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The Effect of Music on Human Brain; Frequency Domain and Time Series Analysis Using Electroencephalogram

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ABSTRACT The aim of this paper is to investigate the effect of music stimuli on human brain using electroencephalogram (EEG). The study comprises of two experiments, a short term and a long term experiment referred to as experiment 1 and experiment 2, respectively. Two types of music stimuli; favorite music (preferred music of the subjects) and relaxing music (composed of alpha binaural beats) are used in experiment 1. Experiment 2 is conducted using relaxing music. Assessment of soothing effects of the music on human brain is done by analyzing different features; absolute power in alpha band, approximate entropy, sample entropy, and frontal asymmetry using EEG recordings. The ANOVA measures for the extracted features indicated no significant change in experiment 1. In experiment 2, the features are evaluated for the music listening group and control group separately. From ANOVA results, no significant change is observed in the control group after both conditions (1^{st} week and 2^{nd} week) with respect to the baseline. On the other hand, significant change was observed in the music listening group, for all features investigated; (a) absolute alpha power: condition (baseline and 1^{st} week) $F = 4.59$, $P < 0.05$, condition (baseline and 2^{nd} week) $F = 18.87$, $P < 0.05$ (b) approximate entropy: condition (baseline and 2^{nd} week) $F = 30.62$, $P < 0.05$ (c) sample entropy: condition (baseline and 1^{st} week) $F = 4.75$, $P < 0.05$, condition (baseline and 2^{nd} week) $F = 38.37$, $P < 0.05$. For inter-hemispheric alpha asymmetry index measured from the frontal region of the brain; no significant change is observed in both experiments. Hence, the main contribution of this study is to investigate the EEG dynamics under different music stimuli. The results indicate that relaxing music has better soothing effects as compared to the favorite music. It is also observed that the effect of relaxation is significant when the relaxing music is listened for a longer period of time (2 weeks).

INDEX TERMS Electroencephalogram (EEG), power spectral density (PSD), approximate entropy, sample entropy, music, binaural beats.

I. INTRODUCTION

Music is considered as a popular source of enjoyment as well as a powerful stimulus for the brain waves. Nowadays, music can be easily accessed using the internet with the help of smartphones and other devices. Music features vary with type and genre of music and therefore produce different effect on the brain signals; for example slow and quiet classical music can be used for relaxation [1]. With the help of advanced techniques developed for neuroimaging, it is easy to understand the behavior of brain [2] and the effect of music on the brain.

It is a common for people listen to music during the execution of routine/daily tasks. Most of the public prefer listening to music when they work on their computers and while travelling. Background music is also played in public places like restaurants and hotels, to provide the customers with a pleasant environment [3].

Different studies are focused on the relationship between music and the brain, and how it affects human attention, mood and cognition. K. Myoungjin et. al. performed a two group experiment with 68 schizophrenia patients. They conducted music therapy for 7 weeks with various music activities like singing, playing and listening to music; and observed an improved cognitive performance measured by Mini-Mental State Examination (MMSE) for the music listening group [4].

Music therapy is a tool which allows the patients to improve their social skills, verbal ability, memory and mood [5]. Significant research has been done on the music as a therapeutic tool for improving cognition in the last few decades. Music therapy as modern cognitive rehabilitation tool has promising results to improve patient's attention and cognition [4]–[6]. The strong relation of music mnemonics with memory and learning ability was investigated in [7]. The subjects who participated in the music group performed better in recalling verbal and word order memory as compared to the non-music group. There is a rapid increase in the population of elderly in the developed countries and it has become difficult to sustain their cognitive performance. Research shows that Buddhist harmonic music intervention has positive results in delaying the cognitive decline in the elderly [6].

Different types of music have different physiological and psychological effects on human body and elicits different emotions, for example happy and sad emotions are induced when the subjects listened to rock and rap genres respectively [8]. The psychological effects can be measured by analyzing the electroencephalogram signals. EEG is the measure of electrical activity of the brain signals, consisting of different frequency bands. Each frequency band has important characteristics that differentiate specific physiological states [9]. Frequency band composed of frequencies from 8 to 13Hz, is called Alpha band. Many studies are conducted on the alpha band activity which shows that alpha band is related to human cognition; and cognitive performance can be improved with the increase of alpha waves [10], [11]. For instance, upper alpha frequency is used as a neuro-feedback feature for the improvement of cognitive performance [12]. 24 subjects participated in this neuro-feedback study. They were divided into control and training groups. Training group (14 participants) was trained for enhancing upper alpha frequency band. The training group showed improved performance on the cognitive task at the end of the study as compared to the control group who did not receive any training.

