computed offline using MATLAB version 2010A. The raw EEG data are always contaminated. These contaminations or signals distortions could be resulted from either technical (environmental) and/or patient-related (biological) [16, 17]. Technical artefacts are produced by AC power line noise like 50/60 Hz, impedance fluctuation, cable movements, broken wire, low battery and electrode connection [16]. Patient-related artefacts are like any minor body movements, EMG, ECG, eye movements and sweating [16]. If these artefacts are not eliminated, useful information from the data could not be extracted easily which resulted in misleading results for analysis. Then the EEG signals are filtered segregating the signals to four sub band utilizing band pass filter and Hamming Window[18, 19]. The four brainwaves sub bands are delta, theta, alpha and beta.

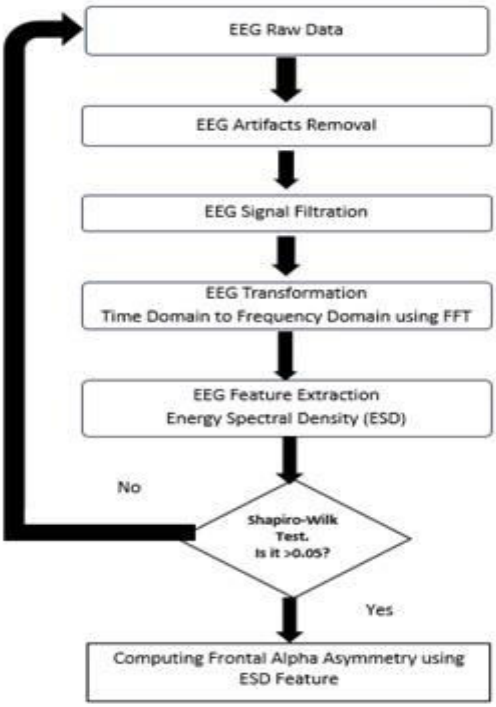

Figure-3. The flow of the EEG signals processing.

The raw EEG signal is in time domain and the distribution of the energy is dispersed. Features buried in the signal can be extracted and analysed if the energy of the signals described in either time or/and frequency domain. However, many researches done before found out that frequency domain is one of the best method to investigate mental task based on EEG signals [20, 21]. The said method is Fast Fourier Transform or FFT, in which the power spectrum is computed by applying the discrete FFT to the signals.

$$X(f) = \int_{-\infty}^{\infty} x(t) e^{-i2\pi f t} \, dt \tag{1}$$

for $-\infty < f < \infty$, $-\infty < t < \infty$, and $i = \sqrt{-1}$.

$$X(j) = \frac{1}{N} \sum_{k=0}^{N-1} x(k) e^{-i2\pi jk/N} \tag{2}$$

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for $j = 0,1,\ldots,N-1$; $k = 0,1,\ldots,N-1$. Both $X(j)$ and $x(k)$ are in complex series. $x(k)$ represents the input signal in the time domain, N is the length of input vector while k is the sampling instances in time domain.

$$E_x = \int_{-\infty}^{\infty} |X(f)|^2 df \quad (3)$$

Eqn. (1) above depicts the Fourier Transform for continuous signal for frequency-domain function. Fast Fourier Transform (FFT) is an upgrade version of Discrete Fourier Transform (DFT) where the task can be computed in a shorter period of time but with the same outcome [22]. Power spectrum density, PSD is derived using Eqn. (2) above.

The energy spectral density or ESD is derived from the non-parametric power spectral density or PSD. ESD provides information on distribution of energy of an energy signal per unit bandwidth as a function of frequency. The unit of ESD is Joules/Hz. In other words, the ESD can also be obtained by calculating the area of the PSD curve. The derivation process is done by implementing FFT technique. The formula for ESD for an energy signal x(t) is given by Eqn. (3) above where X(f) is the Fourier Transform of x(t). The task given can be carried out fast and efficiently by using MATLAB software where MATLAB has built in function to calculate FFT.

FRONTAL ESD ALPHA ASYMMETRY

The ESD Alpha of four electrodes on the left hemisphere, namely AF3, F3, F7 and FC5 are averaged. The same process is done for four electrodes on the right hemisphere that are AF4, F4, F8 and FC6. These values are representing Left Frontal ESD and Right Frontal ESD respectively. Applying Eqn. (4) below, the Frontal ESD Alpha Asymmetry is obtained[4].

$$\text{Frontal ESD Alpha Asymmetry} = \text{natural log}(ESD_{Right}) - \text{natural log}(ESD_{Left}) \quad (4)$$

STATISTICAL ANALYSIS

In this experiment, the analysis of the experiment is partly done using Shapiro-Wilk Normality Test using SPSS statistical version 20.0. Shapiro-Wilk is opted in this study because it has been shown that Shapiro-Wilk is the most powerful normality test outperform Anderon-Darling test,Lilliefor test and Kolmogorov_Smirnov test [23].

