VOLUME 12 NO.2
DECEMBER 2015
ISSN 1675-7017

SOCIAL and MANAGEMENT RESEARCH JOURNAL

Institute of Research Management Innovation (IRMI)

SOCIAL AND MANAGEMENT RESEARCH JOURNAL

Social and Management Research Journal is jointly published by Institute of Research Management Innovation (IRMI) and UiTM Press, Universiti Teknologi MARA, 40450 Shah Alam, Selangor, Malaysia.

SOCIAL and MANAGEMENT RESEARCH JOURNAL

Institute of Research Management Innovation (IRMI)

Vol. 12 No. 2 December 2015 ISSN 1675-7017

The Effect of Listening to Binaural Beats on Frontal EEG Alpha and Beta of Males and Females

Norhazman H., Mohamad Zaini N., Tain M. N., Kama Azura Othman, Jailani R., Omar H. A.

Faculty of Electrical Engineering, Universiti Teknologi MARA, 40450 Shah Alam, Selangor, Malaysia
E-mail: haryanti7076@gmail.com

ABSTRACT

Healthy brain is important in making sure that our lives are run properly. In most cases, normal and emotionally stable persons can think wisely and most of the time they are able to execute proper strategy in any problem solving. Listening to the Binaural Beats tone is one of the methods to distress. The effects of the Binaural Beats tone on male and female were observed on Alpha and Beta sub bands in both hemispheres. 40 subjects were involved in EEG data collection of sessions before and after listening to the binaural beats. The frequency of the beats used in this research is Alpha frequency of 9 Hz. The Energy Spectral Density feature (ESD) for both left and right hemispheres were used. Graphical analysis observing the box plot from the Normality Test shows that in session before, females have higher alpha level in both hemispheres as compared to males. Females have lower beta level in both hemispheres as compared to males. In session after listening to the binaural beats, both males and females have better decrement in beta levels in both hemispheres. Decrement in Beta sub bands also indicates that the subjects are getting more relaxed. The results indicate that male's brain is easier to be entrained. During listening to noise, female group shows that they are easily affected by noise as compared to males.

Keywords: *Binaural Beats, EEG, ESD, female and male.*

INTRODUCTION

Humans differ from each other not only on how we handle pressure or stress, but every one of us is also different with regards to our susceptibility or trigger to stress. Some of us can easily be affected by distractions, e.g. a person can get stress only by hearing little noises around him/her. There are also people who are calmer and less susceptible to stress.

In this context, this paper focuses on studying the differences between men and women when they are in closed eye relaxed condition, induced with stress and entrained with audio alpha frequency. When a person experiences stress, some changes occur to their brainwaves that can be measured from his /her EEG signals. This provides a platform where EEG reading will be taken and analyzed, particularly to identify and distinguish the brainwave patterns between men and women in different circumstances related to stress.

Usually, normal and emotionally stable person can think wisely and they are able to execute proper strategy in problem solving. However, due to stressful life events, some of us are not able to lead a healthy and positive life due to stress. There are many ways to distress ourselves and one of the ways is by listening to binaural beat. Binaural Beats is one of the technique under brainwave entrainment (Huang & Charyton, 2008; Yamsa-ard & Wongsawat, 2014).

The main objective of this research is to study and identify the different patterns of frontal alpha and beta EEG waves of men and women in three different states i) pre-stress state, ii) state of induced stress and iii) state of stress-alleviation. For the stress alleviation state, we employ binaural-beats brainwave entrainment as a method to alleviate stress, which is an alternative to meditation (Yamsa-ard & Wongsawat, 2014).

From this work, we expect to understand more on the patterns of frontal alpha and beta waves of men and women and their relations to stress. And from the analysis of data, we expect to learn and may conclude on the following questions:

- Between males and females, who are easily distracted and more susceptible to stress?

- Between men and women, who can be easily alleviated from stress?

