Estimate the Activation of EEG Bands from Different Brain Lobes with Classified Music Stimulation

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Abstract

Physiological research with human brain is getting more popular because it is the center of human nervous system. Music is a popular source of entertainment in modern era which affects differently in different brain lobes for having different frequency and pitch. The brain lobes are divided into frontal, central and parietal lobe. In this paper, an approach has been proposed to identify the activated brain lobes by using spectral analysis from EEG signal due to music evoked stimulation. In later phase, the impact of music on the EEG bands (alpha, beta, delta, theta) originating from different brain lobes is analyzed. Music has both positive and negative impact on human brain activity. According to linguistic variation, subject age and preference, volume level of songs, the impact on different EEG bands varies. In this work, music is categorized as mild, pop, rock song at different volume level (low, comfortable and high) based on Power Spectral Density (PSD) analysis. The average PSD value is 0.21 W/Hz, 0.32W/Hz and 0.84W/Hz for mild, pop and rock song respectively. The volume levels are considered as 0%-15% volume level for low volume, 16%- 55% volume level for comfortable volume and 56%-100% volume level for high volume. At comfortable volume level the central lobe of the brain is more activated for mild song and parietal lobe is activated for both pop and rock songs based on logarithmic power and PSD analysis. A statistical test two- way ANOVA has been conducted to indicate the variation in EEG band. For two-way ANOVA analysis, the P-value was taken as 0.05. A topographical representation has been performed for effective brain mapping to show the effects of music on the EEG bands for mild, pop and rock songs at the mentioned volume level. The maximum percentage of alpha band activation is 60% in comfortable volume which decreases with high volume and it indicates that, when the music stimuli moved towards the high-volume level, human cognition state moves from relax to stress condition due to the activeness of beta band. A Graphical User Interface (GUI) has been designed in MATLAB platform for the entire work.

Keywords: EEG, Spectral Analysis, ANOVA, Topography, Graphical User Interface.

1. INTRODUCTION

Human brain controls human Central Nervous System (CNS) that assimilates all data, minimal and re-wires existing information and incorporates all into a steady affair. The intricacies of human brain can be realized by identifying the activated brain region at different environmental condition. According to anatomical perspective brain can be sub-divided into three regions:

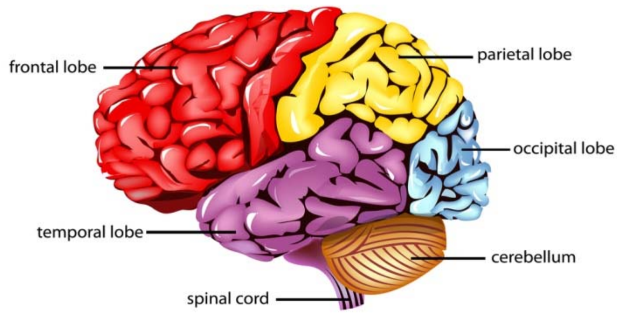

FIGURE 1: Structure of Human Brain and Its Lobes [5].

The Cerebrum, the Cerebellum and the Brain-stem. The largest part of the brain is cerebrum or cortex. Active thinking, action taking and control are associated with the cortex. It consists of two hemispheres: Left and Right. Moreover, the cerebral cortex is made of with four lobes i.e., occipital, temporal, parietal, frontal lobe. Occipital lobe responsible for visual processing of the brain. It is also associated with colour. Long term memory, language comprehension, processing and production are associated with temporal lobe [1]. All the information that brain absorbs are being integrated in parietal lobe. Motor behaviour and object-oriented actions are associated with this lobe. Frontal lobe is responsible for most active thinking of the brain and it is associated with short-term memory, planning and motivation [2]. The Cerebellum is responsible for regulation and control of fine movements, posture and balance. 80% of brain neurons are held by this portion of the brain. The Brainstem is the posterior part of the brain and older, comprising the midbrain, pons and medulla. It houses many of the control centres for important body functions such as breathing, bladder functions and vasomotor control [3]. With phylogenetically old limbic, other subcortical structures and their connections the Limbic system is formed and it deals with three key functions i.e., emotions, memories and arousal [4]. Figure 1 indicates the structure of the brain and its lobes.

Electroencephalogram or EEG is a measuring tool for analysing intricate activity of brain signal that is generated by millions of brain neurons [6]. EEG signal is related with brain regions or lobes and it can directly measure the neural activity. EEG consists of five frequency band: Delta band, Theta band, Alpha band, Beta band and Gamma band [7]. The oscillation of the brain within range 0.5Hz–4Hz is considered as delta band. Delta band is associated with deep unconsciousness, intuition and insight. Delta waves are normally located in frontal lobe of the adults and for children, located in posterior portion of the brain. Theta band is associated with deep meditation and it ranges from 4 Hz to 8 Hz. These waves are generated from thalamic region of the brain. Alpha waves are considered as the wave of active thinking and it ranges from 8 Hz to 13 Hz. Alpha waves are generated from left Parietal lobe or right/left Occipital lobe and responsible for the cognitive activity at relax state. Beta band ranges from 14 Hz to 30 Hz and is responsible for awaken state specially indicates the mental loading or stress. Beta bands are generally produced from frontal and parietal lobe. Gamma band ranges above 30 Hz and it is considered as the waves of abnormal condition. These types of waveforms can be generated from somatosensory cortex during abnormal behaviour of brain. Table 1 shows different bands of the EEG signal and their corresponding frequency with generation region [8].

