Real Time Acquisition and Psychoacoustic Analysis of Brain Wave

Shweta Singh, Dipali Bansal, Rashima Mahajan

Abstract—Psychoacoustics has become a potential area of research due to the growing interest of both laypersons and medical and mental health professionals. Non invasive brain computer interface like Electroencephalography (EEG) is widely being used in this field. An attempt has been made in this paper to examine the response of EEG signals to acoustic stimuli further analyzing the brain electrical activity. The real time EEG is acquired for 6 participants using a cost effective and portable EMOTIV EEG neuro headset. EEG data analysis is further done using EMOTIV test bench, EDF browser and EEGLAB (MATLAB Tool) application software platforms. Spectral analysis of acquired neural signals (AF3 channel) using these software platforms are clearly indicative of increased brain activity in various bands. The inferences drawn from such an analysis have significant correlation with subject's subjective reporting of the experiences. The results suggest that the methodology adopted can further be used to assist patients with sleeping and depressive disorders.

Keywords—'OM' chant, Spectral analysis, EDF Browser, EEGLAB, EMOTIV, Real time Acquisition.

I. INTRODUCTION

SINCE centuries, researchers have been interested in captivating the affective power of music on human body and mind and have developed numerous theories to explain its impact on the listener. But there is still a lack of experimental evidence which can suggest the exact mechanism by which music can evoke complex emotions. Wiebke Trost et al. used functional neuroimaging with parametric analysis to explore wide range of complex emotions evoked by music [1]. The mental stress that human receives in day to day life may lead to depression, anxiety, sleeping disorders etc. Seiji Nishifuji et al. examined the response of brain wave to acoustic stimuli and acoustic environment [2]. Affective computing research can design systems that can interpret, recognize, process and may even simulate human emotions. Anibal Cotrina Atencio et al. designed an offline evaluation of scalp EEG data acquired while a brain computer interface (BCI) user was hearing the unpleasant sounds [3]. Music is considered to be a valuable tool to understand human cognition and the underlying brain neural correlates based on EEG and fMRI studies [4]. In the scriptures of ancient India, 'OM' chant is considered to be most powerful of all the mantras. Ajay Anil Gurjar et al. proposed an algorithm to systematically understand the sound of 'OM' and its effect on nervous system [5]. Stigsby et al. proposed a controlled quantitative study in mantra meditation that the effect of 'OM' sound brings focus to the mind and can break a pattern of mechanisms. Stefan Koelsch et al. designed un updated model of neural perception and its distracting thoughts coming from the noisy mind in a way promoting positive thoughts [6]. Work has also been done to distinguish musical emotions from non musical emotions such as fear and anger [7], [8]. Winkler et al. described the effects of melodious music on growth of infants and early childhood [9], [10]. In the study conducted, the effect of music on premature infants was studied. First group of infants listened to lullaby six times a day and the second group of infants did not listen to and it was discovered that the first group gained weight faster and had fewer complications as compared to second group. A lot of literature can be explored on the EEG response to various visual and auditory stimuli and the way evoked potentials can be affected by pleasant and unpleasant emotions [11], [12]. Lot of research is underway using the technique of functional magnetic resonance imaging (fMRI) to measure neural responses to pleasant/unpleasant sounds that vary over large range. S. Kumar et al. have proposed design for brain mapping such sounds using this technique [13].

The technology of Brain Computer Interface (BCI) focuses on two methodologies i.e. invasive and non invasive. The non invasive methodology is preferred due to simple design and less complications. For brain computer interface to function, it needs some input brain signal. Various EEG signals such as Virtual evoked potentials (VEPs), Slow cortical potentials (SCPs) have been explored for controlling BCI functioning mechanism. The transient VEPs (TVEPs) and steady-state VEPs (SSVEPs) are being used for BCI control [14]-[20].