We have an initial assumption that both of these groups should have different EEG patterns due to their different gender and thus different mental conditions. Two EEG bands which are fast brainwaves will be observed during the experiment for analysis that are Alpha and Beta sub bands. These two EEG sub bands are focused upon since they are seen as ones that actively react to emotional activities, e.g. stress and depression (Tabacaru, 2013; Knott *et. al.*, 2001; Tortella-Feliu *et. al.*, 2014). EEG readings will be read only from the frontal brain, which is normally associated with human emotions ((Tabacaru, 2013; Tortella-Feliu *et. al.*, 2014; Thibodeau *et. al.*, 2006; Davidson & Fox, 1982).

METHODOLOGY

Based on the objective of this study, an experimental procedure was designed for EEG data collection from both men and women subjects. EEG data collected from this experiment will be processed and analyzed especially to study and identify the different EEG patterns of men and women when they are in three different states related to stress as defined earlier. Besides, the EEG readings between men and women will also be compared to identify the differences between genders.

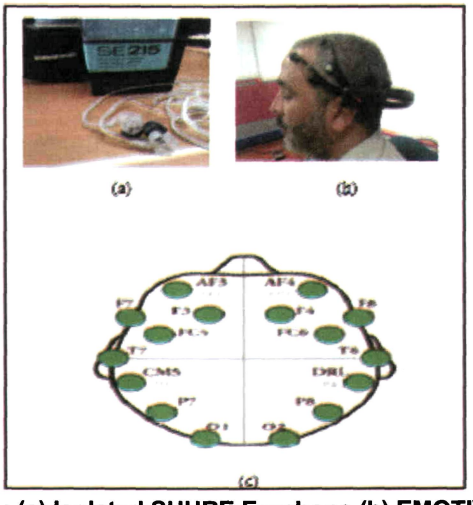

Figure 1: (a) Isolated SHURE Earphone (b) EMOTIV EPOC (c) Location of the 14 electrodes

Source: http://emotiv.com/product-specs/Emotiv%20EPOC%20Specifications%202014.pdf

Figure 2: The procedure taken during EEG recording

SUBJECTS AND DATA ACQUISITION

There were 40 subjects voluntarily involved in this study comprising 18 males and 22 females. All of them are right handed and have no history of mental illnesses. A day before the experiment was conducted the subjects were reminded not to consume any product which contains caffeine. This is due to the fact that caffeine has the ability to increase the level of alertness and to inhibit exhaustion (Smith, 2002). They were also free from any medications. All the subjects were requested to sign consent forms and completed the DASS (Depress, Anxiety and Stress) questionnaire prior to the experiment. The subjects were allowed to leave the experiment if they ever felt uncomfortable. The experiment which included the EEG recording was conducted in a dimly lit and air-conditioned room. The subjects sat

on comfortable chairs. They put on a sleeping mask to reduce distress on their eyes while being closed for quite sometime. An isolated earphone was used to listen to the noise and binaural beat tones. This type of earphone was used because it could obstruct the noise from the surrounding and also promote a good quality of sound of binaural beat tones.

The EEG recording was done using EMOTIV EPOC which has 14 channels connected to a laptop. The 14 electrodes are AF3, AF4, F3, F4, F7, F8, FC5, FC6, P3 (CMS), P4 (DRL), P7, P8, T7, T8, O1 and O2. P3 and P4 are the references. The location of the electrodes followed the International 10/20 System of Electrode Placement. However, in this experiment, only eight frontal electrodes were taken into analysis which are AF3, AF4, F3, F4, F7, F8, FC5 and FC6. The sampling frequency of this equipment is 128 Hz.

Figure 1 shows the EMOTIV EPOC, isolated earphone and the location of the electrodes.

PROCEDURE

Figure 2 shows the summary of the flow of the process during the experiment. The three sessions where EEG signal was recorded were; i) Doing Nothing Session, ii) Listening to Noise Session and iii) After Binaural Beat Session. In this experiment, we used noise as the stress stimulator. The sound of noise being used in the experiment is the traffic noise which is produced from the laptop with the volume being standardized. It is an annoying sound that would normally induce stress in many people (Wagner *et. al.*, 2010).