In this work, music stimuli have been selected with their different genre and pitch to show the indication of brain relaxation or stress level. EEG band which originates from brain regions also get affected by the different types of music stimulation. Pituitary adrenal-cortical hub and the thoughtful adrenal-medullary pivot and the psychological exhibitions are influenced in the wake of listening songs [9], [10]. Cerebrum signal which is named as electroencephalogram (EEG) can be differed by change in neurons and neurotransmitters movement by listening songs [11]. Electrons stream when there is an adjustment in cerebrum movement and this action produces signal and estimating strategy of these signs should be possible by electroencephalogram. Every one of

Band	Frequency Range (Hz)	State	Location
Delta	0.5 - 4	Deep sleep	Frontal and posterior regions
Theta	4 - 8	Light sleep	Just above the brain stem between cerebral cortex and midbrain
Alpha	8 - 13	Relax state with eyes open	Posterior regions
Beta	13 - 30	Alert, active, awake state	Frontal and parietal lobes
Gamma	Above 30	Abnormal condition	Somatosensory cortex (Central brain)

TABLE 1: Different bands of EEG signal and their corresponding frequency range and location.

song has its own frequency range as indicated by which songs can be characterized. Distinctive frequency range or diverse volume level of songs affects diverse brain region. In this paper, actuated mind district is distinguished while tuning in to various sorts of songs at various volume levels.

Many research works are done showing that different types of songs have different effects on the brain. EEG responses of human brain during listening to different music were studied by Independent Component Analysis (ICA) in [12]. The level of enjoyment during music listening is studied by calculating cross-correlation between sound stimuli and EEG signals and a topographical analysis is presented in [13].The effect of music on central nervous system (CNS) from EEG signal using average mutual information and phase-space reconstruction of the signal is experimented in [14].EEG band variation during musical stimuli has been determined by band symmetry, sample entropy and statistical analysis [15]. Authors in [16] had investigated the signatures of EEG by calculating power spectral density of EEG bands for two different music phrases. While listening to passive unconstrained music, the frequency bands of EEG are increased in power level [17]. Many studies have claimed that music stimuli can activate alpha band or beta band. In [18], authors had stated that a relax music stimuli can activate alpha band by reducing the beta band and it is analysed by independent component analysis. In [19], authors have estimated the activation of different EEG bands during listening to different songs which have been categorized according to their PSD value. In this research work, the three types of music mild, pop, rock are categorized based on their power spectra and their impact on brain are analyzed. These three types of songs have enormous effect on EEG bands. These bands effects are analysed with statistical approach, ANOVA and topographical approach is implied for brain mapping. The block diagram of the proposed approach is shown in FIG. 2. In this paper, Section 2 describes the methodology of the proposed work. Result and Discussion is shown in Section 3 and Section 4 concludes the result.

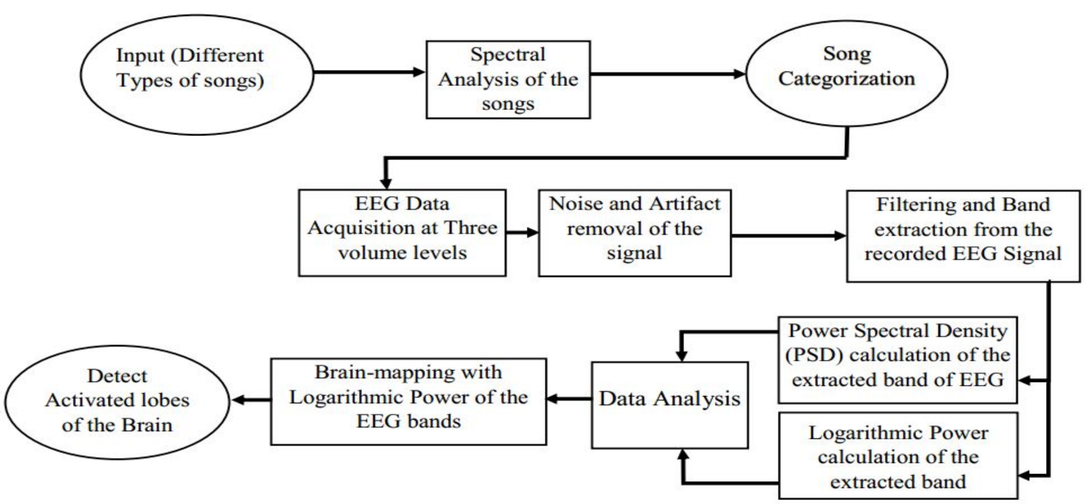

FIGURE 2: Proposed Workflow Diagram of This Research.

2. METHODOLOGY

It is important to process the raw signal for analysis and to identify the activated brain regions with different types of music. Spectral analysis is being performed to extract power spectral density and logarithmic power of raw EEG signal in different brain regions according to which brain activation regions can be identified.

2.1 Song Selection and Subject Preparation

The selected songs for this study were categorized into three types: Mild, Pop, and Rock based on their mean PSD value. The songs could be also categorized on the basis of their frequency spectrum where the PSD is a major component of frequency spectrum [20]. For each type of song ten examples i.e., total thirty songs were considered to determine their power spectral density. Each song was trimmed in 60 seconds length. Power spectral density of each type of songs is almost similar *i.e.*, for ten pop songs, the values are almost same which is easily noticeable from their value of standard deviations. The mean power spectral density (PSD) value has been shown in Table 2. These songs were used as stimuli for EEG data acquisitions.

2.2 Data Acquisition Protocol

In this study, for the EEG data acquisition 9 channel B-Alert X-10 wireless system [21] has been used that acquires EEG data from three major parts of the brain i.e., frontal, central, and parietal lobe. This system covers the F3, Fz, F4, C3, C4, Cz, P3, Poz, and P4 positions according to the international 10/20 system. Different regional data of brain is collected by the help of positioning the electrodes in the frontal, central and parietal lobe. There were 38 volunteers participated in this data acquisition having no psychological and hearing disorder and the experimental room was quite calm and air-conditioned. The participants were verbally informed about the data acquisition protocol and their written consent regarding data acquisition was collected before data acquisition. It is also confirmed by the author that during data acquisition period no violation of Helsinki Principle was occurred [22]. Three types of songs (Mild, Pop, Rock) were selected for the hearing stimuli. The songs were classified on the basis of their power spectral density. Each type of song has three trials and they were of averagely 60 seconds long. Before data acquisition for the concerned stimuli the EEG signal of relaxed state with eyes closed was recorded for each participant as control. During data acquisition the participant was sitting on non-movable chair with the eyes closed to avoid the artifacts regarding eye movement during EEG signal collection. Therefore, the total data acquisition procedure is shown in FIG. 3. Figure 4 shows the recorded EEG signal with 9 channels B-Alert X10.