Frontal alpha asymmetry is used to investigate the difference in the left and right hemisphere of the brain. It is defined as the average difference of the brain activation in the left and right part of the frontal lobe and, is measured as a difference of alpha power between left and right hemispheres of the brain [13]. This difference is associated with different emotions that are broadly categorized into two classes; positive emotions and negative emotions. Many studies conducted on frontal alpha asymmetry show that higher alpha activation is observed in left frontal hemisphere of the brain when subject is experiencing positive emotions. In contrast, right frontal hemisphere has more alpha activation during negative emotions [14], [15]. Different methods are used to change the frontal alpha asymmetry in the human brain. For instance, EEG based neuro-feedback training is one such promising tool that can change the relative frontal asymmetry [16].

Hence the aim of this research study is to investigate the effect of music stimuli, favorite music and relaxing music, and to analyze the soothing effects of these stimuli on the human brain, based on frequency domain and information theoretic analyses of the EEG signals. Some empirical studies have investigated whether binaural beats can modulate specific brain rhythms leading to enhanced relaxation, but contradictory results are observed [17]. It may be because of the implementation of non-standard protocols and difference in the experimental conditions. For instance, the exposure to music for small duration (120 secs) may not be sufficient to provoke noticeable changes in the EEG [18]. Thus, the music used in our experiments has longer duration (247 secs on the average). Furthermore, in [19] the selection of the favorite music is made entirely by the researchers, i.e. either the researcher suggests the music or group of skilled musicians choose it. Sometimes, the selection is based on the prior findings [19]. However, we conducted the study with a novel experimental protocol, that includes an unbiased choice of selection of favorite music, i.e., the favorite music was selected by the participants themselves. In addition, the research on EEG to compare the effect of different music stimulation is still rare [20]. To the best of our knowledge and from the literature reviewed there's still a lot of work needed to investigate the effect of music stimulation on EEG.

Considering the strong association of higher alpha activation with better cognitive performance and increase in relaxation [21], alpha power is considered an appropriate parameter for the analysis. It is hypothesized that, soothing effects of music on the human brain will increase the similarity among patterns in EEG signals. Consequently, the complexity of the brain signals will decrease. Different linear [22] and non-linear approaches [23] are adopted to compute this complexity. EEG recordings are non-linear in nature and non-linearity's in healthy subjects are known to be more frequent than in the protocol adopted in [22]. Therefore, to investigate this complexity, non-linear analysis of EEG signal is considered an appropriate and effective approach [23]. Therefore, two non-linear approaches: Approximate entropy (ApEn) and Sample Entropy (SampEn) are investigated in this study to measure complexity of EEG signals. It has been reported that the complexity of EEG signal increases with the increase in the entropy [24]. To examine the positive and negative emotional responses in the human beings [19], [20], [27], frontal alpha asymmetry is chosen as a potential feature. Hence, the main objective of this work is to investigate (a) which music stimulus is more effective in increasing alpha power; (b) whether the increase in alpha power is significant after listening to the music; (c) the effect of music on the complexity of brain signals; (d) the effect of the music on the frontal alpha asymmetry of the brain.

II. METHODOLOGY

A. PARTICIPANTS

The data used for this analysis is obtained from two different experiments, short term experiment and long term experiment, hereinafter experiment 1 and experiment 2 respectively. Initially, there were 32 subjects in experiment 1 and 10 subjects in experiment 2. Due to the presence of artifacts and inconsistency in the EEG data, 5 subjects from experiment 1 and 2 subjects from experiment 2 were excluded from the study. The subjects were recruited from Faculty of Engineering and Green Technology, Universiti Tunku Abdul Rahman. The participants took part voluntarily in the experiments. They selected the music genre (pop, classical, pop-rap, rock, R&B, pop-rock and electropop) based on their personal interest. The written signed consent was taken from all the participants after experimental procedures were explained to them.

