Research Journal of Applied Sciences, Engineering and Technology 7(17): 3671-3676, 2014
DOI:10.19026/rjaset.7.721
ISSN: 2040-7459; e-ISSN: 2040-7467

Submitted: December 09, 2013 Accepted: December 23, 2013 Published: May 05, 2014

Research Article

Focused Attention Analysis of Meditating and Non-meditating Brains in Time and Frequency Domains Using EEG Data

[1]K. Selvaraj and [2]P. Sivaprakasam
[1]Department of Computer Science, Arignar Anna Government Arts and Science College, Attur, Pin-636121, India
[2]Sri Vasavi College, Erode, Pin-638616, India

Abstract: The activity and the ability of brain to maintain the state of calmness in individuals practicing meditation has been a subject of research from long time. The aim of the study here is to prove that the meditation aids in retaining the state of calmness of brain. A MATLAB based multifaceted framework is developed for analyzing the dataset of brain EEG of people practicing meditation. The proposed method performs the processing of 32 electrode EEG data and denoises the signal in time series. The plotting of data followed by PSD analysis and FFT transform of the signal to analyze the data in frequency domain for examining each frequency band. The comparison is done using the L2 norm. The ICWT is later found to analyze the data and calculate for Modulus and angle of the EEG signal. The statistical analysis in time and frequency domain is use to study the effect of meditation on focused attention and retaining of same in meditating and non-meditating brains.

Keywords: Electroencephalograph (EEG), Inverse Coefficient Wavelet Transform (ICWT), L2 norm, meditation, Power Spectral Density (PSD)

INTRODUCTION

Effect of meditation psychologically, physically and its aid in metacognitive regulation was proven by Tan *et al*. (2014). The effect of meditation helps in slow transition to wandering states of consciousness is proven scientifically by Hasenkamp *et al*. (2012). EEG also known as Electroencephalography is a test to measure the electrical activity of the brain by placing the conductive metal electrode on various portions of scalp of the brain and provided with a computer interface to monitor, record and analyze the brain activity for anomaly or checking of the impact of medication on brain. EEG has a good temporal resolution and is a non invasive technique and hence is a good method of meditating brain analysis and development of computer interface as performed by Wang *et al*. (2005). EEG can hence be used for study of psychological analysis of brain functioning. Fundamental Brainwave Balancing Index (BBI) was proposed by Murat *et al*. (2010) using EEG signals to establish the correlation between psychoanalysis and BBI. A number of mathematical methods were used for the analysis of the EEG raw data for the analysis of the brain activity during and after meditation. One such method was suggested by Shijina and Narayanankutty (2012) which used formation of mathematical modeling for EEG source localization using subspace method. The method used the estimation for the location of sources of electrical activity within brain from EEG signals recorded by the array of sensors. The work used the Multiple Signal Classification (MUSIC) algorithm to locate the multiple dipole sources of EEG data. Another method of for source localization method that simultaneously performs Source and Formard Model reconstruction was proposed by Carsten *et al*. (2010). The Bayseian Framework proved effective in simultaneous source and forward model reconstructed image with improved source density. EEG power spectral analysis and EEG phase shifts were used for the study of brain pre and post mild Traumatic Brain Injury (mTBI) by Napoli *et al*. (2012). Study revealed different frequency bands, the correlation coefficient pro and post mTBI was different.

Lehman *et al*. (2001) studied an advanced meditatorusing a Low Resolution Electromagnetic Tomogrpahy (LORETA) functional images of gamma frequency band for different meditation. A 27 probe of EEG data was used for study of brain neuronal population active in the EEG gama (40 Hz) frequency band during different states. Novel method of Independent Component Analysis (ICA) was performed by separating mixture of 64 electrode system of EEG and for 512 second of naturalistic music stimulus.

Corresponding Author: K. Selvaraj, Department of Computer Science, Arignar Anna Government Arts and Science College, Attur, Pin-636121, India

Dongwei *et al*. (2013) used the ICA analysis and performed a Granger Casuality Analysis (GCA) to studied the nonlinear Independent Component Analysis for EEG brain computer interface system for Blind Source Separation on healthy volunteer on 10-20 electrode system. Omega Complexity during meditation was compared during pre and post meditation by Faber *et al*. (2011).