2.3 Data Filtering and Removal of Noise

B-Alert X-10, Acknowledge 4.1, MATLAB 2018a are used for data acquisition, analysis, storage, and retrieval of the acquired signal. In data processing session several steps have been taken to process the recorded data. Different types of filter such as notch filter, elliptic filter have been used for filtering purpose. For the preliminary processing the recorded data have been filtered by a stop band which is also known as Notch filter. A notch filter with tunable notch frequencies can be designed to process a signal [23]. Elliptic filtering has been used to extract different EEG bands from the raw EEG signal.

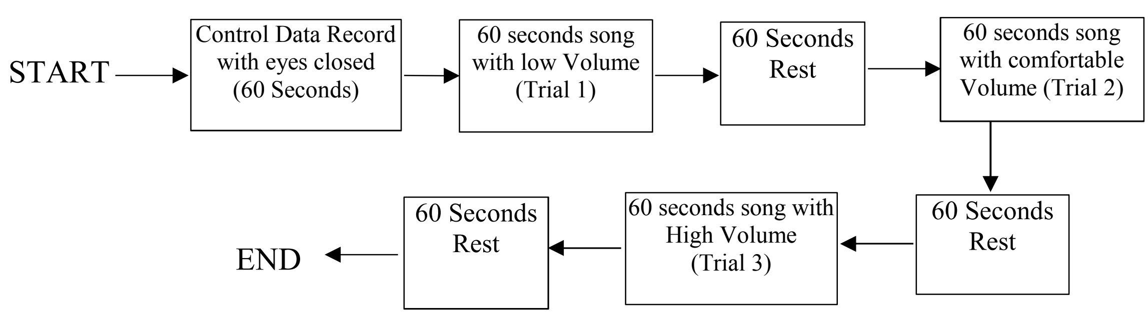

FIGURE 3: Proposed Approach for EEG Signal Recording.

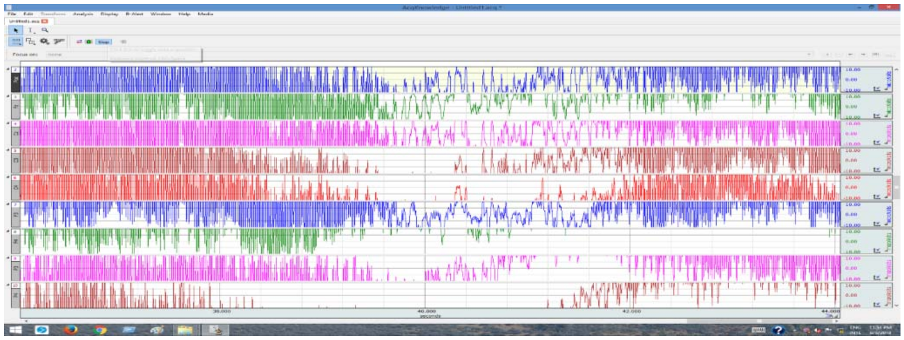

FIGURE 4: Recorded EEG Signal with 9 Channels B-Alert X10.

By using notch filter the noise of the signal can be eliminated. Eq. (1) expresses the transfer function of the notch filter.

$$\frac{Y(s)}{U(s)} = \frac{s^2+\omega_n{}^2}{s^2+2\omega_n s+\omega_n{}^2} \tag{1}$$

After notching, the filtered data were used in next processing step. Elliptic filter was used for extracting the bands of the EEG signal i.e., Alpha, Beta, Theta, Delta and Gamma band. An elliptic filter offers to adjust the ripple for both pass-band and stop-band and it is characterized by fastest transition between pass-band. Eq. (2) expresses the gain (G_n) of a lowpass elliptic filter as a function of angular frequency ω.

$$G_n(\omega) = \frac{1}{\sqrt{1+\varepsilon^2 R^2(\xi\frac{\omega}{\omega_0})}} \tag{2}$$

Where, R_n is the n[th] order elliptic rational function, ω_0 is the cut-off frequency, ξ is the selectivity factor and ε is the ripple factor.

2.4 Spectral Analysis

For spectral analysis of multi-channel Signal, it is important to filter the signal and artefacts should be removed [24]. Spectral analysis reflects the analysis of a signal in frequency domain and in frequency domain analysis frequency spectrum of a signal indicates the frequency component of a signal. Among all frequency domain analysis Power spectral density (PSD) ensures a strong measurement in calculating the signal power versus frequency. The amplitude of the PSD is normalized by the spectral resolution employed to digitize the signal. Moreover, it indicates how a power of a signal is distributed over frequency. If the signal is divided into frequency components, power spectral density calculation turns into another process. Power spectral density of on-sided frequency domain signal can be expressed as Eq. (3) [20].

$$\int_0^Q F_{psd}(x)dx = \int_0^Q \frac{2|p(x)_r^2|}{|t_2-t_1|}dx \tag{3}$$

Where, integration limit sets from 0 to Q (on-sided frequency domain) according to fast Fourier transform and the calculation is in the time range of t_2 to t_1. P (x) is the function of frequency components of harmonic number r. Non-parametric methods find the autocorrelation sequence and power spectral density can be calculated by transforming the signal into frequency by fast Fourier transform. Sequence function can be expressed as Eq. (4).

$$X_n(t) = X(t+np);\ t = 0,1,2,\ldots.q-1;\ While\ n = 0,1,2,\ldots.r-1. \tag{4}$$

Where, $X_n(t)$ the information sequence for calculating power spectral density, np is the start of the sequence and 2q represents data segment that are formed from the r length data [20]. In this research 256 samples are considered as calculating the power spectral density.