B. MUSIC STIMULI

Experiment 1 is conducted with two different types of music, favorite music and alpha binaural beats, hereinafter called the relaxing music. The favorite music was selected by the participants according to their choice. Hence the favorite music selection is highly subjective and depends on individual preferences. It is observed that the emotional response to the same music, is different for different subjects. For example, some people feel relaxed and calm after listening to classical music, while others may not have this feeling. Hippocampus is a brain region, located in the temporal lobe, which is responsible for memory and social emotional association. When people listen to their favorite song, the connectivity between auditory brain areas and hippocampus is matched [28]. That's why, favorite music helps people to experience their memories and thoughts regardless of genre and lyrics of the music. The favorite music selected by the participants belongs to seven different genres, as shown in Figure 1.

The second music used in experiment 1 is relaxing music (downloaded from: https://www.youtube.com/watch?v=03DN380MhXk). This music is specifically formulated with alpha binaural beats (frequency range 8-13 Hz) and it helps the listener to easily achieve the relaxation state (higher alpha brainwave). The level of the relaxation induced by the relaxing music may be different for different subjects, but the induced effect is positive (i.e. relaxing) in majority of the subjects. A survey has been conducted on the use of relaxing music for increasing relaxation levels concluded that relaxing music has better soothing effects on the participants physiological behavior [29]. Therefore, relaxing music is selected as the music stimulus for experiment 2.

C. EEG RECORDINGS

EEG signals were recorded using Emotiv Epoc EEG wireless headset (Emotiv Systems, Inc., San Francisco, CA). Emotiv Epoc consists of 14 active electrodes and 2 reference electrodes. Signal from each electrode is converted to digital form with the help of a built-in 16-bit analog to digital converter (ADC) with sampling frequency of 128 Hz. The active electrodes were placed on the scalp locations AF3, AF4, F3, F4, F7, F8, FC5, FC6, P7, P8, T7, T8, O1 and O2 according to international 10-20 system as shown in Figure 2. The reference electrodes are placed on the mastoid bone behind the ear (CMS-left mastoid)/driven right leg (DRL-right mastoid) ground [30]. All the EEG recordings and music listening sessions were carried out in a silent room.

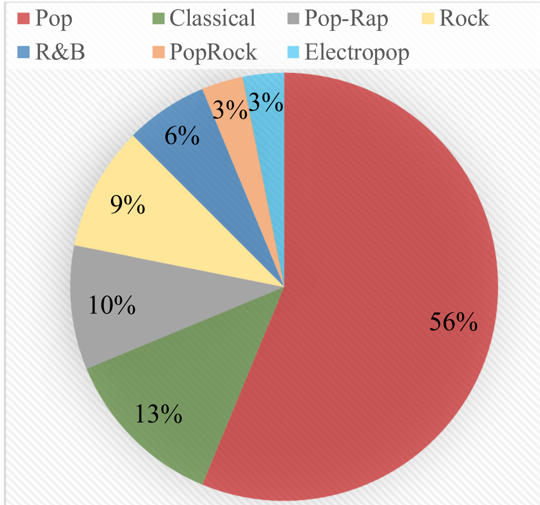


FIGURE 1. Music genres selected by the participants [11].

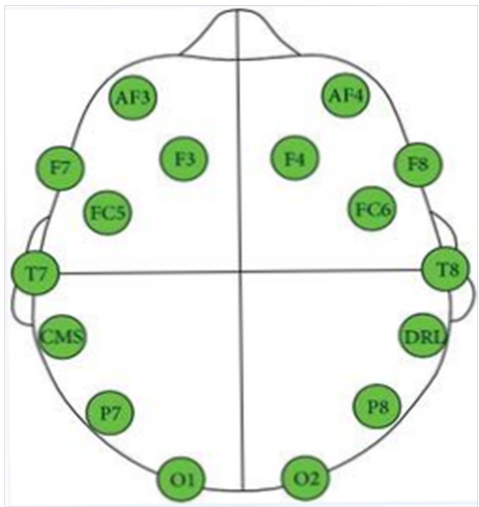


FIGURE 2. Locations of the electrodes on the scalp for Emotiv EPOC headset [31].

D. PROCEDURE

The study was designed into two experiments, experiment 1 and experiment 2. The flow diagrams for both experiments are shown in Figure 3.

1) EXPERIMENT 1

This experiment is used to establish relationship between listening to music and enhancement of relaxation level. Thirty-two (32) participants, 27 males and five females, participated in this experiment. The mean age of the participants was 24.1 ± 7.63 years.

