Jurnal Teknologi

Type of Music Associated with Relaxation Based on EEG Signal Analysis

Nurhanis Izzati Che Marzuki[a*], Nasrul Humaimi Mahmood[a], Norlaili Mat Safri[a]

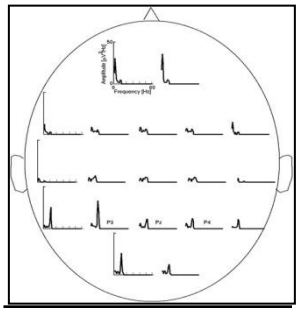
[a]*Biomedical Instrumentation and Electronics Research group, Faculty of Electrical Engineering, Universiti Teknologi Malaysia, 81310 UTM Johor Bahru, Johor, Malaysia*

*Corresponding author: nurhanisizzatichemarzuki@gmail.com

Article history

Received : 30 May 2012
Received in revised form :
9 October 2012
Accepted : 5 January 2013

Graphical abstract



Abstract

Music is the science and the art of tones, or the musical sounds. Music is also the art of combining tones in a manner to please the ear. Music therapy is the planned and creative use of music to attain and maintain health and well-being. There are a lot of experimental efforts to understand musical processing in the brain using electroencephalogram (EEG). It is accepted that listening to music increases the theta and alpha bands power that is associated to increase relaxation. In this study, we are interested to find the type of music that can produce such state of mind by analysing the EEG power spectrum in those frequency bands. 4 types of music were investigated, i.e. sound of instrumental piano, sound of wave, sound of birds and sound of nature. As the result, 71.4% of subjects were able to achieved highest power spectral density in theta and alpha frequency bands while listening to sound of instrumental piano and sound of nature while only 28.6-42.9% of subjects were able to produce the same while listening to sound of wave and sound of bird. From the finding, it can be concluded that sound of instrumental piano and sound of nature increase relaxation as indicated by the increase of PSD in the theta/alpha frequency bands compared to the sound of wave and sound of bird.

Keywords: Music therapy; stress; Electroencephalogram (EEG)

Abstrak

Muzik adalah sains dan seni nada, atau bunyi muzik. Muzik juga adalah seni menggabungkan nada dalam cara untuk didengari oleh telinga. Terapi muzik adalah penggunaan muzik yang terancang dan kreatif untuk mencapai dan mengekalkan kesihatan dan kesejahteraan. Terdapat banyak usaha eksperimen untuk memahami pemprosesan muzik dalam otak yang menggunakan 'elektroensephalogram' (EEG). Dipersetujui bahawa mendengar muzik dapat meningkatkan kuasa jalur theta dan alfa yang dikaitkan dapat meningkatkan ketenangan. Dalam kajian ini, kami berminat untuk mencari jenis muzik yang boleh menghasilkan darjah ketenangan fikiran itu dengan menganalisis spektrum kuasa EEG pada jalur frekuensi yang dinyatakan. Terdapat 4 jenis muzik telah di ambil kira, iaitu bunyi piano instrumental, bunyi ombak, bunyi burung dan bunyi alam. Hasilnya, 71.4% subjek mencapai ketumpatan kuasa spektrum tertinggi pada jalur theta dan alfa ketika mendengar bunyi piano instrumental dan bunyi alam manakala hanya 28.6-42.9% daripada subjek mampu menghasilkan yang sama sambil mendengar bunyi gelombang dan bunyi burung. Dari dapatan kajian, dapat disimpulkan bahawa bunyi piano instrumental dan bunyi alam dapat meningkatkan ketenangan seperti yang ditunjukkan oleh peningkatan ketumpatan kuasa spektrum dalam frekuensi jalur theta / alpha berbanding dengan bunyi ombak dan bunyi burung.

Kata kunci: Terapi muzik; tekanan; Elektroensephalogram (EEG)

1.0 INTRODUCTION

Stress is a feeling that is created when people react to particular events. Nowadays, due to burden work and family matters, many people involved with the stress situation. Most of them do activities such as meditation, picnic or visiting natural places in order to reduce their stress level. All of these activities are time consuming and some require travelling. However, there is an easier way to reduce stress, i.e. by listening to music that do not require travelling and is not time consuming as you can do other things while listening. Moreover, in this modernization era, people can listen to music anywhere using technology such as the handphone, mp3 player and etc.