Logarithmic power calculates the overall power of a signal. This power is considered as regional power of the brain in this study. To calculate the logarithm of the power, it is necessary to calculate the power of each EEG band. The band power of frontal, parietal and central lobe has been calculated as logarithm of the mean power of the recorded EEG signal.

$$P_{band} = \frac{1}{N}\sum_{1}^{N}\left(x_{np}\right)^2 \quad (5)$$

Where, x_{np} is magnitude of pth frequency band of the nth sample, N is the number of samples, P_{band} is power in a specified frequency band.

3 RESULT AND DISCUSSION

3.1 Spectral Analysis of the Music Stimuli

For music stimuli, different songs have been categorized in three major types: Mild, Pop, and Rock based on their spectral analysis and the values of power spectral density. From their spectral analysis, difference between their genre can be identified. Their average PSD values and variation based on their power spectral density has been shown in Table 2. These songs have been listened by the participants in three different volume: low (0%-14% volume level), comfortable (15%-60% volume level) and high (61%-100% volume level).

Song	PSD Value (Watts per Hertz)
Mild	0.1214 – 0.2814
Pop	0.3172 – 0.3632
Rock	0.7448 – 0.9446

TABLE 2: The categories of the songs according to their mean power spectral density range.

3.2 EEG Band Activation in Different Brain Region

EEG signal usually classified according to their frequency, amplitude as well as the position of electrodes on the scalp. Recorded EEG signal after filtering phase is used to calculate the logarithmic power. Total recorded signal has been divided into three parts on the basis of their collection region of brain. For three different regions of the brain: frontal, central and parietal lobe logarithmic power was calculated. Table 3 shows the normalized values of logarithmic power of EEG signals that have been extracted from three brain regions. The participants have heard the songs in three different volume levels. When the volume level was less than 15%, there was no consistency in values of logarithmic power of brain lobes for the three types of song. For a

Volume level	MILD			POP			Rock		
	Frontal	Central	Parietal	Frontal	Central	Parietal	Frontal	Central	Parietal
Less than 15%	1.714	1.694	1.630	1.345	1.697	1.686	1.589	1.534	1.596
	1.652	1.556	1.591	1.513	1.961	1.916	1.494	1.435	1.486
	1.716	1.611	1.668	1.186	1.531	1.437	1.397	1.479	1.432
16% to 55%	1.523	2.296	1.219	1.577	1.003	1.535	1.469	1.280	1.427
	1.342	2.202	1.186	2.455	1.053	2.338	1.575	1.234	1.472
	1.0405	2.179	1.548	1.736	1.140	1.655	1.839	1.725	1.806
Above 56%	1.588	1.689	1.684	1.589	1.627	1.666	1.643	1.642	1.648
	1.698	1.545	1.595	1.811	2.014	2.053	1.551	1.601	1.686
	1.543	1.668	1.697	1.653	1.713	1.722	1.530	1.576	1.631

TABLE 3: Logarithmic power of EEG signal collected from three brain region (Data for three subjects have been shown).

volume level under 15% it is difficult to hear the songs and it will create a stress on the brain. Therefore, no particular brain region is dominating for the signal which was collected keeping the volume level under 15%. For the volume level within the preferable limit, i.e., volume level ranges from 16% to 55%, the logarithmic power indicated that central lobe data is activation is higher for mild songs. But for the pop and rock songs it is found that parietal lobe is dominating the other lobes. Above 56% of volume level, the results are found as non-consistent for different subjects. So, in this research the volume level is selected between the range 16%-55% for brain activation analysis because it is the preferable sound range for the subjects.

3.3 Brain Lobes Activity Identification with PSD

The power spectral density (PSD) then refers to the spectral energy distribution that would be found per unit time, since the total energy of such a signal over all time would generally be infinite. This method is applied in order to selectivity represent the EEG signal extracted from three brain regions. PSD calculates autocorrelation sequence which is found by nonparametric methods. PSD values of recorded EEG signal during hearing the mild, rock and pop music are shown in Table 4. Central lobe is more activated for mild songs and Parietal lobe activation is more for both pop and rock songs. From the results of PSD, the activation of brain region supports the logarithmic band power.

Trial	MILD			POP			Rock		
	Frontal	Central	Parietal	Frontal	Central	Parietal	Frontal	Central	Parietal
1	0.125	0.203	0.166	0.206	0.139	0.204	0.188	0.142	0.186
2	0.156	0.179	0.141	0.170	0.143	0.162	0.232	0.130	0.213
3	0.304	0.698	0.567	0.219	0.161	0.190	0.245	0.23	0.232
4	0.347	0.420	0.331	0.254	0.329	0.365	0.252	0.305	0.325
5	0.202	0.239	0.227	0.354	0.316	0.348	0.269	0.330	0.310
6	0.319	0.438	0.386	0.400	0.385	0.330	0.341	0.305	0.317
7	0.371	0.443	0.347	0.184	0.145	0.172	0.406	0.398	0.399
8	0.198	0.266	0.200	0.194	0.125	0.193	0.365	0.350	0.335
9	0.242	0.285	0.229	0.126	0.111	0.124	0.190	0.182	0.178

TABLE 4: Power Spectral Density (W/Hz) of different brain regions while listening different music at comfortable volume (16% - 55%) level.

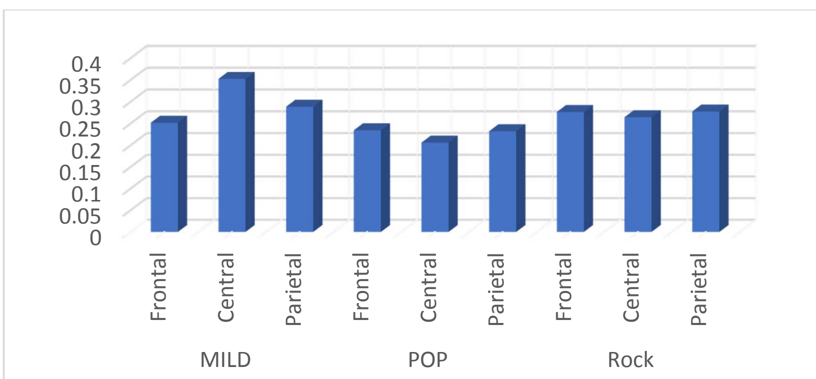

FIGURE 5: Bar plot of average PSD value of brain regions while listening different songs at comfortable volume.