After listening to the noise, the subject is given time to listen to binaural beats audio for 20 minutes. The binaural beats tone is produced using Brainwave Generator software which is installed in the lap top. We estimated that by listening to binaural beats tone, the subject's EEG will respond positively. The EEG reading is taken only after the subject has finished listening to binaural beats. We conjectured that the effect of such audio entrainment will last not only during the entrainment session but also after the entrainment session.

Signals Pre-processing

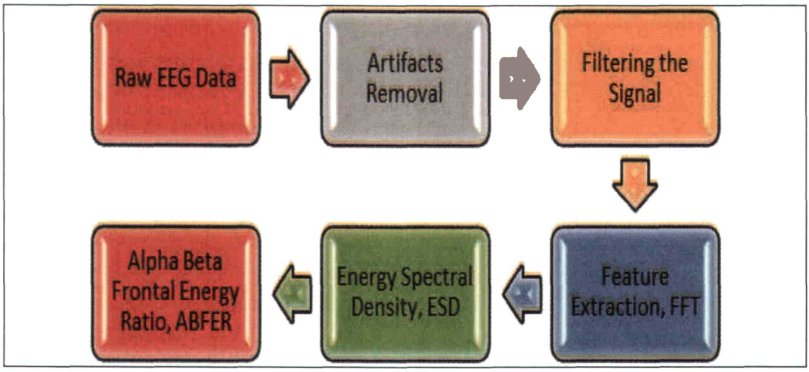

Figure 3: The steps taken in the EEG signals pre-processing

Figure 3 shows the EEG data pre-processing method. The recorded EEG raw signal will undergo these processes before it can be analyzed. The pure EEG signals are always contaminated by artifacts such as ocular artifact (Croft & Barry, 2000) and muscular movement artifacts (Achanccary & Meggiolaro, 2008). These artifacts if not removed, will corrupt the EEG data and thus it will cause difficulty in extracting useful information from the data which later on could lead to misleading results (Ferlazzo *et. al.*, 2014). Then, the signal is segregated into four sub bands by applying Hamming band pass filter.

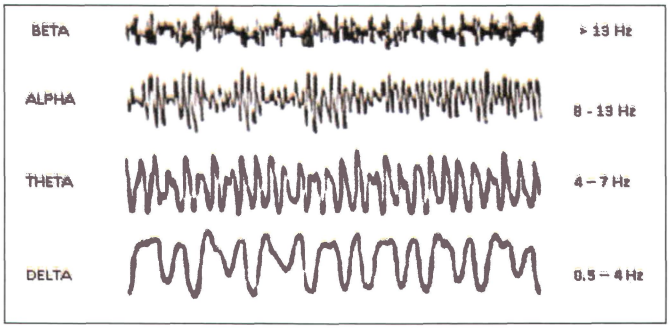

Figure 4: The four sub bands of brainwaves

Figure 4 shows the four sub bands with their range of frequencies. Delta sub band is observed to have the highest amplitude while Beta sub band has the lowest amplitude. Next, feature extraction takes place by

applying Fast Fourier Transform, FFT to the filtered signal. This process is done to extract the ESD feature on which later to be analyzed. The signal pre- processing is done using MATLAB 2010A. The ESD features from eight frontal electrodes, namely AF3, F3, F7 and FC5 correspond to the left hemisphere and AF4, F4, F8 and FC6 correspond to the right hemisphere.