Meditation states and traits were analyzed and compared for the EEG, ERP and neuroimaging studies by Cahn and Polich (2006). The study on neuroelectric and imaging was done on meditation subject's revealed sensory evoked potential and amplitude and changes for some common practices and components. Neuroimaging studies showed increased regional cerebral blood flow measurement during meditation.

The objective of this study is to analyze the 32 electrode EEG signal of brain on a number of individuals practicing meditation from varying period of time. The statistical analysis is performed on the frequency and time domain of the EEG signal to determine the effect of meditation on focused attention and its retentivity among group of people practicing meditation.

MATERIALS AND METHODS

We propose a statistical analysis for analyzing the EEG data set for comparison of attention levels of detect the interactive dependencies between independent components of ICA. Oveisi *et al*. (2007) meditated brain with that of non meditating brain as shown in Fig. 1. The system obtains the EEG dataset information for 60 min and performs denoising, time domain analysis, FFT analysis, Power spectral density analysis, ICWT analysis and L2 norm analysis for meditation effect analysis.

Denoising the EEG signals: The signals of EEG require denoising. The method involving the denoising of the brain is based on the noise invalidation technique by Nikvand *et al*. (2010). Discarding of the coefficients that are smaller than a threshold value is performed on signal. The denoising of the EEG signals from the data base is as shown in Fig. 2.

Plotting of 32 channel data: Plotting of channel data is a simple plot of the raw data file. The plots are shown for each of the 32 electrodes as shown in the Fig. 3a and b. The figure shows the two plots of EEG analysis of two data sets namely PAT 10 (a non meditating brain) and PAT 07 (a meditating brain from 2 years).

The Table 1 shows detailed analysis done on 10 subjects. Subject PAT 10 is compared to the EEG data bases of the others to observe for the difference in EEG patterns between a regular meditator PAT 01 to PAT 09 to that of PAT 10 who is a non-meditator.

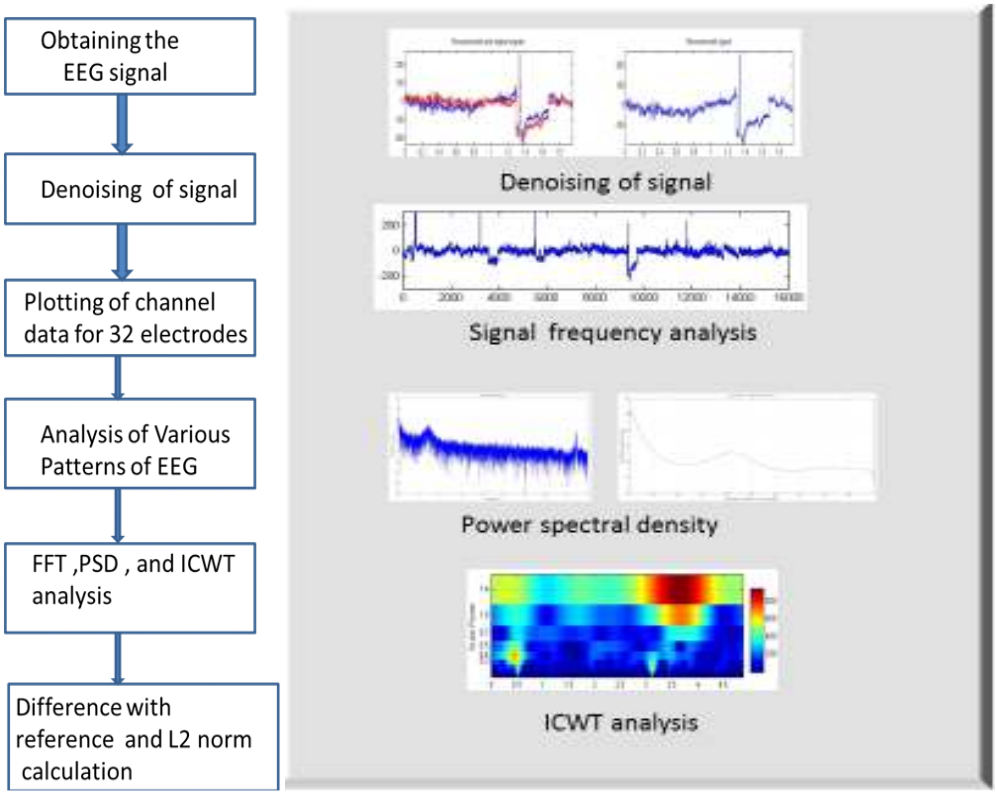
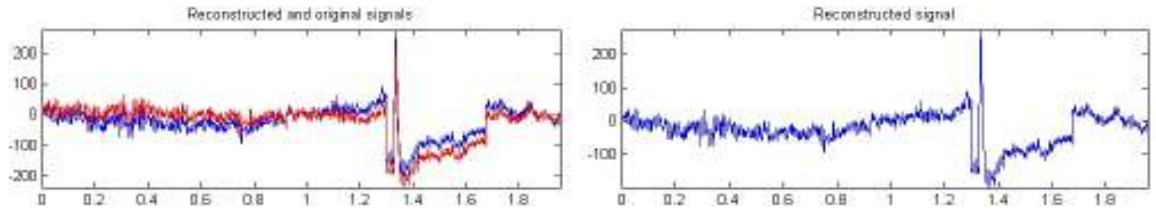
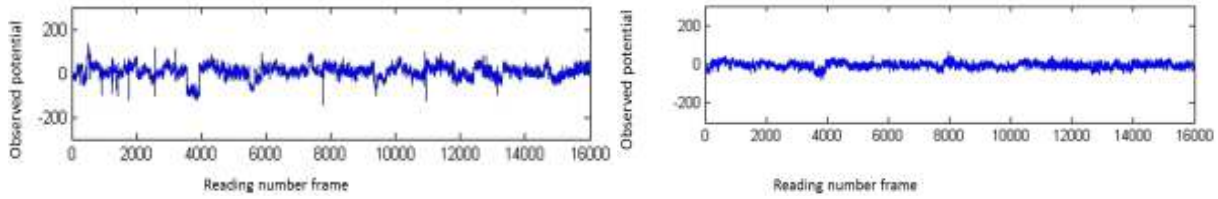