3.4 Topological Representation

Topographical representation has been performed for brain-mapping which actually indicates the activation of EEG bands in different brain lobes during listening to the mild, pop and rock songs at different volume level. In this paper, alpha band activity has been shown for different brain lobes. It indicates if alpha band is more activated for different songs and at different brain lobes then stress level of the brain is less so beta band activation is less and alpha band activation is less then beta band is more activated, so stress level increases at different brain lobes. The percentage of alpha band activation at different brain lobes for different songs at different volume level is shown in Table. 5. The activation of alpha band for mild songs at different volume level is shown in FIG.6. It is shown that at comfortable volume level alpha band is most effective in central region of the brain which is 56% of the total brain. The activation of alpha band for pop songs at different volume level is shown in FIG.7. It is shown that at comfortable volume level alpha band is most effective in frontal region of the brain which is 51% of the total brain. The activation of alpha band for pop songs at different volume level is shown in FIG.8. It is shown that at comfortable volume level alpha band is most effective in frontal region of the brain which is 47% of the total brain.

Volume level	MILD			POP			Rock		
	Frontal	Central	Parietal	Frontal	Central	Parietal	Frontal	Central	Parietal
Less than 15%	52%	30%	18%	30%	48%	22%	38%	43%	19%
16% to 55%	15%	56%	29%	51%	35%	14%	47%	31%	22%
Above 56%	34%	45%	21%	30%	16%	54%	38%	15%	47%

TABLE 5: Percentage of alpha band activity in brain lobes for the songs at different volume level.

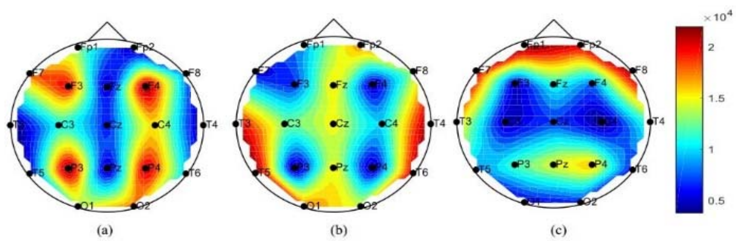

FIGURE 6: Brain mapping through topographical representation for estimating alpha band activity of mild song at (a) comfortable, (b) low, (c) high volume.

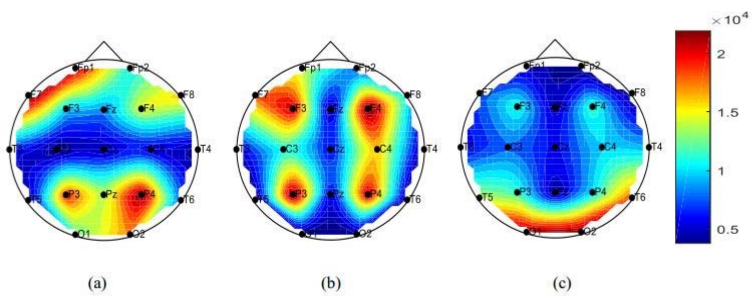

FIGURE 7: Brain mapping through topographical representation for estimating alpha band activity of pop song at (a) comfortable, (b) low, (c) high volume.

3.5 Statistical Analysis

A two-way ANOVA (Analysis of variance) is conducted to find the significant variations of EEG signal among the EEG bands with respect to the comfortable and high-volume level. ANOVA is a way to find out the significance of the experiment results by dividing the values into two groups. Here one group variable is the lobes (Frontal, Central, and Parietal) and the other group is prepared with the corresponding log power values of the regarding stimuli. The same analysis was performed on the PSD values of the EEG signal. The significance level was set to 0.05 and if the P-value of the test greater than the significance level there is no variation in the results. From the results, it is found that both the values of log power and PSD had the significant variations in the three lobes. The variations were found for the alpha and beta bands.

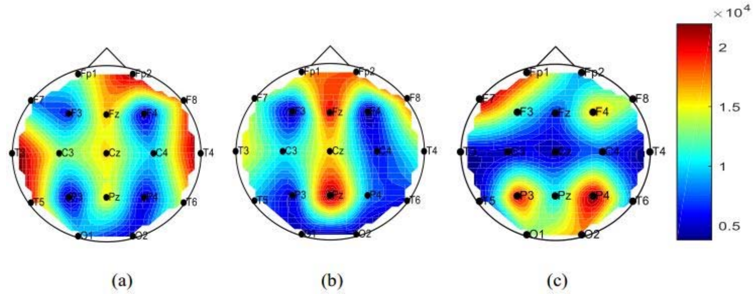

FIGURE 8: Brain mapping through topographical representation estimating alpha band activity of rock song at (a) comfortable, (b) low, (c) high volume.

When the participants were listening to mild songs in medium volume level, the variation in alpha band $(F\ (2,8)\ = 3.9, 5.02;\ P - values < 0.05)$ has been found. The variation in beta band $(F\ (2,8)\ =\ 5.13, 6.07);\ P - values < 0.05)$ has been also found in the experiment. These variations denote that, there is a difference between the effects when a subject listens the mild songs in low and in comfortable volume. In addition, there is a significant variation for both pop and rock songs in lobe to lobe and volume level to volume level difference. Table 7 and Table 8 shows the detail information of F-values and P-values of the corresponding band for log power and PSD values respectively. Table 8 shows the property variations of different EEG bands among the low and comfortable volume level as well as high and confortable volume level. The F-value denotes the interaction which is basically used for establishing relationship between factor and significance level. From the entire discussion for the ANOVA test result it can be stated that, there is a variation between in EEG bands while listening to different songs at different volume.