The music used in the musical therapy is various, and it takes therapist and patient a long time to select the music. If the music effective for the musical therapy is easily found, the time of selecting the music can be shortened and the musical therapy can be carried out effectively.[1]

Since the times of ancient Greeks and Romans, music was known to effect human behaviour. Music provides a helpful mnemonic for verbal learning throughout life, and most notably during early development and in educational settings.[2] However,

music is more likely to have positive effect on individuals if they enjoy the type of music to which they are listening. Many researchers have proven that using music enabled us to increase the relaxing state beyond the mind. The most prominent changes are in theta or alpha frequency bands happened upon the influences of music.[3]

The electroencephalogram (EEG) is a recording of electrical activity originating from the brain. It is the visual plotting of the brain neural electric activities projected to the scalp surface. The earliest attempt to hear brainwaves as music was made in 1934.[4] In most of these early works, however, only the amplitude of the alpha waves or other simple and direct characters of EEG signals was utilized as the driving sources of the musical sound. In the 1990s, various new music generating rules were created from digital filtering or coherent analysis of EEG.[5]

There are lot of experimental efforts to understand musical processing in the brain using EEG. One of them studies three broad problems, i.e. the perception of musical tones, interpretation of acoustical information relevant to music and emotional response to musical messages.[3] They have found that during listening of music, a significant power increase in theta and alpha bands and that the subjects have described their musical experiences as very pleasant whenever the significant rise of theta and powers are observed. They have related this finding with relaxation of mind.

There is also a study on EEG signal based on aromatherapy.[6] It is about the use of aromatherapy to reduce stress and increase relaxation. The study focuses on measuring EEG signal at frontal region because it is most associated with the sense of smell.[6] They found that the increasing power spectral density (PSD) value of alpha wave indicates that subjects feel more relaxed while decreasing PSD value of beta wave indicates that subjects feel less alert and start to relax. The study has proven that subjects feel relax and calmer after they're exposed to aromatherapy.

There is also another study done to identify resting state and calming mind during reciting Quran using EEG.[7] The paper discusses the analysis of EEG signal of resting state and calming mind during reciting Quran. They have found that EEG power spectrum was high in alpha band, indicating the state of calming mind.

The other study on EEG signal is done to identify the EEG signal during listening to native and foreign languages songs. As the result of the paper, it can be see that when people are listening to different languages songs, the brain will produce different EEG signal patterns.[8] The paper analyize two kinds of songs (Chinese lyrics and Japanese lyrics) to stimulate the subject and at the same time they record the EEG signals using 64-channel Neuro-scan device.

From the study of feature extraction from EEG patterns in music listening, the paper discusses on the measurement and extraction of EEG difference between music genres as characteristic data. The method that they used is to rnakes the data based on frequency appearance rate, extuct features by the principal component analysis, and then analyze them by using a neural network. Finally they carried out computer simulations by using the real data in order to sbow the effectiveness of the proposed method.[1]

To represent mental state by music can be done by using the method of translating human EEG into music which is discussed in study of music composition from the brain signal which representing the mental state by music. [9] The paper states that the arousal levels of the brain mental state and music emotion are implicitly used as the bridge between the mind world and the music. This arousal level is based on the EEG features extracted mainly by wavelet analysis, and the music arousal level is related to the musical parameters i.e pitch, tempo, rhythm, and tonality. As the result from the paper, the music pieces of different sleep stages are of different features in music structure.