Electroencephalography (EEG) is the most suitable non invasive technique to interface brain with computer. However, it requires a lot of precision and trained staff to acquire EEG signals and thus it is one of the challenging tasks in research institutes. Thus EMOTIV EEG neuro headset is used for this research. It is a consumer grade headset available in the market for EEG acquisition. It is simple, easy to use, cost effective, portable device which has higher bit rate and better resolution.

Ms Shweta and Ms Rashima are Research Scholars at Manav Rachna International University, Faridabad, Haryana, India (e-mail: shweta_mmec@yahoo.com, rashimamahajan@gmail.com).
Dr Dipali is the HOD of ECE Department at Manav Rachna International University, Faridabad, Haryana, India (e-mail: dipali.fet@mriu.edu.in).
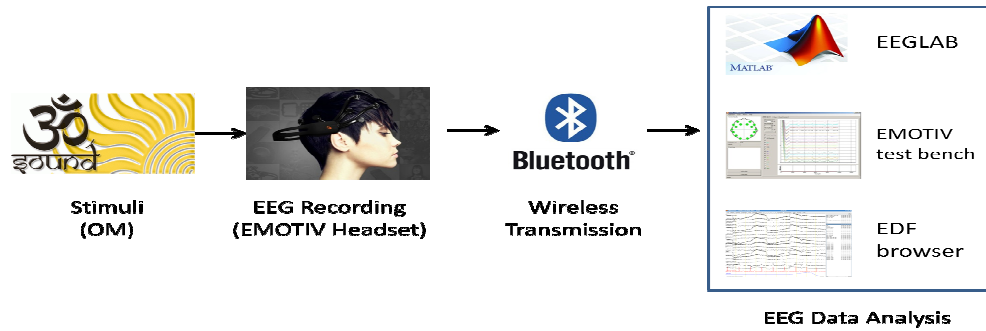
Fig. 1 Block Diagram for real time acquisition and analysis of EEG data

II. MATERIAL & METHOD

The functional block diagram of the developed EEG based brain computer interface (BCI) is shown Fig. 1. It consists of subjects, EEG recording and EEG data analysis.

A. Subjects

Six subjects, three males and three females, aged 25 to 38, all of whom were considered to be in good health, participated in the experiment. The experiment that consisted of a 20 minutes session consisted of having the participant sit in a dark room with eyes shut throughout the session. All subjects volunteered with informed written consent before the experiment. Acquisition of real time raw EEG is done from subject's scalp using a portable EEG Neuro-headset unit EMOTIV. A baseline reading is recorded and established corresponding to the normal relaxed state of each subject.

B. EEG Recording

Real time EEG dataset is acquired at a sampling rate of 128 Hz from 14 assembly electrodes sensors placed on subject's scalp using a portable EMOTIV EEG Neuro-headset unit. The EMOTIV headset is the most advanced consumer grade EEG headset available in the market. The 14-assembly electrode sensors are AF3, F7, F3, FC5, T7, P7, O1, O2, P8, T8, FC6, F4, F8, AF4 with 2 reference electrodes P3 and P4. It can also detect head movement using a built in gyroscope. The transmission of the acquired EEG signal to the computer is done via wireless bluetooth dongle that comes along with the headset. The EMOTIV Test Bench (software provided by EMOTIV) saves the recorded EEG dataset in .edf (European data format). The real time EEG dataset is acquired for each subject twice, at 10 minutes intervals, following the musical stimulation ('OM' chant) for a total period of 20minutes.