Song Type	Bands	F values (2,8)	P values
Mild	Alpha	F (2,8) =3.9, 5.02	0.0416, 0.003
	Beta	F (2,8) = 5.13, 6.07	0.0189, 0.0011
	Delta	F (2,8) = 0.79, 2.24	0.4696, 0.0816
	Theta	F (2,8) = 1.7, 6.71	0.2134, 0.0006
Pop	Alpha	F (2,8) = 8.91, 14.59	0.006, 0.0003
	Beta	F (2,8) = 4.68, 2.46	0.0368, 0.1054
	Delta	F (2,8) =2.49, 2.56	0.1328, 0.0963
	Theta	F (2,8) = 3.08, 33.02	0.0907, 0
Rock	Alpha	F (2,8) = 16.82, 17.26	0.0006, 0.0001
	Beta	F (2,8) = 2.49, 1.11	0.1323, 0.4139
	Delta	F (2,8) = 0.48, 2.79	0.6332, 0.0784
	Theta	F (2,8) = 1.32, 13.48	0.3097, 0.0004

TABLE 7: ANOVA test result for log power for EEG bands (Variation in Lobe to Lobe).

3.6 Graphical User Interface (GUI) Design

A Graphical User Interface (GUI) has been developed using AppDesigner in MATLAB 2018a to show the entire work in a single frame. The GUI has been designed for the multiple songs input which can be randomly selected from the source and they will be categorized according to their PSD value.

In FIG. 9 GUI popup menu has been shown. The categorization of the songs and their corresponding EEG data, topographical representation, PSD value, logarithmic power has been shown in FIG.10 and 11 respectively. In FIG. 12 ANOVA test result between alpha and beta band has been extracted by GUI.

Song Type	Bands	F values (2,8)	P values
Mild	Alpha	F (2,8) =7.06, 9.75	0.0122, 0.0013
	Beta	F (2,8) = 9.31, 20.7	0.0052, 0.0001
	Delta	F (2,8) = 1.02, 2.31	0.3964, 0.1214
	Theta	F (2,8) = 0.64, 1.97	0.5474, 0.1684
Pop	Alpha	F (2,8) = 13.57, 1.3	0.0014, 0.3368
	Beta	F (2,8) = 17.64, 5.24	0.0005, 0.0128
	Delta	F (2,8) =1.53, 5.71	0.2631, 0.0096
	Theta	F (2,8) = 12.22, 10.07	0.0021, 0.0012
Rock	Alpha	F (2,8) =23.32, 4.3	0.0002, 0.0239
	Beta	F (2,8) = 5.16, 2.04	0.0289, 0.1577
	Delta	F (2,8) = 0.01, 3.16	0.9865, 0.0390
	Theta	F (2,8) = 5.98, 4.17	0.0196, 0.0262

TABLE 8: ANOVA test result for power spectral density of EEG bands.

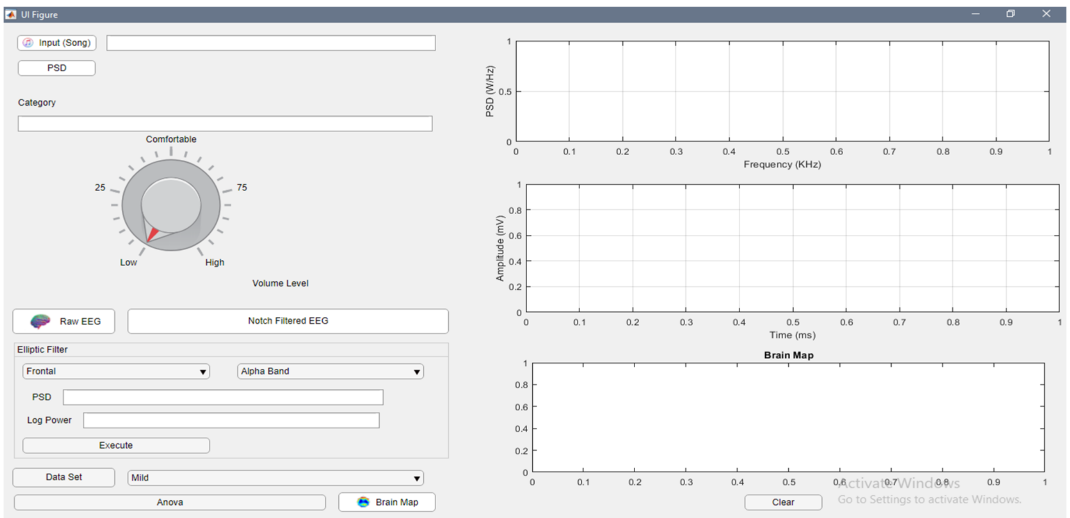

FIGURE 9: GUI Popup Menu.

