ANALYSIS OF EFFECT OF SOUND LEVELS ON EEG

Renu Bhoria[1], Poonam Singal[2], Deepika Verma[3]
Department of Electronics and Communication Engineering,
Deenbandhu Chhotu Ram University of Science and Technology, Murthal, Sonepat, Haryana- 131039.
renubhoria@gmail.com, poonam.singal@rediffmail.com, deepika_crsce@yahoo.co.in

Abstract

This paper describes the effects of various levels of sound on brain using Electroencephalogram (EEG). In this study music (a form of sound) has been considered and analyzed. International 10-20 System has been used to get 19 channels of EEG signal. Consequently, the brainwave's signal has analyzed and the comparison between these different sound levels is discussed. This experiment focused mainly on two types of brain waves which are alpha (8-12 Hz) and beta wave (13-30 Hz). The analysis is carried out using Power Spectral Analysis method. Alpha wave is important as stress indicator meanwhile beta wave is associated with fast brain activity or disturbed situation of brain. High power of alpha waves and low power of beta waves that obtained during low levels of sound indicate that subjects were in relaxed state. However, when subjects exposed to 100db, beta waves power increased indicating subjects in disturbed state. Meanwhile, the decrease of alpha wave magnitude showed that subjects in tense.

Keywords- Electroencephalogram(EEG), Power Spectral Analysis.

Introduction

Many research studies conducted on the neurological effects of sound have shown that the human brain responds to pure tone in highly specific ways. PET Scans, which measure glucose consumption at the cellular level show that pure sound and music (without words) stimulate an increase of cellular activity in the right or “non-dominant” hemisphere of brain. Several studies have been conducted focusing on the effect of music intensity[1], emotion[1], and rhythm[2] on Electroencephalogram (EEG). Hearing different quality of sound, i.e. loud or soft, high pitch or low pitch, audible or inaudible etc., will have different effects on our brain. Here the effect of different sound level of music is studied. The human brain do produces different electrical activity due to the different levels of music.

Sound activates the pituitary adrenal-cortical axis and the sympathetic-adrenal-medullary axis [3]. In the acute and chronic noise experiments, researchers frequently found changes in stress hormones including epinephrine, norepinephrine and cortisol [3]. Number of studies [4] had showed that loud sound does affect human behavior and physiological measurement such as blood pressure, heart rate and blood flow. P. Lercher *et al*. reported the changes of behavior when exposed to the sound above 55 dB [4].

In this study, we used power spectral analysis to analyse to discover the EEG responses of subjects with different sound level of musical signal. Different bands of EEG have been defined to describe the different physiological conditions. In music-related researches, the band powers are important parameters.

A. Electroencephalogram (EEG)

The *electroencephalogram (EEG)* is defined as electrical activity of an alternating type recorded from the scalp surface after being picked up by metal electrodes and conductive media. The medical imaging technique that reads scalp electrical activity generated by brain structures is called Electroencephalography. The EEG measured directly from the cortical surface is called *electrocortiogram* while when using depth probes it is called *electrogram*. When brain cells (neurons) are activated, local current flows are produced. Only large populations of active neurons can generate electrical activity recordable on the head surface[5].

B. EEG Acquisition

EEG signals acquisition is very important requirement in biomedical engineering for signal analysis [5]. Signal acquisition is done by using recording electrodes appropriately placed on the head/scalp. Several different recording reference electrode placements are mentioned in the literature. In our experiments, the 10-20 System of electrode placement [figure1] is employed, which is based on the relationship between the location of an electrode and the underlying area of cerebral cortex (the "10" and "20" refer to the 10% or 20% inter-electrode distance). Electrode placements are labeled according to adjacent brain areas: F (frontal), C (central), T (temporal), P (posterior), and O (occipital). Encephalographic measurements employ recording system consisting of following parts:

- electrodes with conductive media
- amplifiers with filters
- A/D converter
- recording device.