RESULTS AND DISCUSSIONS

This section presents the results obtained from the experiments done.

GENDER

There are 17 males and 22 females involved in this study. Overall, we would like to observe the general trend of frontal alpha asymmetry in three sessions in both genders. This can be observed in Figure-4 and Figure-5 respectively. It seems that in both genders, their level of frontal alpha asymmetry fluctuate in the range from 0 to 0.5 except for male. In Figure-4, the level of frontal alpha asymmetry attained by subject number 11 was visibly above 0.75. Meanwhile, in Figure-5 that shows analysis on female subjects, the dotted line which denotes the listening to noise session, in subject number 22 was way below -0.5.

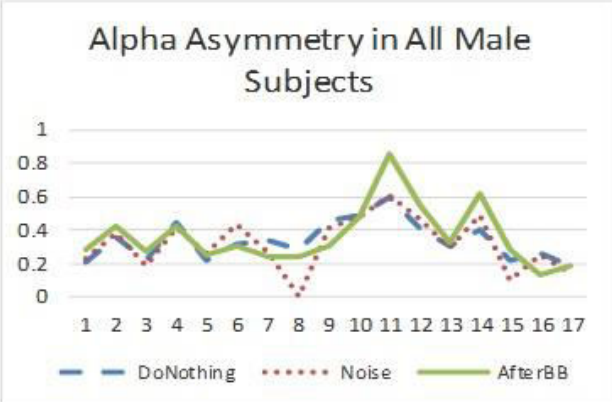

Figure-4. The Alpha Asymmetry of all male subjects in three sessions.

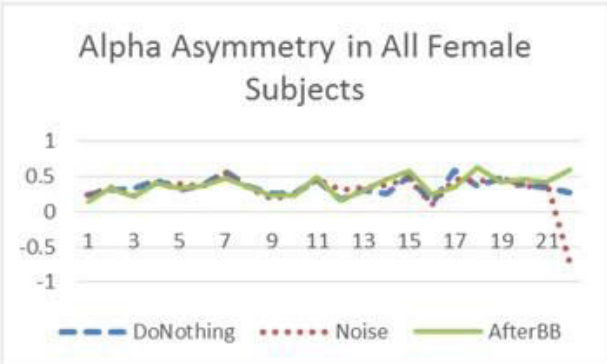

Figure-5. The Alpha Asymmetry of all female subjects in three sessions.

Summarizing these two figures for separate genders, Figure-6 and Figure-7 demonstrate the pattern of the frontal alpha asymmetry in subject male and female respectively during three sessions. Noticeably, frontal alpha asymmetry level decreased in both genders during listening to the noise session for five minutes and increased after listening to the binaural beats Alpha frequency for 20 minutes. These pattern is analogous with previous researches done where greater relative right frontal is activated during negative emotion (listening to noise) and greater relative left frontal is activated during positive emotion (after listening to binaural beats tone) [2, 24-26]. These were resulted from the phenomenon of two conditions. First, the right hemisphere which correspond to negative thinking was elevated causing the energy spectrum density of alpha in right hemisphere to decrease and second, the left hemisphere which correspond to positive thinking was elevated eliciting the energy

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spectrum density of alpha in left hemisphere to decrease[1, 2, 27] .

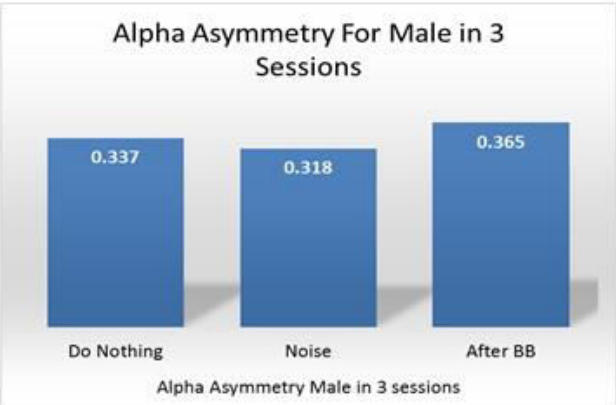

Figure-6. The average of Alpha Asymmetry for male in three sessions.