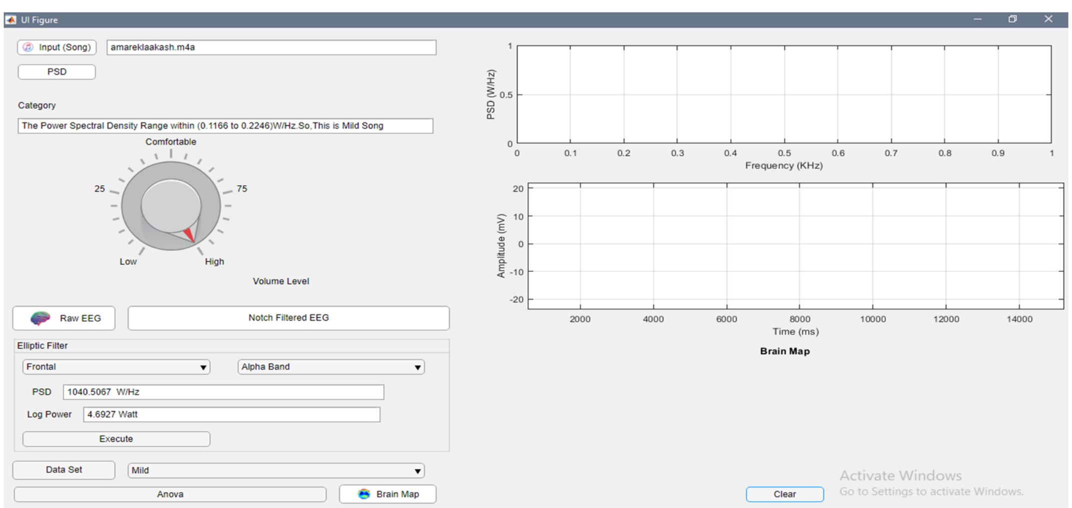

FIGURE 10: Categorization of The Songs with PSD Analysis.

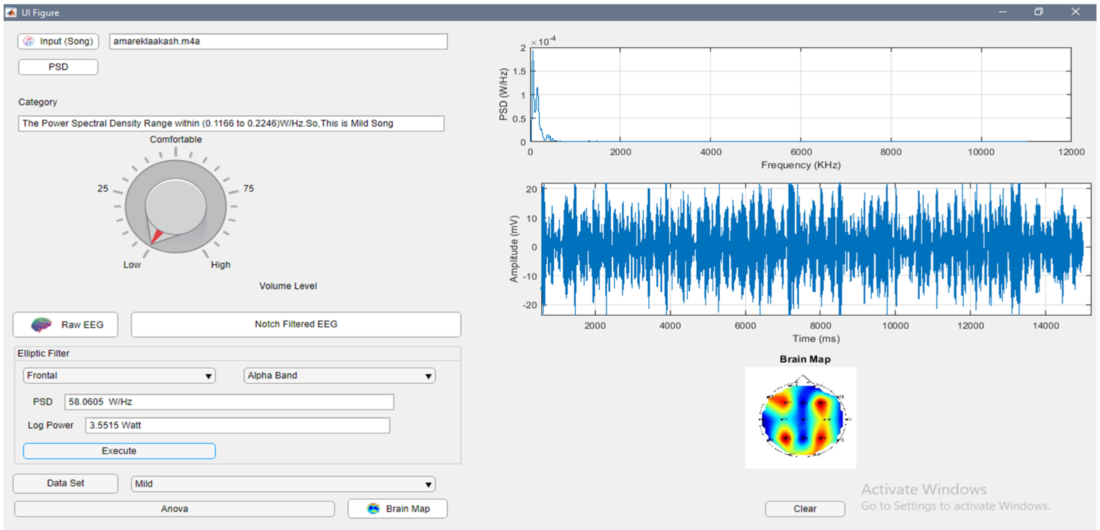

FIGURE 11: Song categorization, PSD value and corresponding alpha band and brain-mapping for mild song at low volume.

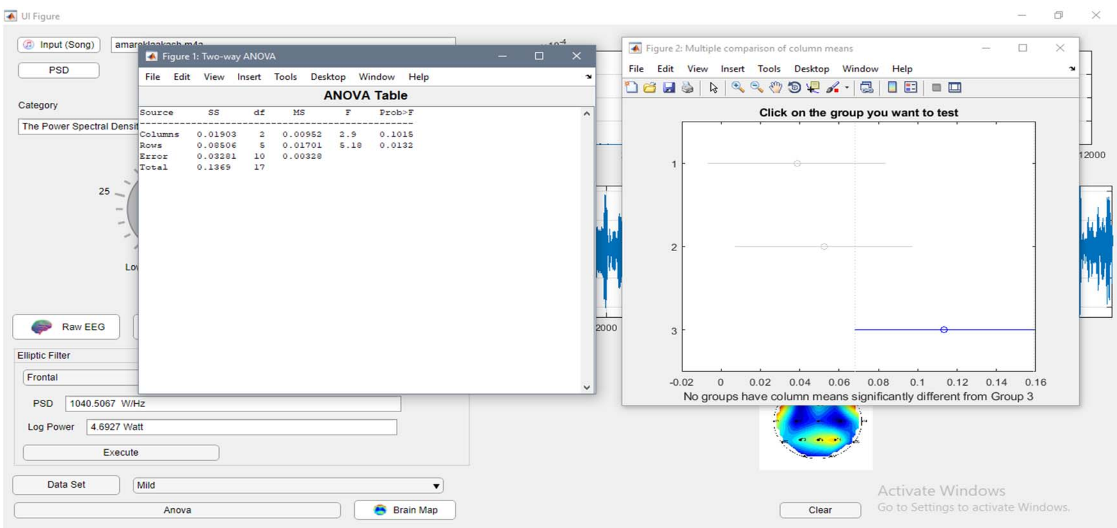

FIGURE 12: ANOVA test result of the EEG signal for the selected mild song between alpha and beta band.

4 CONCLUSION

This work states the effect of mild, rock and pop songs on different bands of EEG signal which have been categorized according to their power spectral density. The correlation coefficient varies from 0.0318 to 0.048 which indicates that there exists largest variation among different types of songs which affects differently on individual EEG bands. The average PSD values for mild, pop, rock songs are 0.2114, 0.3272 and 0.8448 W/Hz respectively. Raw EEG signals of the subjects were collected at three different volume levels which were less than 15%, 16% to 55% and above 56% by B-alert X-10. Tunable notch filter is being used for signal filtering which is passed through an elliptic filter for extraction of individual EEG bands. A two-way ANOVA was designed to investigate significant variation among the bands. Brain-mapping has been performed for the topographical representation. While listening songs at comfortable volume level (15%-60%), largest variation is observed for alpha band which is 60%, 52%, 45% for mild, pop and rock songs respectively which keeps the subject relax while for lower or highest volume level the activation region of alpha band decreases and beta band gets more activated which keeps the subject more stressed. So, this is an innovative approach to indicated the activity of different EEG bands while listening songs which will play a significant role in physiological research area of human cognition. This study proposed a dynamic approach to identify the activated brain region for different songs. Spectral analysis is done to extract power spectral density and logarithmic power at different lobes. For the sound volume level less than 15%, there was no consistency in result to identify active brain region for different subjects. For the volume level between 16% and 55%, consistent result is found. In this volume level, central lobe of the brain is activated for mild songs and parietal lobe is activated for both pop and rock songs. From this study, it can be concluded that brain response to different songs affects human brain lobes differently with different sound level and different song category. A Graphical User Interface (GUI) has been successfully designed to extract all the features that requires in this thesis in a single frame.