The EEG signal related to music listening also have discussed on the study of discovering EEG signals response to musical signal stimuli. This paper used the time frequency anlysis and independent component analysis (ICA) in order to analysis the EEG data. The musical stimuli that they used are metal music, sonata music and favorite music selected by subjects. The ICA was applied in the study to assist them in the process of isolating noise components. As the result of the study, from the ICA, some of the independent component showing more significant differences for different types of music. The PSD of each frequency band are similar in listening metal music but showed less smilarity in listening to sonata music.[10]

Other than music listening, the cognitive neuroscience of creativity also has been studied using the non invasive electrical recording which the EEG system. The paper discussed the major aspects on performing the research using EEG i.e recording of the EEG signals and signal analysis for better understanding of the neural correlates of processes involved in creativity. As the result, the study provide a way to understand the spatial activations and temporal development of the large scale electrical activity in the during creative tasks.[11]

As previously mentioned, listening to music increases the theta and alpha bands power that is associated to increase relaxation. In this study, we are interested to find the type of music that can produce such state of mind by analysing the EEG power spectrum in theta and alpha frequency bands.

■2.0 THEORY

2.1 Frequency and Classification of Waveform

Brain waveforms have been categorized into 5 basic groups namely Gamma, Alpha, Beta, Theta and Delta. Generally, brain wave ranges from 0.5 Hz ~ 500 Hz but most of the clinical EEG signals are carried out on a paper-writing instrument which ranges between 20 Hz to 40 Hz. Gamma wave are in between 13 Hz to 30 Hz. Gamma wave are normally happened when human in processes activity mode. Alpha wave normally ranges from 8 Hz to13 Hz. Alpha wave has been thought to indicate both a lack of concentration and relaxed awareness. Beta wave is larger than 13 Hz. Beta wave is the typical waking rhythm of the brain associated with vigorous thinking, active attention, focused on the outside world otherwise related to solving concrete problems. Theta wave ranges from 3.5 Hz to 7.5 Hz. The wave illustrates consciousness slips toward drowsiness. Another wave is called Delta. Delta waves are normally 3 Hz or lower. Delta wave is mainly related with deep sleeps, in a waking status and indicates some physical defects in the brain.[12]

2.2 Fast Fourier Transform

The most commonly method to analyzed the signal is the Fourier transform. Fast Fourier Transform (FFT) is an efficient algorithm to compute the Discrete Fourier Transforms (DFT) and its inverse.[13] A DFT decomposes a sequence of values into components of different frequencies.[14] This operation is very useful in many fields but computing it directly from the definition is often too slow to be practical. Computing a DFT of N points in the obvious way, using the definition, takes O (N^2) arithmetical operations, while an FFT can compute the same result in only O (N log N) operations.[14]

The Fourier transform used a simple mathematical transformation that changes a signal from time domain to

frequency domain. For example, the human EEG signal the non-period signals which is varies with time can changes in term of frequency domain using this Fourier transform. The Fast Fourier Transform equation is shown in equation (1).[14]

$$X(f) = \int (x(t)[cos(-2\pi ft) + jsin\,(-2\pi ft)])\,dt \qquad (1)$$

From equation (1), *x(t)* is the product of the time function and a [complex trigonometric expression] yield the frequency function of *X(f)* when integrated over time, t for a specific frequency, *f*.

2.3 Power Spectral Density Analysis

Power spectral density, PSD shows the strength of the energy (power) of a time series as a function of frequency. That is to say, it demonstrates strong variations at which frequencies and at which frequencies variations are weak and this might be quite useful for further analysis. Scientifically, PSD is described as the Fourier Transform of the autocorrelation sequences of the time series or the square of the Fourier Transform of the time series scaled by a proper constant period. The above definitions of PSD require the existence of Fourier Transform signal which means the signals are square sum-able or square integrable. The unit of PSD is power per frequency and power can be acquire within a specific frequency band by integrating PSD within that frequency range.[13]

PSD is a very useful tool when comes to identifying oscillatory signals in our time series data as well as to know their amplitude. Even though we do not hold any pure oscillatory signals in our data, PSD will still remain useful as we often compute and plot PSD to get a "feel" of data at an early stage of time series analysis. Looking at PSD is like looking at simple time series plot, rather than considering time series as a function of time, we take time series as a function of frequency. Hence it can be say that frequency is a transformation of time and looking at variations in frequency domain is just a different way to look at variations of time series data.