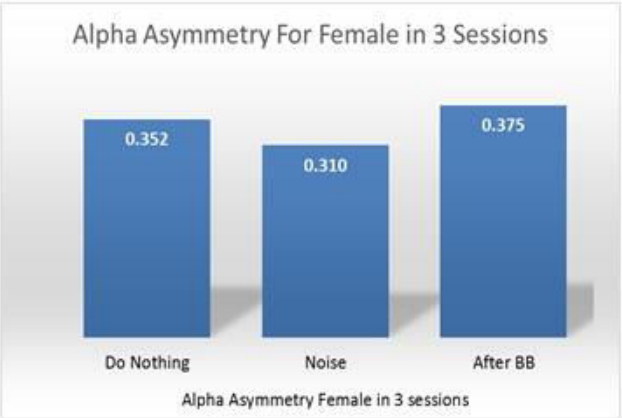

Figure-7. The average of Alpha Asymmetry for female in three sessions.

STATISTICAL ANALYSIS

The significance of the data is observed from the Shapiro_Wilk normality test. This is to indicate whether the data is normally distributed hence determines the hypothesis to be rejected or not. From Shapiro-Wilk normality test, the box plot is analysed in order to perceive the pattern of the data during three sessions in both genders. Box plot, a graphical method is considered as one of the easiest way and most common means to check for normality of the data [23].

The data is normally distributed if the significant value is above 0.05. As the significant value approaching 1, the data is indicated to be normal [23]. Table-1 and Table-2 above show the result of Shapiro-Wilk normality test in both genders during three sessions. For male group, the data is normally distributed in both doing nothing and listen to noise sessions. However, the data of session after listening to binaural beats attains 0.03, which is less than 0.05. In female, both doing nothing and after listen to binaural beat tone sessions acquire significant value above 0.05 which are 0.72 and 0.788 respectively.

Table-1. The results of Shapiro-Wilk Normality Test for male in three sessions.

3 Sessions	Shapiro-Wilk		
			sig.
Doing Nothing	0.938	7	.292
Listen Noise	0.976	7	.913
After Binaural Beats	0.878	7	.030

Table-2. The results of Shapiro-Wilk Normality Test for female in three sessions.

3 Sessions	Shapiro-Wilk		
			sig.
Doing Nothing	0.970	2	.720
Listen Noise	0.628	2	.000
After Binaural Beats	0.973	2	.788

Figure-8 and Figure-9 below illustrate the box plot of gender male and female respectively during three sessions. In both figures, the line in the box shows the median value of the data. There is one outlier appear in the box plot for male during session after listening to the binaural beat tone as observed in Figure-8. This condition has effected the result of significant value for normality test during that session in male. The same goes with the listen to noise session in female as seen in Figure-9 where we can observe the emergence of one extreme outlier. This has resulted in the significant value to be 0.00.

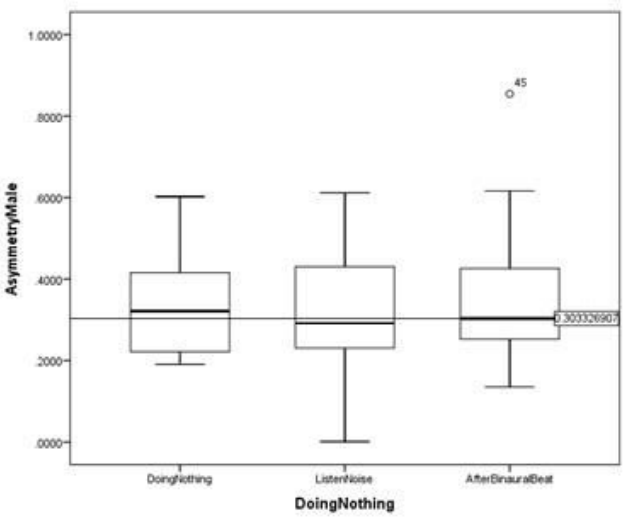

Figure-8. The box plot of alpha asymmetry for male subjects in three sessions.

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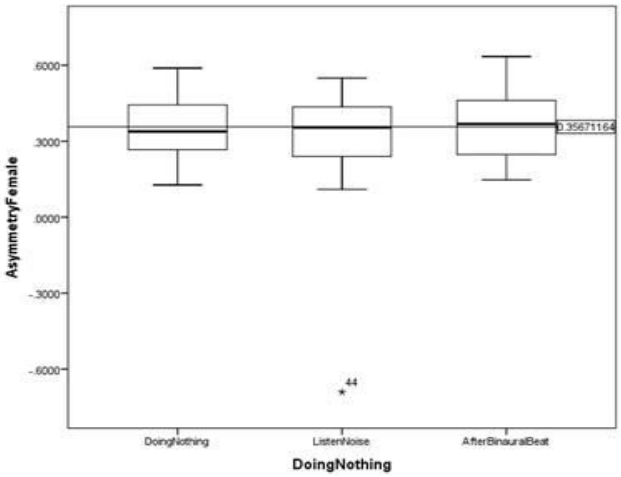

Figure-9. The box plot of alpha asymmetry for female subjects in three sessions.