Fig. 1: Flow chart of the proposed methodology



(a) (b)

Fig. 2: The reconstruction of EEG signal using denoising by noise invalidation



(a) (b)

Fig. 3: (a) The channel reading of PAT 10 3, (b) the channel reading of PAT 07

Table 1: Detailed study of the EEG wave pattern (frequencies are averaged for the 32 electrodes)

Subject No. and details	Delta wave	Theta wave	Alpha wave	Beta waves	Gamma waves	Inference
PAT 10 Age: 32 meditation practiced: 0 years	Prominently non existent	Occasional for 7 min duration	Prominent during study	Most prominent	Non existent	Subject did not showed major alpha or beta waves during closed eye relaxation
PAT 09 Age: 37 Meditation practiced: 4 years	Existent for 3 min	Existent for 10 min	Existent for 20 min	Found during 10 min of initial start	Non existent	Subject showed significant presence of alpha and beta waves for 30 min
PAT 08 Age: 35 Meditation practiced: 6 years	Existent for 6 min	Existent of 7 min	Existent for 16 min	Found during 18 min of initial start	Found few pulses of 21 Hz for 10 to 15 sec	Subject showed significant presence of alpha and beta waves for 33 min
PAT 07 Age: 37 Meditation practiced: 2 years	Existent for 10 min	Existent of 11 min	Existent for 25 min	Found during 11 min of initial start	Non existent	Subject showed significant presence of alpha and beta waves for 36 min
PAT 06 Age: 39 Meditation practiced: 4 years	Existent for 2 min	Existent for 17 min	Existent for 09 min	Found during 08 min of initial start	Non existent	Subject showed significant presence of alpha and beta waves for 17 min
PAT 05 Age: 39 Meditation practiced: 5 years	Existent for 15min	Existent for 22 min	Existent for 04 min	Found during 07 min of initial start	Non existent	Subject showed significant presence of alpha and beta waves for 11 min
PAT 04 Age: 32 Meditation practiced: 1 years	Existent for 13 min	Existent for 17 min	Existent for 09 min	Found during 08 min of initial start	Non existent	Subject showed significant presence of alpha and beta waves for 17 min
PAT 03 Age: 37 Meditation practiced: 3.5 years	Existent for 07 min	Existent for 12 min	Existent for 06 min	Found during 15 min of initial start	Non existent	Subject showed significant presence of alpha and beta waves for 21 min
PAT 02 Age: 41 Meditation practiced: 1 years	Existent for 19 min	Existent for 10 min	Existent for 12 min	Found during 11 min of initial start	Non existent	Subject showed significant presence of alpha and beta waves for 23 min
PAT 01 Age: 34 Meditation practiced: 1 years	Existent for 09 min	Existent for 14 min	Existent for 19 min	Found during 11 min of initial start	Non existent	Subject showed significant presence of alpha and beta waves for 30 min