Due to artefacts and inconsistent EEG data, 5 subjects were excluded from the study during the pre-processing. Each participant, beforehand selected his/her own favorite music

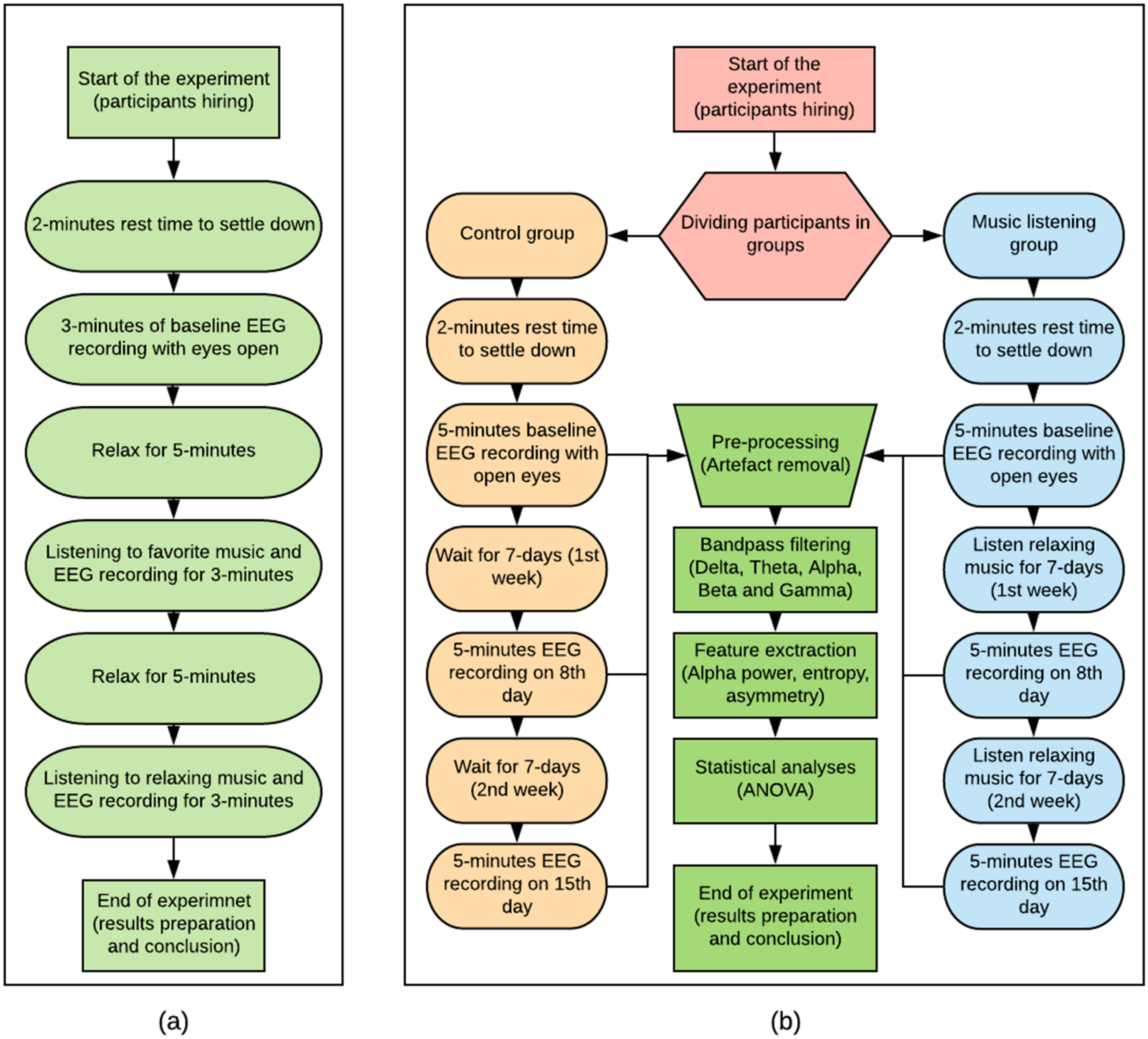


FIGURE 3. Flow diagram of (a) experiment 1 (b) experiment 2.

and gone through a music listening session. The flow of music listening session is shown in Figure 3(a). Two different types of music, favorite music and relaxing music, is used in experiment 1. This experiment is designed such that there is a five minutes' gap between the two music listening sessions The purpose of this gap is to introduce enough separation between the two music stimuli, so that the effect produced by the first music is eliminated [8]. Apart from the EEG recordings after listening to "favorite" and "relaxing" music, 3-minutes EEG with open eyes was also recorded before the start of the experiment. This EEG recording is used as an active baseline condition.