Alpha Beta Frontal Energy Ratio, ABFER

The average values of four frontal electrodes on the left hemisphere and four frontal electrodes on the right hemisphere are obtained according to their sub bands. Equation 1 and 2 below shows the formula used to attain the Alpha Beta Frontal Energy Ratio, ABFER (Bos, 2006).

$$ABFER_{Alpha\ Left/Right} = \frac{ESD_{Alpha\ Left/Right}}{ESD_{Alpha\ Left/Right} + ESD_{Beta\ Left/Right}} \quad (1)$$

$$ABFER_{Beta\ Left/Right} = \frac{ESD_{Beta\ Left\ /\ Right}}{ESD_{Alpha\ Left/Right} + ESD_{Beta\ Left/Right}} \quad (2)$$

STATISTICAL ANALYSIS

In order to interpret the data correctly, we need statistical analysis. In this experiment, the statistical analysis was carried out using SPSS statistical version 20.0 for windows. The observation of the data was done based on the Shapiro-Wilk normality test. This test is applied since the number of data is less than 50 ($N<50$). The Shapiro-Wilk normality test is utilized in this study due to its proficiency outperforming Anderson-Darling test, Lillie test and Kolmogorov Smirnov test (Razali & Wah, 2011).

RESULTS AND DISCUSSION

This section presents the results obtained from the experiments collected from the three sessions on 40 samples which comprised 18 males and 22 females. Results are segregated into two parts which are male and female.

Male

There are 18 male subjects involved. The results of Shapiro-Wilk Normality Test in Table 1 are referred. It can be observed that for male gender, there are only two features have significant values above 0.05 that is 0.139 for both Alpha Left and Beta Left in session Doing nothing. The rest of the features in three sessions obtain significant values lower than 0.05. The low significant values obtained are also resulted from the existence of the two outliers as observed in the boxplot in Figure 5 and Figure 7. The outliers appear during session listen to noise.

Table 1: Results of Shapiro-Wilk Normality Test of Alpha Left, Alpha Right, Beta Left and Beta Right for male gender in three sessions

Tests of Normality				
	Male	Shapiro-Wilk		
		Stats.	df	Sig.
AlphaLeft	Doing Nothing	.922	18	.139
	Listen Noise	.888	18	.036
	After Binaural Beat	.887	18	.034
AlphaRight	Doing Nothing	.870	18	.018
	Listen Noise	.887	18	.034
	After Binaural Beat	.892	18	.042
BetaLeft	Doing Nothing	.922	18	.139
	Listen Noise	.888	18	.036
	After Binaural Beat	.887	18	.034
BetaRight	Doing Nothing	.870	18	.018
	Listen Noise	.887	18	.034
	After Binaural Beat	.892	18	.042