C. EEG Data Analysis

All data analysis is performed using EMOTIV Test Bench, EDF Browser and EEGLAB v 13.0.1 in MATLAB workspace application software platforms. The proposed approach is developed and implemented using Core i3 processor with speed 2.40 GHz. The recorded EEG signal (.edf) is imported in the EEGLAB toolbox of MATLAB to locate all 14 channels on the subject's scalp shown in Fig. 2. FFT for all the recorded EEG signals is done using EMOTIV Test Bench which is further verified by carrying out the spectral analysis of such signals in EDF Browser software platform. The EEG signals in .edf format are header edited and filtered using Butterworth high pass filter so as to obtain the corresponding power spectrum using Fast Fourier Transform.
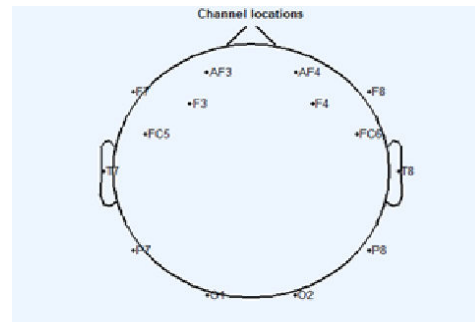

Fig. 2 All 14 channel locations in EEGLAB

III. RESULTS & DISCUSSION

The various results recorded are discussed in this section. Using EMOTIV Test Bench, FFT of the real time EEG signal (.edf) acquired through AF3 channel of the headset for the normal relaxed state of the subject is plotted in Fig. 3 (a). This can be established as the base line reading. FFTs of the EEG signals (AF3 channel) recorded after 10 minutes and at the end of 20 minutes session of 'OM' chant are plotted in Fig. 3 (b) and Fig. 3 (c) respectively. The spectral analysis of these signals is also done using EDF browser so as to verify the validity of conclusions drawn. Corresponding results are plotted in Fig. 4.
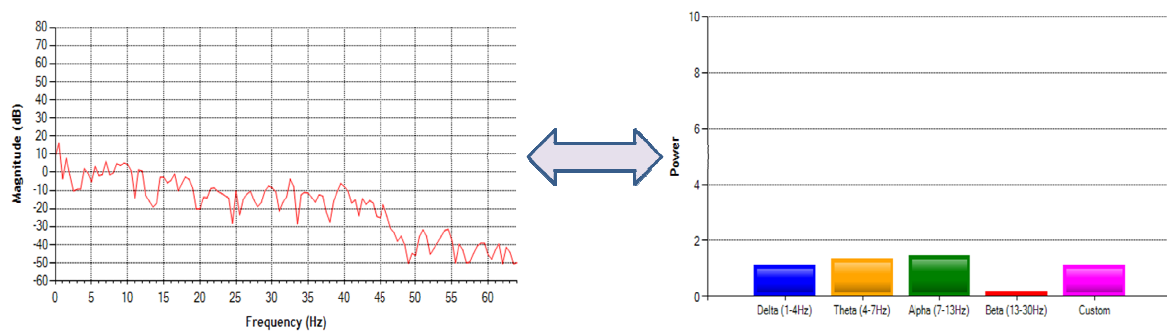
Fig. 3 (a) FFT of EEG signal for eyes closed baseline
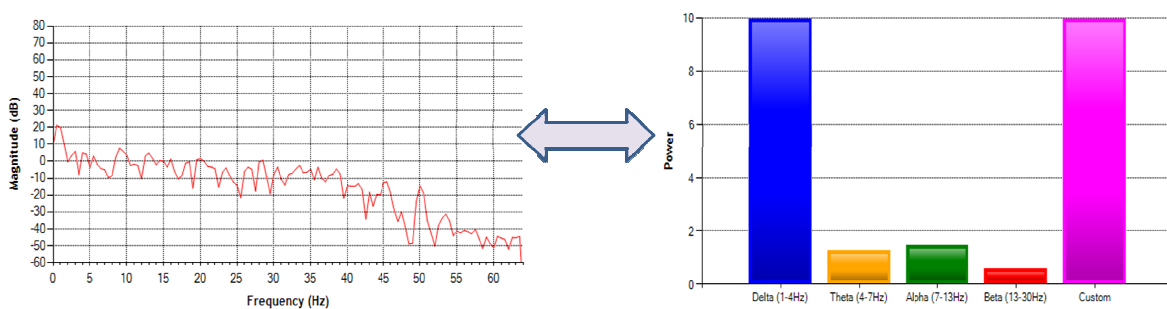