The aim of this experiment was to compare the brain activation elicited in the subjects while listening to their favorite music versus the relaxing music. Listening to favorite music is considered a reliable way for inducing relaxation in the subjects [32]. On the other hand, alpha binaural beats from the pool of music associated with relaxation are identified as a music stimulus that invokes relaxed feelings in the subjects [29]. The objective of this selection was to investigate the relaxing response in the participants induced by the music.

2) EXPERIMENT 2

To investigate the long term effect of music, data is collected in experiment 2 after listening to relaxing music as stimulus for a longer period of time. Ten subjects (2 females) participated in this experiment. The subjects were equally divided into two groups, control group and music listening group. Control group served as the non-music listening group. The subjects in the music listening group listened to relaxing music for two consecutive weeks, at least 30-minutes each day. The purpose of the control group was to compare the brain signals of participants in the music listening group with the non-music listening group. The mean age of participants in the control group and music listening group was 34.6years (SD=17.05) and 33.3years (SD=14.47) respectively. There was no significant difference in the age between the two groups. However, the age group of experiment 1 and experiment 2 are different.

III. DATA ANALYSES

A. EEG DATA ANALYSES

1) PRE-PROCESSING

Raw EEG data is pre-processed for artefact removal and band decomposition using EEGlab [33]. Linear Finite Impulse Response (FIR) filter is used to band pass the data between 1 and 60Hz. The data was plotted for visual inspection for artefact removal. The artefacted portion of the data is eliminated using the eegplot function provided in the EEGlab. After artefact removal clean EEG signal of approximately 120 seconds is processed for band decomposition. Different EEG bands (delta, theta, alpha, beta and gamma band) are extracted from the clean. EEG data using digital filtering techniques available in MATLAB. The digital filter designed for this purpose is an elliptic filter of 8^{th} order with 0.1dB ripples in the pass band and 70dB attenuation in the stop band operating with 128 Hz sampling rate. The sampling rate of EEG data is also 128 Hz.

a: ALPHA POWER SPECTRAL ANALYSES

EEG signal is composed of five frequency bands, delta (0.5-4Hz), theta (4-7Hz), alpha (8-13Hz), beta (13-30Hz) and gamma (30-40Hz). These frequency bands are very important in identifying a particular physiological state of the human brain [9]. The clean EEG signal after artefact removal is decomposed into different frequency bands and power spectral analysis is carried out for alpha band. The spectral analysis is performed using the spectopo function provided in the MATLAB signal processing toolbox associated with EEGlab (with a resolution of 1Hz) to measure absolute (μV^2/Hz) power density. For the spectrum analysis the input data needs to be stationary. Therefore, the EEG data is divided into brief epochs (of 1000ms), thus in this small interval of time the data is considered stationary to perform the analysis. The power spectrum of one of the participants plotted using EEGlab is shown in the Figure 4.

b: APROXIMATE ENTROPY

Approximate entropy [34] measures the self-similarity of signals to compute the complexity [35]. Higher values of approximate entropy indicate higher complexity in the time series data. The general steps for calculating approximate entropy are as follows [24], [35], [36].

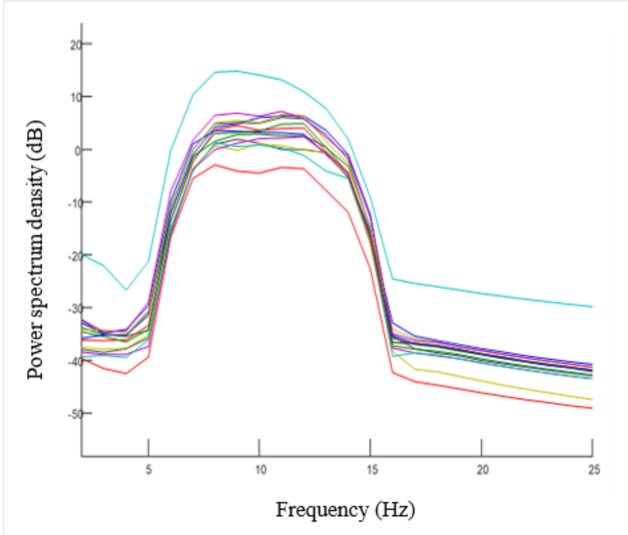


FIGURE 4. Power spectrum of clean EEG of one of the participants in experiment 1.