Mathematically, PSD describes the general frequency composition of the data in terms of the spectral density of its mean square value.[15] The mean square value in frequency range is $(f, f + \Delta f)$ in equation (2):

$$\Psi^2{}_x(f, \Delta f) = \lim_{T\to\infty} \frac{1}{T}\int_0^T x\,(t, f, \Delta f)^2\,dt \qquad (2)$$

where $x\,(t, f, \Delta f)^2$ is a portion of x(t) in $(f, f + \Delta f)$. Spectral analysis is typically performed with EEG segments by computing the Discrete Fourier Transform (DFT).

DFT of the given EEG signal *x(n)* is given by

$$X(k) = \sum_{n=0}^{N-1} x(n)\exp(-j\frac{2\pi}{N}kn) \quad k = 0,1,2,\dots,N-1, \qquad (3)$$

where N is the number of EEG samples taken for analysis. The DFT is typically computed using the Fast Fourier Transform algorithm (FFT) which computes the Fourier transform coefficients *X(k)* quickly.[11]

The spectral density function is related to the autocorrelation function by a Fourier Transform. The autocorrelation function contains information about the expected frequency content of the random process. The autocorrelation function can be computed using the formula

$$R(\tau) = \frac{1}{N}\sum_{n=0}^{N-|\tau|+1} x(n)x(n+\tau) \qquad (4)$$

where if the signal *x(t)* contains a periodic component, then *R(t)* also contains a periodic component with the same period.[11]

The power spectral density (PSD) function can be used to provide spectral information, and the PSD is defined as the Fourier transform of the autocorrelation sequence. Spectral analysis can also be performed by using models, typically linear stochastic models. The most popular model is the autoregressive model (AR). AR modeling is used extensively in modeling random signals like EEGs.[11] For AR models, it have form of function

$$x[k] + \sum_{i=1}^{M} a_i\,x\,[k-i] = n[k], \qquad (5)$$

where *x[k]* is the EEG signal, *n[k]* is zero mean white noise, a_i's is the AR coefficients, and *M* is the AR order.[11]

In this study, even-though 19 EEG signals were recorded, only three EEG signals were analysed, i.e. P_3, P_z and P_4. They were chosen because they had shown an increase in alpha activity during resting state.[7]

■3.0 METHODOLOGY

3.1 Participants

Seven healthy subjects participated in the study: 4 female and 3 male with age ranges from 23 to 24 years old with normal hearing and free from disease and medication. All the subjects were selected from undergraduate program in the university campus.

3.2 Stimuli

Four types of music were used in this experiment. They were the sound of instrumental piano (Music 1), the sound of wave (Music 2), the sound of birds (Music 3) and the sound of nature (Music 4). The stimuli were delivered from headphone to the left and right ear of the participants.

3.3 Experimental Setup

19 EEG signals were recorded based on 10-20 electrode placement system. All signals were digitized with the sampling frequency of 1000 Hz. Figure 1 shows the setup of EEG machine.

Figure 1 EEG machine setup

First and foremost, the experiments was carried out in single session in a quiet and air-conditioned room. The temperature of the room was between 22 and 25°C. For single session, only 1 subject are participated during the experiment. The room must be completed with the EEG machine. Subject sat on a chair and was told to minimize their body movement to minimize the artifact. Then cap with electrodes attached was attached to the scalp. Conductive gel was inserted into an electrode tube to reduce the impedance between the scalp and the electrodes. After that, the subject was put into relax condition, i.e. sitting on the chair with the eyes closed. Subject was given 5 minutes to reach a relaxed condition. Then, the EEG signals were recorded for 1 minute (Control condition). Next, the subject was exposed to the musics for 1 minute/music type via headphone. While listening to music, the EEG signals were taken from the subject.

3.4 Data Analysis

After the raw EEG signal taken from the subject, the data are in form of graph. Then the data of the raw signal was converted into ASCII format. This format will be read using the Microsoft Excel or Notepad. The data then save as the Comma Delimited Value (CSV) format. The software that we use in this study is FEDORA software. By using this software, the EEG signals were analysed using Fast Fourier Transform (FFT) and Power Spectral Density (PSD). In order to perform the PSD, we used the command in FEDORA programming. Firstly, the saved data in CSV format is calling in the command window of the FEDORA. The programming started with the memory allocation and initialization. After that, it bulid up the memory space for EEG data. Then, command for the crucial part for calculation of EEG to form FFT and PSD data are called. Lastly, the average FFT for all epochs is perform.