5 REFERENCES

[1] Suto, J., & Oniga, S. (2018). Music Stimuli Recognition in Electroencephalogram Signal. *Elektronika ir Elektrotechnika*, *24*(4), 68-71.

[2] Schellenberg, E. G. (2012). Cognitive performance after listening to music: A review of the Mozart effect. *Music, health, and wellbeing*, 324-338.

[3] Staeren, N., Renvall, H., De Martino, F., Goebel, R., & Formisano, E. (2009). Sound categories are represented as distributed patterns in the human auditory cortex. *Current Biology*, *19*(6), 498-502.

[4] Rajmohan, V., & Mohandas, E. (2007). The limbic system. *Indian journal of psychiatry*, *49*(2), 132.

[5] Froneman, T. (2019). The Assessment of Concussion Recovery Using Electroencephalography.

[6] iMotions Biometric Research Platform (2016). EEG Pocket Guide.

[7] Kumar, J. S., & Bhuvaneswari, P. (2012). Analysis of Electroencephalography (EEG) signals and its categorization–a study. *Procedia engineering*, *38*, 2525-2536.

[8] Hasan, M. K., Al Mahmud, N., Hossain, M. S., & Ahmad, M. (2015, December). Alpha band dependency of EEG signal on different stimulation of brain for human computer interaction. In *2015 2nd International Conference on Electrical Information and Communication Technologies (EICT)* (pp. 148-151). IEEE.

[9] Nawrocka, A., & Holewa, K. (2014). The Analysis of the Different Frequencies Sound Waves Effect on the EEG Signal. In *Solid State Phenomena* (Vol. 208, pp. 177-182). Trans Tech Publications.

[10] Soeta, Y., & Nakagawa, S. (2012). Auditory evoked responses in human auditory cortex to the variation of sound intensity in an ongoing tone. *Hearing research*, *287*(1-2), 67-75.

[11] Mercadié, L., Caballe, J., Aucouturier, J. J., & Bigand, E. (2014). Effect of synchronized or desynchronized music listening during osteopathic treatment: An EEG study. *Psychophysiology*, *51*(1), 52-59.

[12] Lin, W. C., Chiu, H. W., & Hsu, C. Y. (2006, January). Discovering EEG signals response to musical signal stimuli by time-frequency analysis and independent component analysis. In *2005 IEEE Engineering in Medicine and Biology 27th Annual Conference* (pp. 2765-2768). IEEE.

[13] Kumagai, Y., Arvaneh, M., & Tanaka, T. (2017). Familiarity affects entrainment of EEG in music listening. *Frontiers in human neuroscience*, *11*, 384.

[14] Dey, A., Palit, S. K., Bhattacharya, D. K., & Tibarewala, D. N. (2014, April). Study of the effect of different music stimuli on autonomic nervous system of a single subject. In *2014 International Conference on Communication and Signal Processing* (pp. 1322-1326). IEEE.

[15] Nawaz, R., Nisar, H., & Voon, Y. V. (2018). The Effect of Music on Human Brain; Frequency Domain and Time Series Analysis Using Electroencephalogram. *IEEE Access*, *6*, 45191-45205.

[16] Schaefer, R. S., Vlek, R. J., & Desain, P. (2011). Music perception and imagery in EEG: Alpha band effects of task and stimulus. *International Journal of Psychophysiology*, *82*(3), 254-259.Markovic, A., Kühnis, J., & Jäncke, L. (2017). Task Context Influences Brain Activation during Music Listening. Frontiers in Human Neuroscience, 11.

[17] Straticiuc, V., Nicolae, I. E., Strungaru, R., Vasile, T. M., B jenaru, O. A., & Ungureanu, G. M. (2016, June). A preliminary study on the effects of music on human brainwaves. In *2016 8th International Conference on Electronics, Computers and Artificial Intelligence (ECAI)* (pp. 1-4). IEEE.

[18] Haque, C. A., Islam, M., Saad, A. M., & Yusuf, M. S. U. (2019, February). An Approach to Estimate the Activation of Different Bands of EEG Signal using Classified Songs. In *2019 International Conference on Electrical, Computer and Communication Engineering (ECCE)* (pp. 1-6). IEEE.

[19] Islam, M., Ahmed, T., Yusuf, M. S. U., & Ahmad, M. (2015). Cognitive state estimation by effective feature extraction and proper channel selection of EEG signal. *Journal of Circuits, Systems and Computers*, *24*(02), 1540005.

[20] Advanced Brain Monitoring, Inc. (2014). B-Alert User Manual.

[21] WMA declaration of Helsinki: Ethical principles for medical research involving human subjects 2013. (2014). Guildford, Surrey: Canary Publications.

[22] Xu, W., Li, A., Shi, B., & Zhao, J. (2018). A Novel Design of Sparse FIR Multiple Notch Filters with Tunable Notch Frequencies. *Mathematical Problems in Engineering*, *2018*.

[23] Al-Fahoum, A. S., & Al-Fraihat, A. A. (2014). Methods of EEG signal features extraction using linear analysis in frequency and time-frequency domains. *ISRN neuroscience*, *2014*.