Spectral power density analysis: Fast Fourier Transform is performed for the conversion of the time series data into frequency domain to analyze the various frequency spectrums like the Power Spectrum Density (PSD). The data from FFT is binned into frequency ranges according to standard EEG definitions. The FFT of the signals is performed and Power spectral density is plotted for each signal.

The spectrum of power density was calculated by MATLAB and results were plotted for same by

observing. The signal in time series which is positive function of a frequency variable is plotted. The observations were noted in Table 2. The spectral density thus found was very less for PAT 07 for all the frequency ranges. The PSD for frequency range for other meditated brains in comparison to PAT 10 were lesser with observed effects.

Difference in signal analysis and L2 norm observation: For further comparison of the EEG analysis, reference is taken as PAT10 and the readings are compared with reference to other subjects. The highest difference in the readings was found in PAT 07 compared to other. The L2 norm finds the seminorm with the difference calculated among the other subjects and is again highest for PAT 07. L2 norm gives us the vector difference among various signals (Table 3).

Study of the scalar power using the ICWT analysis: The study of EEG signal by wavelet transform methods is difficult due to the complexity of the data associated. The ICWT analysis plots the coefficients of the inverse transform to analyze the modulus and angle of the EEG data. ICWT is carried out using a band pass filter forward transform. It is performed on a band of frequencies to be analyzed.

Table 2: Power spectral density observations

Subject No.	Frequency range (0-2) Hz (db/Hz)	Frequency range (2-4) Hz (db/Hz)	Frequency range (4-6) Hz (db/Hz)	Frequency range (6-8) Hz (db/Hz)	Frequency range (8-10) Hz (db/Hz)
PAT 10	9.2	15.1	8.2	3.2	3.4
PAT 09	9.1	15.2	8.1	3.0	2.9
PAT 08	9.2	15.2	7.9	3.1	2.8
PAT 07	8.9	15.2	6.2	2.2	2.3
PAT 06	7.2	15.3	5.8	2.3	2.8
PAT 05	7.1	14.9	5.6	3.2	2.3
PAT 04	7.4	15.2	5.2	3.0	2.1
PAT 03	7.9	15.4	5.1	2.2	2.2
PAT 02	7.2	15.4	5.0	2.0	2.0
PAT 01	7.1	15.2	5.9	2.8	3.2
Subject No.	Frequency range (8-10) Hz (db/Hz)	Frequency range (10-12) Hz (db/Hz)	Frequency range (12-14) Hz (db/Hz)	Frequency range (14-16) Hz (db/Hz)	Frequency range (16-18) Hz (db/Hz)
PAT 10	-4.5	6.2	4.5	-6.2	9.2
PAT 09	-2.3	5.8	4.2	-4.2	8.2
PAT 08	-3.4	5.7	4.3	-4.0	8.0
PAT 07	-3.2	5.2	4.0	-2.3	7.2
PAT 06	-3.2	4.8	4.6	-2.0	8.0
PAT 05	-3.0	4.4	4.8	-2.2	6.5
PAT 04	-2.9	4.2	4.4	-3.2	6.2
PAT 03	-2.2	4.3	4.2	-3.3	6.3
PAT 02	-3.2	4.1	4.1	-3.2	6.1
PAT 01	-3.4	4.7	4.1	-3.2	6.1

Table 3: Relative difference in percentage and L2 norm in comparison to reference PAT 10

Subject	Relative difference in percentage (%) with PAT 10	L2 norm in percentage (%) in relation to PAT 10
PAT 09	16.52	23.80
PAT 08	06.64	33.75
PAT 07	24.03	45.20
PAT 06	16.44	21.18
PAT 05	15.23	32.25
PAT 04	19.56	34.52
PAT 03	18.25	12.65
PAT 02	17.56	13.25
PAT 01	12.25	14.22