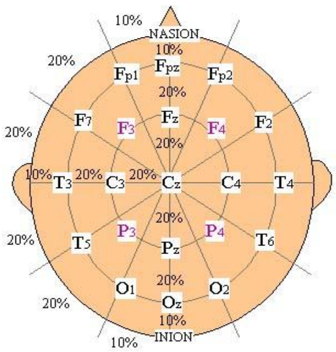

Figure1:Labels for points according to 10-20 electrode placement system

C. EEG Waves Classification

EEG measures brainwaves of different frequencies present within the brain [6]. The most widely used method of EEG analysis has been decomposition into different frequency bands based on the Fourier Transform. EEG consists of mainly four basic frequency components namely:

- Delta - 0.5-4 Hz - associated with the deep sleep
- Theta - 4-8 Hz - associated with drowsiness
- Alpha - 8-12 Hz - associated with relaxed, alert state of consciousness
- Beta - 14-30 - associated with active, busy or anxious thinking

Although none of these waves is ever emitted alone, the state of consciousness of the individuals may make one frequency range more pronounced than other. Figure2 represents various EEG wave patterns.

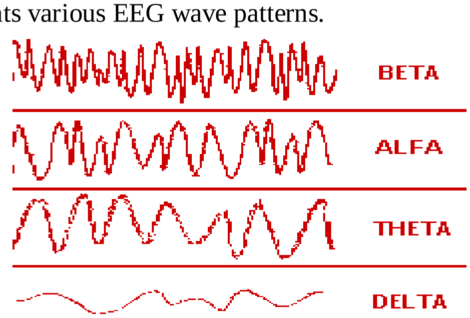

Figure2: Shows various EEG wave patterns

D. Sound Pressure Level

Sound is a sequence of waves of pressure that propagates through compressible media such as air or water. The perception of sound in any organism is limited to a certain range of frequencies. For humans, hearing is normally limited to frequencies between about 20 Hz and 20,000 Hz, although these limits are not definite. The upper limit generally decreases with age. Other species have a different range of hearing. Sound pressure is the difference, in a given medium, between average local pressure and the pressure in the sound wave. The faintest sound that a human ear can detect is known as the threshold of hearing**.** The most intense sound that the ear can safely detect without suffering any physical damage is more than one billion times more intense than the threshold of hearing. Since the range of intensities that the human ear can detect is so large, the scale that is frequently used by physicists to measure intensity is a scale based on multiples of 10. This type of scale is sometimes referred to as a logarithmic scale. The scale for measuring intensity is the **decibel scale**.

Decibel scale is the more general term used for the sound pressure level. Infact the real term is dBSPL. Sound pressure levels are measured without weighing filters. Decibel scale gives number in much more manageable range.

The threshold of hearing is assigned a sound level of 0 decibels (abbreviated 0 dB); this sound corresponds to an intensity of $1*10^{-12}$ W/m^2. A sound that is 10 times more intense ($1*10^{-11}$ W/m^2) is assigned a sound level of 10 dB. A sound that is 10*10 or 100 times more intense ($1*10^{-10}$ W/m^2) is assigned a sound level of 20 db.

E. Significance of research

This research concentrates on human brain activities particularly on alpha and beta waves state. The significant of this project is to study the effect of different sound level of music, on the brainwave. It is to determine by listening different levels that, what range of sound level is appropriate for human brain in listening music safely. Also, it is to determine, which decibel level will be more relaxing while music listening.

Subjects And Methods

A. Subjects

A total of 6 students voluntarily participated in this experiment. All of them were male aged between 24 to 27 years old with the same educational level background. All of them had been proved with no chronic medical history.

B. Experimental Conditions

EEG data was recorded at the Biomedical Lab (Department of Biomedical Engg.) in Deenbandhu Sir Chhotu Ram University of Sciences and Technology, Murthal, Sonepat. A total of 21 electrodes were used (Fp1, Fp2, F3, F4, F7, F8, T3, T4, T5, T6, C3, C4, P3, P4, O1, O2, A1, A2, Fz, Cz and Pz) placed in the positions set out by the International 10-20 System of Electrode Placement. All silver/silver chloride electrodes were referenced to linked earlobes, and impedances were kept below 5 kQ. The sample rate of EEG data is 200 Hz/s.

In this study, subjects were asked to keep their eyes closed and were made to listen same music with different sound levels at different times for 5 minutes. During this time period the respondents EEG was recorded.

The sound clip: The clip was presented through earphones. All clips were generated by the computer with a sample rate of 44,100 Hz in 16 bit stereo format. EEG recordings can be divided into four steps:

- When no music is provided
- When music of 60dB sound level is provided
- When music of 75 dB sound level is provided
- When music of 100dB sound level is provided

During the EEG acquisition the EEG signals have been segmented into silent, low, medium and high based on the nature of the experiments.