4.0 RESULTS AND DISCUSSIONS

An example of PSD for the 19 EEG signals for Music 1 is shown in Figure 2. It is taken from subject 1. The channel is depended on the part on human brain which is prefrontal lobe (Fp_1, Fp_2), frontal lobe (F_7, F_3, F_z, F_4, F_8), temporal lobe (T_3,T_4, T_5, T_6), central lobe (C_3, C_z, C_4), parietal lobe (P_3, P_z, P_4) and occipital lobe (O_1, O_2). One of the electrodes is used as a reference electrode and standard locations for the reference include the tip of the nose, the ear lobes and locations near the both side of head. From the figure, peak PSD can be observed at alpha frequency band at P_3, P_z and P_4 scalp locations. The data in y-axis are the amplitude of the PSD in μV^2/Hz and the x-axis referred to the frequency in Hz.

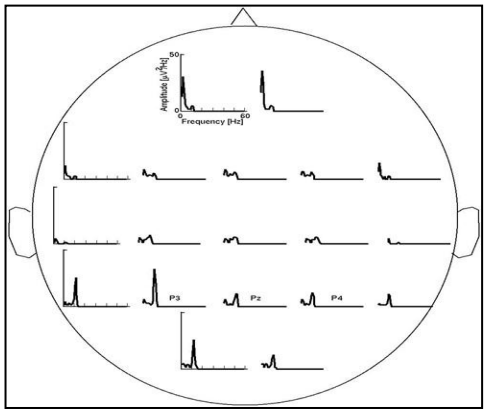


Figure 2 PSD of 19 EEG signals for Music 1

Figure 3 shows the frequency bar chart for the peak of PSD of the three scalp locations for Music 1 for all subjects. From the figure, it is obvious that five subjects (71.4%) showed the peak of PSD in the theta/alpha frequency bands at P_4. At P_3 and P_z, there are 4 subjects that showed the peak of PSD in the theta/alpha frequency bands. This frequency band involved at frequency between 4 to 13 Hz stated as a relaxed state.

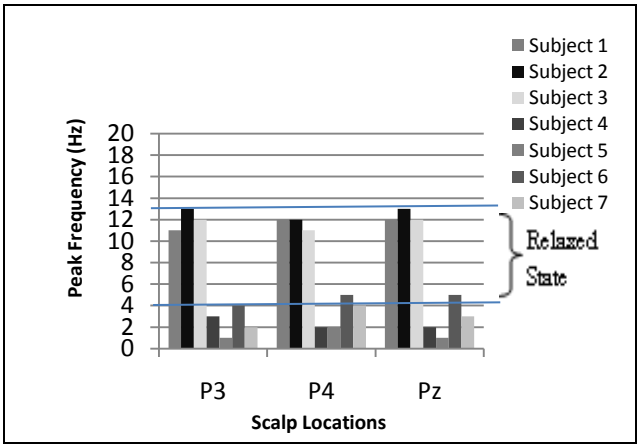


Figure 3 Frequency that produce peak of PSD for Music 1

Meanwhile, Figure 4 shows the frequency bar chart for the peak PSD of the three scalp locations for Music 2 for all subjects. Only three subjects had peak of PSD in the alpha frequency band for all three scalp locations. The other four subjects had the peak of PSD in the delta frequency bands which normally characterized as in deep sleep state.