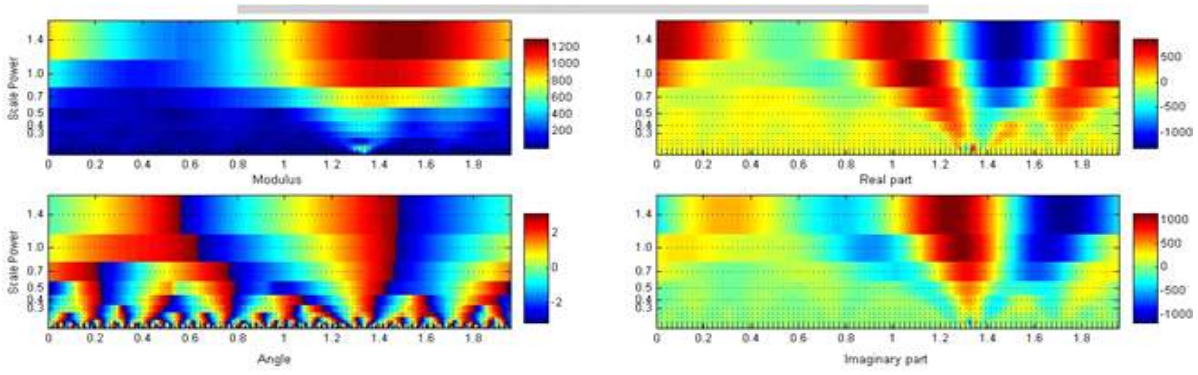


Fig. 4: Scalar power plot using the ICWT transform for PAT 10

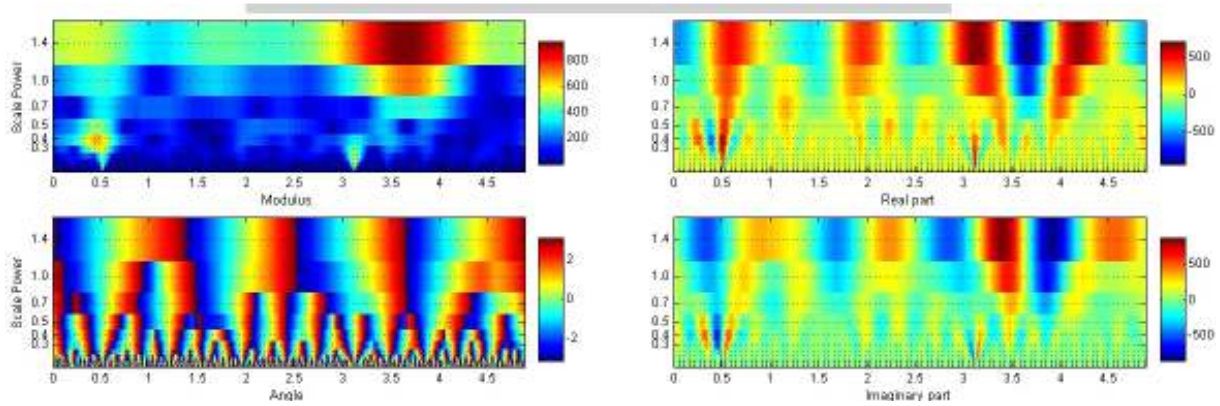


Fig. 5: Scalar power plot using the ICWT transform for PAT 07

Inverse Coefficient Wavelet Transform is used for the reducing the complexity of wavelet transform and calculation of non-zero coefficients (Guo and Sunnyvale, 1998). The study of the ICWT analysis for PAT 10 and PAT 07 is shown in Fig. 4 and 5, respectively. The plot shows that the scalar power in both modulus and real part in case of PAT 10 is higher than that of PAT 07 signifying an act of calmness of brain. The Angle plot of PAT 07 has a characteristic periodic pattern as compared to that of the PAT 10 with irregularities.

RESULTS AND DISCUSSION

The significant observations of the study revealed that the regular meditation practitioners have a higher rate of calm state retentively. The time required to obtain the calm state in meditating brain is faster than that of a non meditating brain. The meditating brains with more than 1 to 2 years of meditation experience have higher time duration of Theta and Alpha waves. Subject PAT 07 showed up maximum retentively in Theta and Alpha wave for close to 33 min. near similar effects were found in the subjects with nearly same number of years of practicing meditation. The power spectral density analysis of PAT 07 also showed less evoked potential in the Theta and Alpha wave ranges. PAT 07 recorded the lowest Power Spectral density among all the subjects studied. The L2 norm analysis also showed maximum relative difference of 24.03% in case of PAT 07 when compared to PAT 10. L2 norm percentage also showed highest in case of PAT 07 in reference to PAT 10. Higher scalar power in ICWT analysis in case of PAT 10 compared to PAT 07 shows the significant reduced potential of long meditating brain in PAT 07 compared to PAT 10.