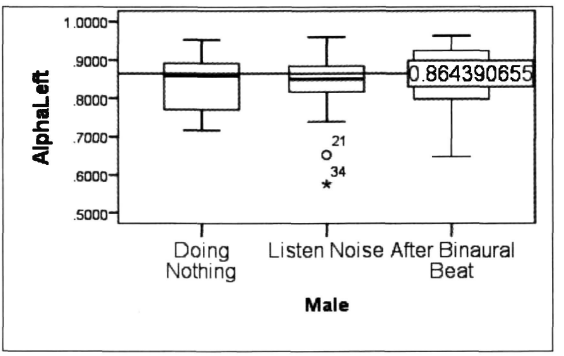

Figure 5: The box plot of Alpha Left sub band for male during three sessions

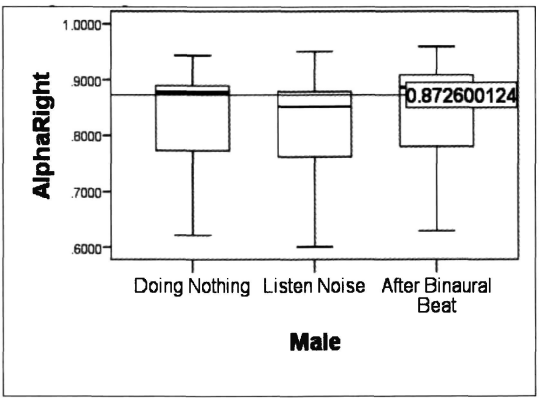

Figure 6: The box plot of Alpha Right sub band for male during three sessions

The box plot in Figures 5 and 6 shows the trend of the alpha sub bands in male during three sessions. Figure 5 shows the pattern in alpha left sub band. It can be observed during listening to noise sessions, the median value for alpha left in male decreased a bit as compared to the median of the box plot during doing nothing session. This is expected since alpha sub band will decrease when the subject is not relaxed. Also, it proves that the sound of noise used in the experiment is able to induce stress on subjects. However, after listening to the binaural beat tones, it can be seen that the median of the box plot increases. In fact, the increment is higher than the median of box plot during doing nothing session. As expected, it shows that the subjects become more relaxed after listening to the binaural beats tone. The same trend can be observed in Figure 6. The only difference is that no outliers appeared in the box plot in Figure 6.

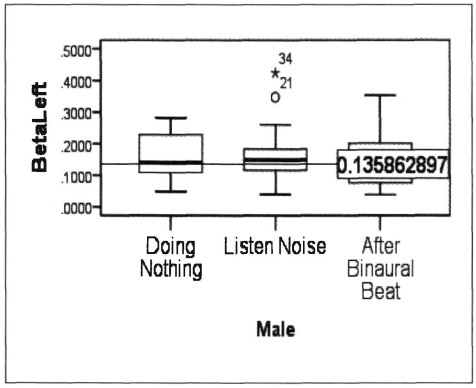

Figure 7: The box plot of Beta Left sub band for male during three sessions

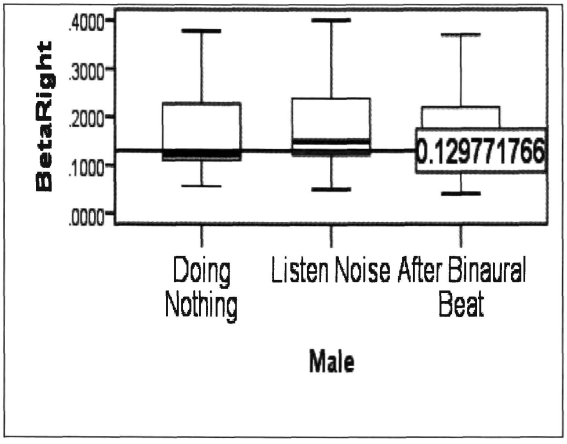

Figure 8: The box plot of Beta Right sub band for male during three sessions

The box plot in Figures 7 and 8 show the plot of beta sub band for male in three sessions. We can observe that in beta left sub band, the median of the box plot during listening to noise increased as compared to the median during doing nothing session. The beta sub band is associated to thinking, intensity or anxiety (Huang & Charyton 2008), thus intense thinking or stress will increase the level of beta sub band. On the other hand, it can be observed that after listening to the binaural beat tone, the median of the box plot in beta sub band decreased significantly in both hemispheres. In fact, it was even lower than the median line of box plot during doing nothing session. This shows that the subjects become more relaxed after listening to the tone.

Female

There were a total of 22 female subjects. Table 2 shows the result of Shapiro-Wilk Normality Test. It can be observed that for female gender, both alpha and beta sub bands in both hemispheres during the three sessions obtain significant values > 0.05. There is one outlier detected in all the box plot of alpha right sub band. Figure 9 and 10 shows the box plot of alpha left and alpha right sub bands during three sessions for female. In both figures, during listening to the noise session, female subjects show that they are notably affected by the noise. This can be perceived from the significant decrement of both alpha left and right sub band median level during the said session. Alpha sub band is associated with calmness. The decrement of the alpha sub band shows that the level of calmness of female subjects has been reduced due to the noise induced. However, the level of the alpha sub band increased after the subjects were introduced to the binaural beat tones for 20 minutes. This also shows that the subjects become more relaxed. Comparing with male subjects, the median level of alpha sub band for female subjects does not go beyond the median level of alpha sub band during doing nothing session.