(a) The time series data, consisting of N data points is decomposed as shown in (1)

$$\{x(n) = x(1), x(2), \ldots, x(N)\} \tag{1}$$

(b) Define $N-m+1$ vectors $X(1)\ldots X(N-m+1)$ given in (2), where $i = 1, \ldots, N-m+1$

$$X(i) = [x(i), x(i+1), \ldots, x(i+m-1)] \tag{2}$$

(c) Compute the distance called the maximum norm between $X(i)$ and $X(j)$ as follows:

$$d[X(i), X(j)] = \max_{k=1,2,\ldots,m} |x(i+k-1) - x(j+k-1)| \tag{3}$$

(d) For specific $X(i)$, find the number of vectors $X(j)$, where $j = 1, \ldots, N-m+1$, with the condition that $j \neq i$, which fulfils the condition $d[X(i), X(j)] \leq r$. Where r is the tolerance value for comparison. We used $r = 0.2 * std(EEGdata)$. We adopted this value from [34] based on their empirical findings that the value of r between 0.1 to 0.25 SD of the data produces good statistical validity. Let B_i be the number of vectors fulfilling the above condition, we compute the probability of similar patterns using the following function.

$$C_r^m(i) = \frac{B_i}{(N-m+1)} \tag{4}$$

Find out the average of the natural logarithm of the above function.

$$\varphi^m(r) = \frac{1}{N-m+1} \sum_{i=1}^{N-m+1} \ln C_r^m(i) \tag{5}$$

(e) With the increase of the dimension by one, repeat the above steps to compute the value of $C_r^{m+1}(i)$ and $\varphi^{m+1}(r)$ and then calculate the difference between the two logarithmic functions to measure the value of approximate entropy as follows;

$$ApEn\,(m, r, N) = \varphi^{m}(r) - \varphi^{m+1}(r) \tag{6}$$

where m and r are fixed values. We used $m = 2$ based on the empirical findings of [35].

c: SAMPLE ENTROPY

Sample entropy is used to measure the signal complexity of time series EEG data. The general procedure of computing the sample entropy [34], [36], [37] is explained below.

(a) Segment the EEG time series signal into "m" consecutive vectors, starting from the i^{th} point [36]. These vectors represent the m consecutive values from the EEG signal for $1 \leq i, j \leq N - m + 1$ and $i \neq j$.

$$X\,(i) = [x\,(i)\,, x\,(i+1)\,, \ldots, x(i+m-1)] \tag{7}$$

(b) The distance between the two vectors $X(i)$ and $X(j)$ is computed as the absolute maximum difference of their scalar components:

$$d\,[X\,(i)\,, X\,(j)] = \max_{k=1,2,\ldots,m-1} |x\,(i+k) - x(j+k)| \tag{8}$$

(c) For the specified value of "r" find the value of B_i which is the count of distances having values less than or equal to the tolerance value "r". Then compute the ratio of B_i to the total number of segments as follows;

$$B_i^m\,(r) = \frac{B_i}{N-m+1} \tag{9}$$

(d) Find out the average value

$$B^m\,(r) = \frac{1}{N-m+1} \sum_{i=1}^{N-m+1} B_i^m\,(r) \tag{10}$$

(e) Increase the value of m by one and repeat the steps from (a) to (d) to calculate $B^{m+1}\,(r)$ as follows:

$$B^{m+1}\,(r) = \frac{1}{N-m+1} \sum_{i=1}^{N-m+1} B_i^{m+1}\,(r) \tag{11}$$

(f) The sample entropy is the negative of natural logarithm of the ratio of the two values found in the steps (d) and (e);

$$SampEn\,(m, r, N) = -\ln\left[\frac{B^{m+1}\,(r)}{B^m\,(r)}\right] \tag{12}$$

The values of m and r for the sample entropy is the same as for the approximate entropy. Conceptually sample entropy is similar to approximate entropy. However, there is a slight different between the two. Approximate entropy counts self-similarity matches while sample entropy does not [35]. Also, approximate entropy depends on the data size while sample entropy does not. Because of the availability of sufficient data (more than 200,000 data points for each sample) in our case, we analyzed both parameters.