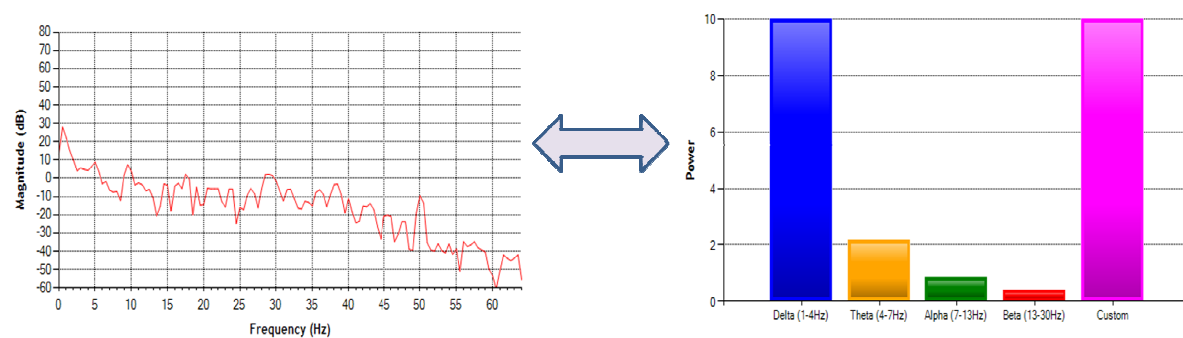Fig. 3 (b) FFT of EEG signal after 10 minutes of session

Fig. 3 (c) FFT of EEG signal after 20 minutes of session

Immediate visual indication of Fig. 3 (b) (after 10 minutes of the session) shows a considerable increase in delta band (0.5-4 Hz) and a small increase in beta band (13-30Hz) which shows that the subject felt deep level of relaxation but at the same time was in waking/alert state as well. In the next 10 minutes i.e. at the end of the session, visual indication of Fig. 3 (c) shows increased theta activity (4-7Hz) and small decrease in alpha (7-13Hz) and beta activity. This indicates a state of awareness associated with vivid internal imagery but still remaining deeply relaxed. Moreover, there was a significant correlation between subject's subjective reporting of the experiences during the session and the brain wave indications suggested by the researcher.

The spectral analysis of acquired signals using EDF browser indicates the dominant frequency component at 0.256000Hz in the baseline measurement (Fig. 4 (a)) but gradually shifting to 0.512000Hz (Figs. 4 (b) & (c)) as the session progresses which also interprets that the intensity of action corresponds to standard frequency range of the EEG signal. There is a gradual shift towards right hand side of the spectrum and is indicative of increased delta activity of the brain as already inferenced.

The results shown here are for one subject with a known history of no regular meditation practice but there is seen a high incidence of similar results/ reports from other subjects as well. Among the subject's comments were such typical descriptions as "I completely lost sense of my body and felt very light", "I am feeling relaxed," I felt as if I was flying," etc. No significant difference appeared in reports by either sex or age.
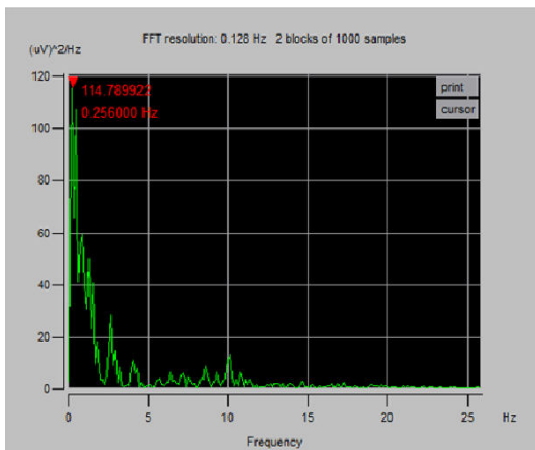
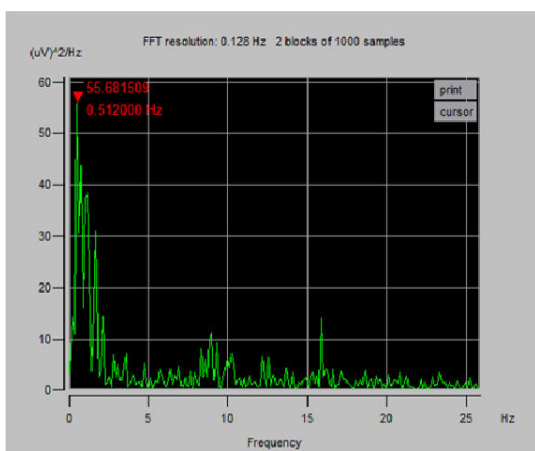Fig. 4 (a) Power spectrum- baseline reading