SESSIONS

The analysis is resumed for both genders in segregated session. The rationale of doing this is to have better perspective on how affective the three sessions had on the frontal asymmetry of both genders. Figure-10, Figure-11 and Figure-12 show the average of the frontal alpha asymmetry between two genders in three different sessions. In doing nothing (relax condition) (see figure 10), the level of frontal asymmetry for female is higher as compared to male. It shows that female is more relax than male at that particular moment.

Figure-11 shows the frontal alpha asymmetry in both genders during listening to noise session. The noise gave more negative impact on female as compared to male. The frontal alpha asymmetry level in female decreased by 4.2% as compared to 1.9% only in male. On the other hand, in Figure-12, it appears that after listening to the binaural beats tone, the level of frontal alpha asymmetry for female increased by 6.5% as compared to 4.7% in male. This shows that female obtain more positive impact as compared to male. The percentage of decrement and increment as mentioned above can be referred in Table-3 below.

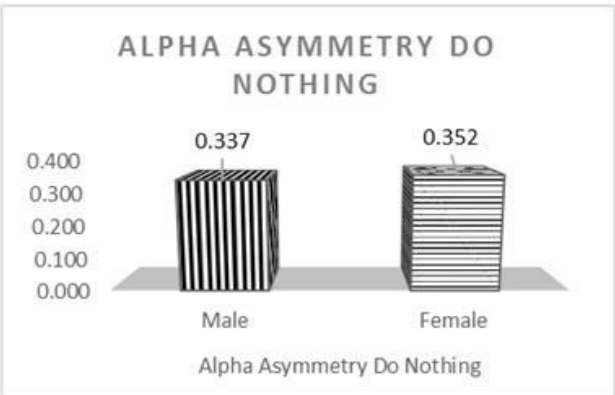

Figure-10. Session doing nothing in both gender.

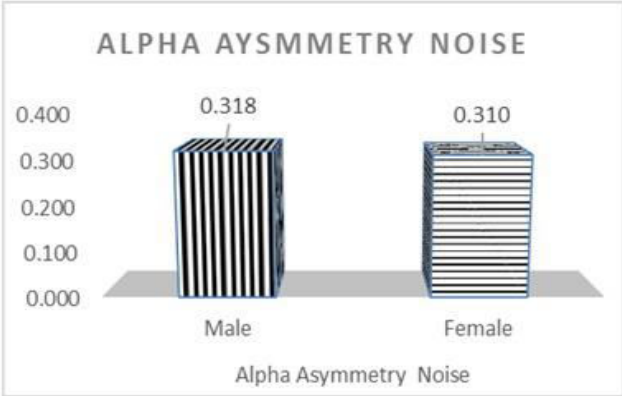

Figure-11. Session listen noise in both gender.

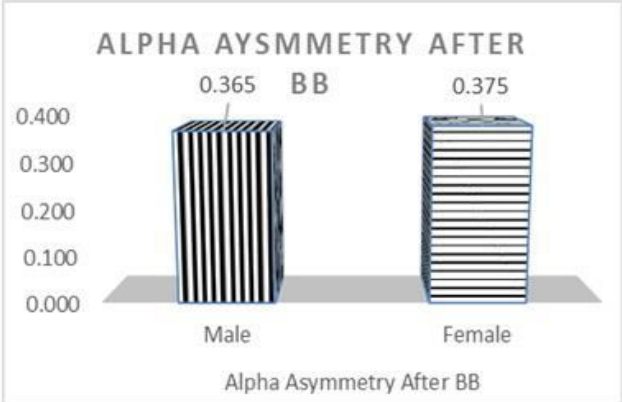

Figure-12. Session after listening to Binaural Beats in both gender.

Table-3. Percentage of changes for Alpha Asymmetry level for both genders in different sessions.

Session	Male		Female	
Do Nothing to Listen Noise	1.9%	↓	4.2%	↓
Listen Noise to Binaural Beats	4.7%	↑	6.5%	↑

CONCLUSIONS

In our work, Binaural Beats tone is capable to entrain our brain from stress to relax condition. The ESD feature, which is computed from PSD and later applied in computing the Frontal ESD Alpha Asymmetry is proficient to demonstrate the changes in emotion in both male and female genders. Box plot from Shapiro-Wilk Normality Test was utilized to validate these patterns. Male is emotionally more stable as compared to female when comes to stress because they are not easily effected by noise (stress). However, females are easier to be entrained with calmness as compared to male.

Future work will include classification of different profiles for different session.

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