Table 2: Results of Shapiro-Wilk Normality Test of Alpha Left, Alpha Right, Beta Left and Beta Right for female gender in three sessions

Tests of Normality				
	Female	Shapiro-Wilk		
		Stats	df	Sig.
AlphaLeft	Doing Nothing	.922	22	.082
	Listen Noise	.947	22	.270
	After Binaural Beat	.932	22	.138
AlphaRight	Doing Nothing	.934	22	.148
	Listen Noise	.942	22	.215
	After Binaural Beat	.929	22	.115
BetaLeft	Doing Nothing	.922	22	.082
	Listen Noise	.947	22	.270
	After Binaural Beat	.932	22	.138

BetaRight	Doing Nothing	.934	22	.148
	Listen Noise	.942	22	.215
	After Binaural Beat	.929	22	.115

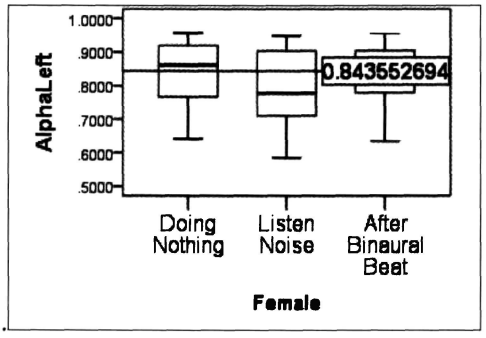

Figure 9: The box plot of Alpha Left sub band for female during three sessions

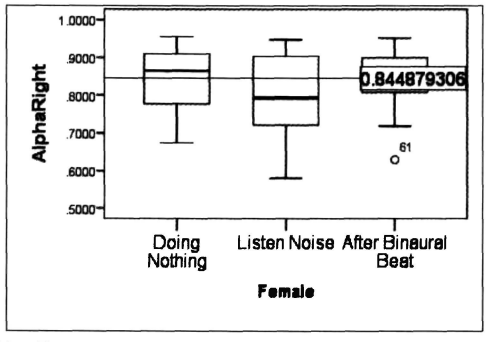

Figure 10: The box plot of Alpha Right sub band for female during three sessions

Figure 11 and 12 shows the box plot of beta left and beta right sub band during three sessions in females. The trend of the beta sub band in both hemisphere for female shows the same pattern with male where the beta sub band increased during listening to noise as compared to the doing nothing session. The level of beta decreased after subjects listened to the binaural beat tones for 20 minutes. Comparing with male subjects, the level

of the median box plot for beta sub band in female does not go higher than the median level in doing nothing session.

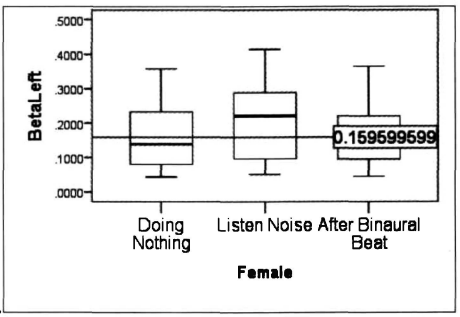

Figure 11: The box plot of Beta Left sub band for female during three sessions

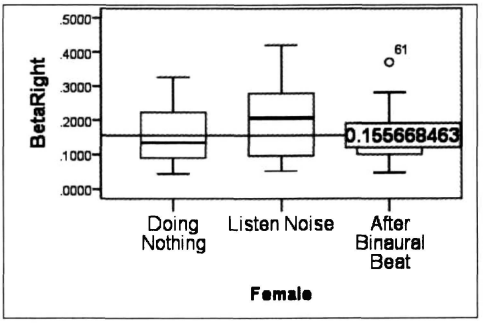

Figure 12: The box plot of Beta Right sub band for female during three sessions

CONCLUSION

In our work, the Alpha Beta Frontal Energy Ratio feature is capable to demonstrate the effect of binaural beat tones on alpha and beta sub bands of different profiles namely male and female. Using graphic statistical analysis, the box plot, it can be observed that in both hemisphere, alpha and beta sub band behaved as hypothesized where the alpha sub band decreased during stress induction and increased after entrained with binaural beat tones. In contrast, beta sub band increased after stress was induced and decreased after entrained with binaural beats tone.