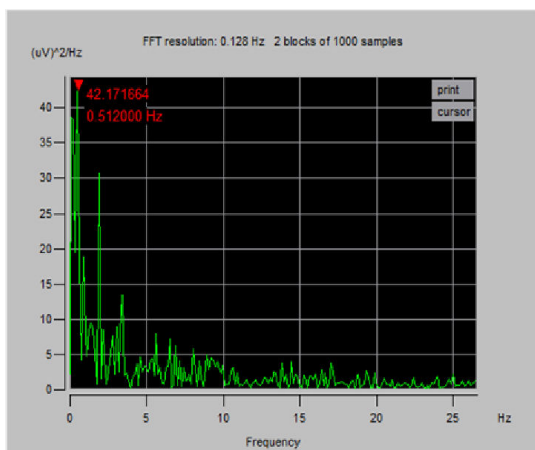Fig. 4 (b) Power spectrum-after 10 minutes

Fig. 4 (c) Power spectrum-after 20 minutes

IV. Conclusion

In this paper, an EEG based BCI using EMOTIV EEG neuro headset is implemented. EMOTIV technology is efficient, low price and has shorter preparation time for use. Spectral analysis techniques are explored in order to recognize the dominant frequency components corresponding to brain activity resulting on exposure to music stimuli. For such type of studies a large sample of subjects is vital so as to predict that whether the results experienced by one individual are likely to be experienced by others. The results obtained here suggest that the design proposed has been successful in brain mapping with minor variations on different subjects. If such findings are substantiated by future research, it can prove to be helpful in altering a variety of Psycho physiological conditions such as stress, anxiety, sleeping disorder, self esteem etc which will further be extended and utilized in the field of cognitive brain therapy.

References

[1] Wiebke Trost; Thomas Ethofer; Marcel Zentner; Patrik Vuilleumier. Mapping Aesthetic Musical Emotions in the brain. Cerebral Cortex Advance Access. *Laboratory of Behavioral Neurology and Imaging of Cognition*, Department of Neuroscience, Medical School, University of Geneva. Switzerland 15 December, 2011

[2] Seiji Nishifuji; Masahiro Sato; Daisuke Maino; Shogo Tanaka. Effect of Acoustic Stimuli and Mental Task on Alpha, Beta and Gamma Rhythms in Brain Wave. In *Proceedings of SICE Annual Conference. Taipei.* 18-21 August, 2010.

[3] Anibal Cotrina Atencio; Teodiano Freire Bastos Filho; Andr´e Ferreira; Alessandro Botti Benevides. Evaluation of ERD/ERS Caused by Unpleasant Sounds to be applied in BCIs. *PPGEE. Federal University of Espirito Santo.* 2011.

[4] Stefan Koelsch. Toward a Neural Basis of Music Perception- A Review and Updated Model. *Frontiers in Psychology. Berlin, Germany.* 9 June 2011.

[5] Ajay Anil Gurjar; Siddharth A. Ladhake; Ajay P. Thakare. Analysis Of Acoustic of 'OM' Chant to Study It's Effect on Nervous System. IJCSNS *International Journal of Computer Science and Network Security*, VOL.9 No.1.India.January 2009.