d: ALPHA ASYMMETRY

Alpha asymmetry is calculated for the frontal area of the brain using two electrode pairs, F3/F4 and F7/F8. Different studies documented different methods for the measurement of asymmetry index. Alpha asymmetry index is calculated as log-transformed alpha power density values in individual alpha band, $ln(F4) - ln(F3)$ [38]. However, in current study our focus in on the absolute value of power in alpha band to calculate alpha asymmetry. We will use the asymmetry formulas found in [33], as given below;

$$A1 = \frac{power(F4) - power(F3)}{power\,(F4) + power(F3)} \tag{13}$$

$$A2 = \frac{power(F8) - power(F7)}{power\,(F8) + power(F7)} \tag{14}$$

B. STATISTICAL ANALYSES

We performed statistical analyses to investigate whether listening to the music changes alpha power, approximate entropy and sample entropy. For experiment 1, Repeated Measures ANOVA (Analysis of variance) (RMA) was conducted with test conditions (baseline, after favorite music and after relaxing music) and channels (AF3, AF4, F3, F4, F7, F8, FC5, FC6, P7, P8, T7, T8, O1, O2) or lobes (frontal, temporal, parietal, occipital) as with-in subject factors. For experiment 2, we analyzed alpha power, approximate entropy and sample entropy from the test conditions (baseline, after 1st week and after 2nd week). Separate RMA were performed on music listening group and control group with test conditions (baseline, after 1st week and after 2nd week) and channels or lobes with-in subject factors and groups (control and music listening) as between subject factors.

The statistical analyses were performed using Minitab™ 18.0 for windows. An alpha level of 0.05 was used to indicate a significant effect.

IV. RESULTS

A. SUBJECTIVE ASSESSMENT

In the subjective assessment, the participants were required to answer the questions provided to them in the form of a questionnaire. The questions were designed so that the participants may express their feelings and specify their current mood from six different mood options (stressed, low mood, depressed, pleasant, relaxed, and neutral). Two separate questionnaires one each for experiments 1 and 2 were filled by each participant. In the experiment 1 the questionnaire was filled by each participant before listening to music and after listening to each music piece. The data collected from the questionnaire for experiment 1 is shown in Figure 5. Based on the analyses of the questionnaires, it is observed that the participants' mood changed after listening to the music. As we can see from the figure 5 that the number of participants reporting relaxed state increased from 7 to 17 after listening to their favorite music and further increased to 25 after listening to the relaxing music. Therefore, it means that listening to the music produces soothing effect and this effect

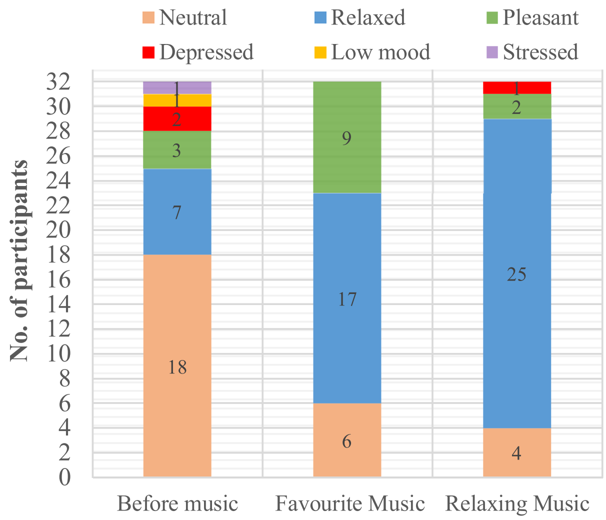


FIGURE 5. Participants mood before listening to music, after listening to favourite music and after listening to relaxing music [11].

is more significant for the relaxing music. In experiment 2, the participants were given a new questionnaire to assess their mood levels before the experiment and after listening to the relaxing music for two weeks. They were also instructed to record the total time they spend in listening to the music during the two weeks. On the average each participant listened to the relaxing music for 10 hours in two weeks. All the participants expressed themselves as neutral before the experiment and after two weeks all the participants reported themselves as relaxed. Based on these observations, it is concluded that their mood is improved after listening to relaxing music for two weeks [11].