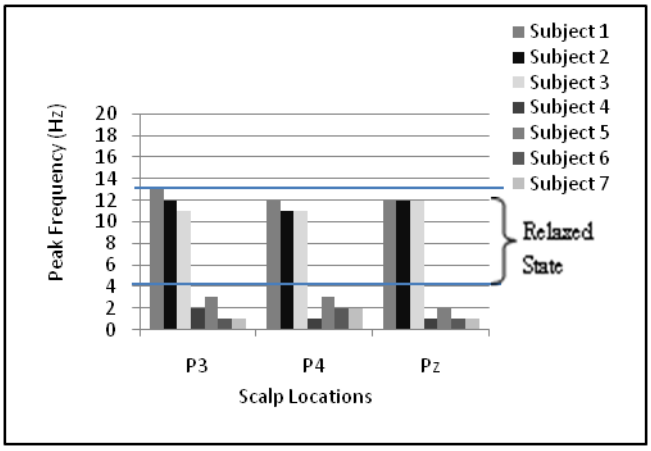


Figure 4 Frequency that produce peak of PSD for Music 2

As for Music 3, only two subjects managed to obtain peak of PSD in theta/alpha frequency bands for all three scalp locations shown in Figure 5. The others five subjects are attempting to show the delta frequency bands.

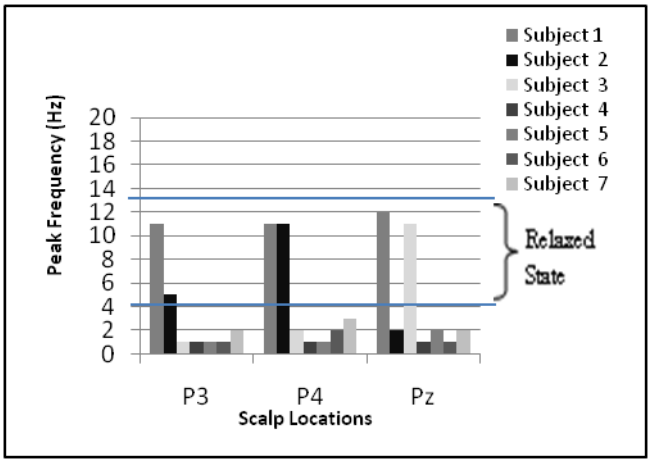


Figure 5 Frequency that produce peak of PSD for Music 3

Similar to Music 1, for Music 4, five subjects (71.4%) managed to produce peak of PSD in the theta/alpha frequency bands for all 3 scalp locations as shown in Figure 6. Only two subjects are managed to show the delta frequency band which they attempt to have a deep sleep while listening to Music 4.

Table 1 shows the summary of the number of subjects that achieved relaxation state based on PSD increased in theta and alpha frequency bands. From the table, for Music 1, the number of subject that achieved alpha frequency band is three subjects, and theta frequency band is two subjects. For Music 2, there are only three subjects showing relaxed state in an alpha frequency band from the total of seven subjects. Meanwhile, for Music 3, only two subjects are achieved the alpha frequency band. Equivalent as Music 1, Music 4 showing the same number of subjects that achieved relaxed state, which is three subjects in alpha frequency band and two subjects in a theta frequency band. As a result, Music 1 and Music 4 show the highest number of subject with relaxed state.

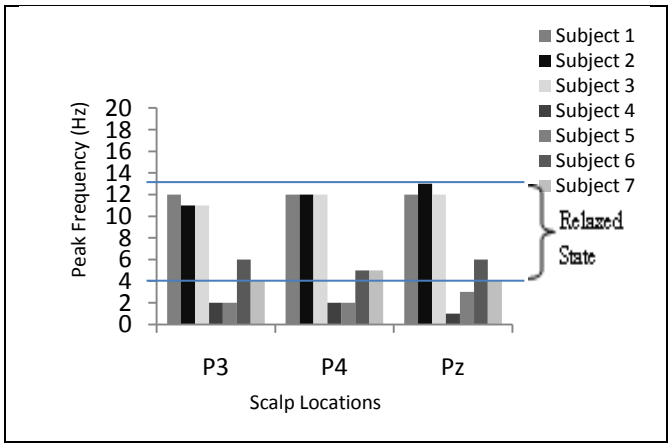


Figure 6 Frequency that produce peak of PSD for Music 4

5.0 CONCLUSION

In this paper, we have done the experiment based on listening to different types of music to analyse characteristic of EEG signal. The music that were used is sound of instrumental piano (Music 1), the sound of wave (Music 2), the sound of birds (Music 3) and the sound of nature (Music 4). From the finding, it can be concluded that sound of instrumental piano and sound of nature increase relaxation as indicated by the increase of PSD in the theta/alpha frequency bands compared to the sound of wave and sound of bird.