[6] Stigsby B; J. C. Rodenburg; H. B Moth. Electroencephalographic Findings during Mantra Meditation (Transcendental Meditation): *A Controlled Quantitative Study of Experienced Mediators.*

[7] Zentner M. Homer's Prophecy: An Essay on Music's Primary Emotions. 2010 *Music Anal.* 29:102—125.

[8] Scherer K, Zentner M. Emotional Effects of Music: Production Rules. In: Juslin P. N, Sloboda J, editors. Music and Emotion: Theory and Research. 2001 *Oxford: Oxford University Press.* p. 361--392.

[9] Winkler, I; Kushnerenko, E; Horváth, J; Ceponiene, R;,Fellman, V., Huotilainen, M., et al. Newborn Infants Can Organize the Auditory World. *Proceedings of the National Academy of Sciences, U.S.A.*2003. 100, 11812–11815.2262 Journal

[10] Trehub, S. E., Bull, D., & Thorpe, L. A. Infants' perception of melodies: The role of Melodic Contour. Child Development. 1984. 55, 821–830.

[11] L. I. Aftanas and S. V. Pavlov. Trait Anxiety Impact on Posterior Activation, Asymmetries at Rest and During Evoked Negative Emotions: EEG investigation. *International J. Psychophysiology.* 2005. vol. 55, pp. 85- 94, 2005.

[12] Oya, H. Kawasaki; M. A. Howard III; Ralf Adolphs. Electrophysiological Responses in the Human Amygdale Discriminate Emotion Categories of Complex Visual Stimuli. *J. Neuroscience.* 2002 vol. 22, pp.9502 – 9512.

[13] S. Kumar; H. M. Forster; P. Bailey; T. D. Griffiths. Mapping Unpleasantness of Sounds to Their Auditory Representation.. *J Acoust Soc Am.* 2008 vol. 124, no. 6, pp. 3810–7.

[14] Jinghai, Y.; Derong, J.; Jianfeng, H. Design and Application of Brain-Computer Interface Web Browser Based on VEP. In *Proceedings of the International Conference on Future BioMedical Information*

Engineering (FBIE'09), Sanya, China, 13–14 December 2009; pp. 77–80.

[15] Zhu, D.; Bieger, J.; Garcia Molina, G.; Aarts, R.M. A Survey of Stimulation Methods Used in SSVEP-Based BCIs. *Comput. Intell. Neurosci.* 2010, doi: 10.1155/2010/702357.

[16] Guangyu, B.; Xiaorong, G.; Yijun, W.; Bo, H.; Shangkai, G. VEP-Based Brain-Computer Interfaces: Time, Frequency, and Code Modulations [Research Frontier]. *IEEE Comput. Intell. Mag.* 2009, *4*, 22–26.

[17] Lee, P.; Hsieh, J.; Wu, C.; Shyu, K.; Wu, Y. Brain Computer Interface Using Flash Onset and Offset Visual Evoked Potentials. *Clin. Neurophysiol.* 2008, *119*, 605–616.

[18] Allison, B. Z.; McFarland, D. J.; Schalk, G.; Zheng, S. D.; Jackson, M.M.; Wolpaw, J. R. Towards an Independent Brain-Computer Interface Using Steady State Visual Evoked Potentials. *Clin. Neurophysiol.* 2008, *119*, 399–408.

[19] Dan, Z.; Alexander, M.; Xiaorong, G.; Bo, H.; Andreas, K.E.; Shangkai, G. An Independent Brain-Computer Interface Using Covert Non-Spatial Visual Selective Attention. *J. Neural Eng.* 2010, *7*, 016010.

[20] Wu, Z.; Lai, Y.; Xia, Y.; Wu, D.; Yao, D. Stimulator Selection in SSVEP-Based BCI. *Med. Eng. Phys.* 2008, *30*, 1079–1088.