CONCLUSION

The method of statistical analysis distinguishes the non meditated brain and meditated brain significantly. The meditating brain achieves the state of relaxation faster than the non meditating brain. Also the time of retentively at the relaxed and calm stage is higher in meditating brains. The number of years of practicing of meditation did not showed much effect as evident in case of PAT 07 achieving good meditating result even though PAT 07 had less meditating experience. The ICWT analysis clearly demarks the brain activity from a meditated brain to that of a non meditated brain. The work can be further elaborated and made precise by application of a classification algorithm on the statistical approach presented in this study.

REFERENCES

Cahn, B.R. and J. Polich, 2006. Meditation states and traits: EEG, ERP and neuroimaging studies. Psycol. Bull., 132(2): 180-211.

Carsten, S., M. Morten, W. Ole and K.H. Lars, 2010. SOFOMORE: Combined EEG Source and Forward Model Reconstruction. A White Paper by Technical University of Denmark. Department of Informatics and Mathematical Modeling. Richard Petersens Plads, 2800 Lyngby, Denmark, 1: 1-4.

Dongwei, C., W. Fang, W. Zhen and H. Li, 2013. EEG based emotion recognition with brain network using independent components analysis and grangers causality. Proceeding of IEEE International Conference on Computer Medical Analysis (ICCMA), 1: 1-6.

Faber, P.L., D. Lehman, P. Milz, S. Tei and K. Kochi, 2011. Dimensionality of multichannel EEG (omega complexity) during meditation in five traditions. Eur. Psychiat., 26(Suppl. 1): 944-947.

Guo, H. and C.A. Sunnyvale, 1998. Mapped inverse discrete wavelet transform for data compression. Proceeding of IEEE International Conference on Acoustics, Speech and Signal Processing, 3: 1385-1388.

Hasenkamp, W., D. Christine, W. Mendelhall and E. Duncan, 2012. Mind wandering and attention during focused meditation: A fine-grained temporal analysis of fluctuating cognitive states. NeuroImage, 59(1): 750-760.

Lehman, D., P.L. Faber, P. Achermann, D. Jeanmonod, L.R. Gianotti and D. Pizzagalli, 2001. Brain sources of EEG gamma frequency during volitionally meditation-induced, altered states of consciousness and experience of the self. Psychiat. Res., 108(2): 111-121.

Murat, Z.H., M.N. Taib, S. Lias and R.S.S.A. Kadir, 2010. EEG analysis for Brainwave Balancing Index (BBI). Proceeding of 2nd International Conference on Computational Intelligence, Communication System and Networks (CICSYN), 1: 389-393.

Napoli, A., K. Darvish and I. Obied, 2012. Assessing traumatic brain injuries using EEG power spectral analysis and instantaneous phase. Proceeding of 38th IEEE Annual Northeast Bioengineering Conference, 1: 3-4.

Nikvand, N., B.H. Rafsanjani and M.A. Khalilzadeh, 2010. ECG signal denoising using noise invalidation. Proceeding of 17th Iranian IEEE Conference on Biomedical Engineering (ICBME), 1: 1-4.

Oveisi, F., S. Oveisi, A. Efranian and P. Ioannis, 2007. A white paper on nonlinear independent component analysis for EEG based brain computer interface system. Iran Univ., Sci. Technol., 8: 165-180.

Shijina, P. and K.A. Narayanankutty, 2012. Mathematical modeling for EEG source localization using subspace method. Int. J. Adv. Comput. Eng. Commun. Technol., 1(1): 87-92.

Tan, L.F., Z. Dienes, A. Jansarai and S.Y. Goh, 2014. Effect of mindfulness meditation on brain computer interface performance. J. Consciousness Cogn., 23: 12-21

Wang, D., T. Kochiyama, S. Lu and J.W. Long, 2005. Measurement and analysis of electroen cephalograph using directional visual stimuli for brain computer interface. Proceeding of International Conference on Active Media Technology (AMT, 2005), 1: 34-39.