Other than that, the brainwave of males is easier to be entrained as compared to females or in other words, males are easier to be alleviated from stress meanwhile for females it shows that they are more susceptible to stress. In other words, it is shown that binaural beats has the ability to help in reducing our stress. Future work will include classification of different profiles for different session.

ACKNOWLEDGMENT

Author would like to express appreciation to all participants, members of BioMedical Lab Level 7 and members of ASPRG Lab Level 10 (both in UT Shah Alam) for the cooperation. This work is supported by RAGS KPT grant (5/3 (45/2012)).

REFERENCES

Achanccaray, D. R. and Meggiolaro, M. A. (2008). Detection of artifacts from EEG data using wavelet ransform, high-order statistics and neural networks. *XVII Brazilian Conference on Automatica.* 23.

Bos, D. O. (2006). EEG-based emotion recognition. *The Influence of Visual and Auditory Stimuli,* 1-17.

Croft, R. and Barry, R. (2000). Removal of ocular artifact from the EEG: a review. *Neurophysiologie Clinique/Clinical Neurophysiology. 30*: 5-19.

Davidson, R. J. and Fox, N. A. (1982). Asymmetrical brain activity discriminates between positive and negative affective stimuli in human infants. *Science, 218*:1235-1237.

Ferlazzo, E., Mammone, N., Cianci, V., Gasparini, S., Gambardella, A., Labate, A., Latella, M. A., Sofia, Elia, M., Morabito, F. C. and Aguglia, U. (2014). Permutation entropy of scalp EEG: A tool to investigate epilepsies: Suggestions from absence epilepsies. *Clinical Neurophysiology, 125*:13-20.

Huang, T. L. and Charyton, C. (2008). A comprehensive review of the psychological effects of brainwave entrainment. *Alter Ther Health Med, 14*:38-50.

Knott, V., Mahoney, C., Kennedy, S. and Evans, K. (2001). EEG power, frequency, asymmetry and coherence in male depression. *Psychiatry Research: Neuroimaging, 106*:123-140.

Razali, N. M., and Wah, Y. B. (2011). Power comparisons of Shapiro-Wilk, Kolmogorov-Smirnov, Lilliefors and Anderson-Darling tests. *Journal of Statistical Modeling and Analytics, 2*:21-33.

Smith, A. (2002). Effects of caffeine on human behavior. *Food and Chemical Toxicology, 40*:1243-1255.

Tabacaru, B. A. (2013). Evaluation of emotional influence on EEG activity in the frontal lobes. *E-Health and Bioengineering Conference (EHB)*: 1-4.

Thibodeau, R., Jorgensen, R. S. and S. Kim, S. (2006). Depression, anxiety, and resting frontal EEG asymmetry: a meta-analytic review. *Journal of Abnormal Psychology*, 115-715.

Tortella-Feliu, M., Morillas-Romero, A., Balle, M., Llabrés, J., Bornas, X. and Putman, P. (2014). Spontaneous EEG activity and spontaneous emotion regulation. *International Journal of Psychophysiology*, *94*:365-372.

Wagner, J., Cik, M., Marth, E.,. Santner, B.I., Gallasch, E., Lackner, A. and Raggam, R.B. (2010). Feasibility of testing three salivary stress biomarkers in relation to naturalistic traffic noise exposure. *International Journal of Hygiene and Environmental Health. 213*:153-155.

Yamsa-ard, T. and Wongsawat, Y. (2014). The relationship between EEG and binaural beat stimulation in meditation. *Biomedical Engineering International Conference (BMEiCON),* 7:1-4.