C. Power Spectral Analysis

The raw EEG data is obtained after signal acquisition and then filtering of the obtained signals is done. After the filtering of the EEG signals, alpha band (8 to 12Hz), beta band (12 to 30Hz), gamma band (30 to 50Hz) and theta band (4 to 8Hz) would be resulted.

Using power spectral analysis we calculated the absolute power of all frequency bands and observed the distribution of band power in frequency bands. Mainly the absolute power of two frequency bands, alpha and beta band has been analyzed in this experiment.

Results and Discussions

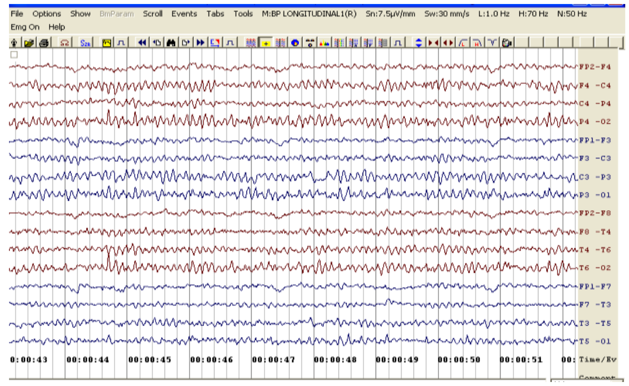

Figure 3: 16 channel EEG data plots

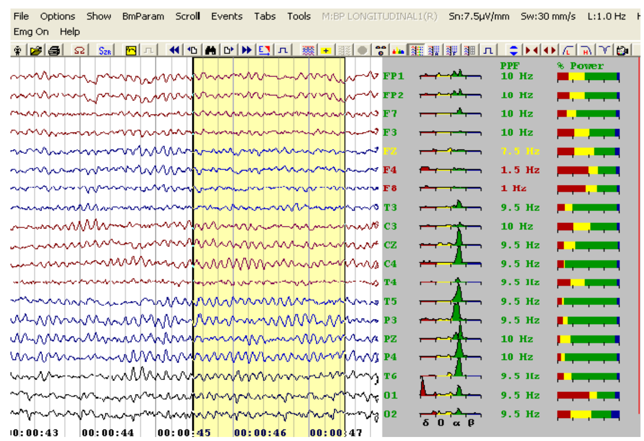

Figure 4: Shows two seconds of selected EEG with high α activity

The time courses of the 16 EEG channels are shown in figure 3. Figure4 represents 2 seconds of selected EEG for frequency analysis showing high activity of α band. Right side shows Power Spectra in **δ** , **θ** , **α** and **β** bands , **PPF** (Peak Power Frequency) and contribution of each band in total Power for each electrode.

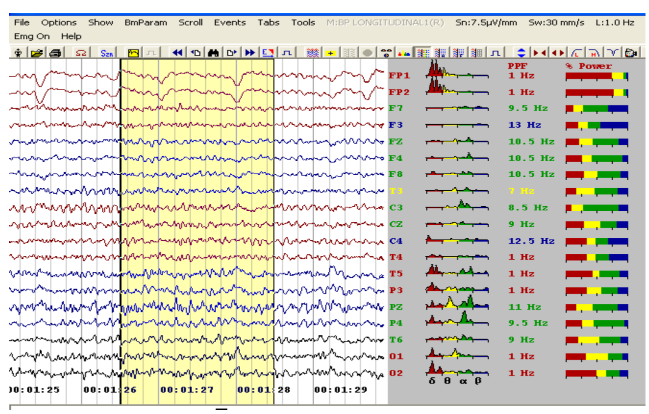

Figure5 represents 2 seconds of selected EEG for frequency analysis showing reduced activity of α band and high activity of β band.

In our study, in the first three cases i.e when no music, 60 dB and 75dB sound level is applied, the absolute power of alpha band was found very high, which showed the subjects in relax condition. But when music of 100 dB sound level was applied than alpha band power decreased and beta band power increased, which showed the subjects in disturbed condition. Hence, the results of analysis showed that as the loudness of music increases to 100db the absolute power of beta band increases and absolute power of alpha band decreases, which was higher in all other cases.

Conclusion

In our work, Power Spectral Analysis method is used to analyze the effect of various sound levels with increasing loudness. The results showed that loud sound does effect the human brain adversely. So, long exposure to loud music may lead to harmful effects.

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