Table 1 Number of subjects showing relaxed state

Frequency Band (Hz)	Types of Music			
	Music 1	Music 2	Music 3	Music 4
Alpha (8-13)	3	3	2	3
Theta (4-7)	2	-	-	2
Alpha & Theta	5 out of 7	3 out of 7	2 out of 7	5 out of 7

Acknowledgement

This paper is a part of a publication series on Research and Development in Signal, Image and Sensors in Biomedical Engineering Applications. The authors would like to express their greatest gratitude to all staff and students in Medical Electronics Laboratory, Faculty of Electrical Engineering, Universiti Teknologi Malaysia for supporting this study.

References

[1] T. Ogawa, S. Ito, Y. Mitsukura, 2004. Feature Extraction from EEG Pattern in Music Listening. *Proceedings of IEEE International Symposium on Intelligent Signal Processing and Communication Systems*: 17–21.

[2] S. L. Calvert, R. L. Billingsley. 1998. Young children's recitation and comprehension of information presented by songs. *J. Appl. Dev. Psychol.* 19: 97–108.

[3] L. Skaric, M. Tomasevic, D. Rakovic, E. Jovanov, V. Radivojevic, P.Sukovic, M. Car, D. Radenovic. 2007. Electrocortical (EEG) correlates of music and states of consciousness. *Neuropsychological Trends*. 2: 75–83.

[4] E. Adrian and B. Mattews. 1934. The Berger Rtythms: Potential Changes from the Occipital Lobes in Man. *Brain*. 57: 355–385.

[5] D. Rosenboom. 1997. Extended Musical Interface with the Human Nervous System. *Intenational Society for the Arts, Science and Technology, San Francisco*. Monograph, Calif, USA.

[6] N. N Bahanudin. 2011. EEG Signal Based On Aromatherapy. Bachelor Degree Thesis, Universiti Teknologi Malaysia.

[7] N. H Mahmood, N. A Zakaria, N. F. Kamal, R. Sudirman, N. Mat Safri and F. K. CheHarun. 2011. Identification of Resting State and Calming Mind during Reciting Quran using Electroencephalogram. *International Conference on Medical Information and Bioengineering*.196–199.

[8] S. Shao-Jie and L. Bao-Liang. 2009. EEG Signal Classification during Listening to Native and Foreign Languages Songs. *4th International IEEE/EMBS Conference on Neural Engineering*. 440–443.

[9] D. Wu, C. Li, Y. Yin, C. Zhou and D. Yao. 2010. Music Composition from the Brain Signal: Representing the Mental State by Music. *Computational Intelligence and Neuroscience*. 1–6.

[10] W. Lin, H. W. Chiu and C. Y. Hsu. 2005. Discovering EEG Signals Response to Musical Signal Stimuli by Time Frequency analysis and Independent Component Analysis. *Engineering In Medicine and Biology 27th Annual Conference*. 2765–2768.

[11] Narayanan Srinivasan. 2007. Cognitive Neuroscience of Creativity: EEG based Approaches. *Methods*. 109–116.
[12] W. Ridzwan, E. A. Ali, N. H.Mahmood. 2011. Salat and Brainwave Signal Analysis. *Jurnal Teknologi*. 54: 181–192
[13] W. James, Cooley and J. W. Tukey. 1965. An Algorithm for the Machine Calculation of Complex Fourier Series. *Math. Comput*. 19: 297–301.
[14] D. Potts, G. Steidl, and M. Tasche. 2001. Fast Fourier Transforms for Nonequispaced Data: A Tutorial. *Modern Sampling Theory: Mathematics and Applications*. Birkhauser.
[15] A. Lagg. 2012. Spectral Analysis and Time Series. Retrieved on 25 May 2012 fromhttp://www.solar-systemschool.de/lectures/numerical_methods/ span.pdf