B. NEUROPHYSIOLOGICAL ASSESSMENT

The EEG data is processed to extract the features; alpha power, approximate entropy, sample entropy, and alpha asymmetry as discussed in section III. The results are obtained for both the experiments with respect to all channels and lobes, and will be discussed in this section.

1) EXPERIMENT 1

a: ALPHA ABSOLUTE POWER

The band of interest for the power analysis in current study is alpha band (8-13Hz). For each subject, the alpha absolute power is calculated for the baseline data and two different conditions i.e. after listening to the favorite music and the relaxing music. The mean absolute power for all channels and lobes is calculated by taking the average across all subjects.

The results are normalized by taking the ratio of mean absolute power of three groups of data (baseline, after listening to favorite and relaxing music) w.r.t baseline data. The normalized mean absolute power for all channels and lobes is shown in Figure 6. Figure 6(a) shows that alpha power is increased in F7, FC6, F8 and AF4 locations after listening to the music as compared to the baseline data. However, absolute alpha power is decreased in rest of the lobes after listening to the music except for the frontal lobe, where alpha power is increased after listening to the relaxing music as shown in Figure 6(b).

b: APPROXIMATE ENTROPY

Approximate entropy is measured for all channels and lobes. The results are averaged out for all the participants and normalized with respect to the baseline data. Figure 7 shows the normalized results for experiment 1. The approximate entropy for most of the channels, i.e., AF3, F3, FC5, T7, P7, O1, O2, P8, T8, and F4 is higher after listening to the music except for few channels, i.e., F7, F8, FC6, and AF4, as shown in Figure 7(a). Hence Approximate entropy is increased in parietal, temporal and occipital lobes, and decreased in frontal lobe after listening to the music as shown in Figure 7(b).

c: SAMPLE ENTROPY

Mean sample entropy is measured for the baseline data and after listening to both favorite music and relaxing music. The results are normalized and plotted for channels and lobes in Figure 8. Sample entropy is increased after listening to the music in all channels except F7, FC6, F8, and AF4 as shown in Figure 8(a). Similar to the channels, there is an increase in sample entropy in all the lobes except the frontal lobe. A small decrease in sample entropy in the frontal lobe is observed as shown in Figure 8(b).

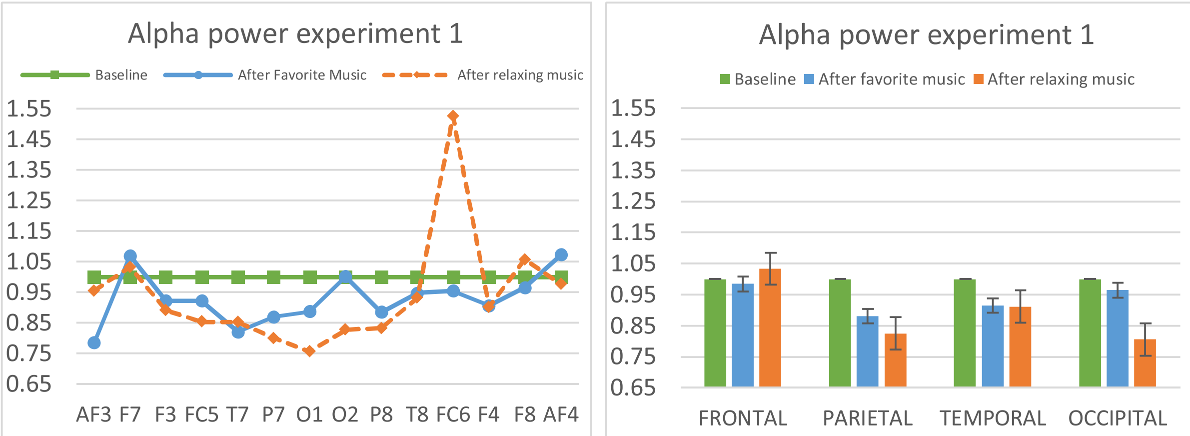
d: ALPHA ASYMMETRY

Two alpha asymmetry indices, A1 and A2, are measured from electrode pairs F3/F4 and F7/F8 respectively. The baseline alpha asymmetry is tested against the asymmetry after listening to favorite and relaxing music. ANOVA results summarized in Table 1 shows F-statistics and P- values for alpha asymmetry for experiment 1. All measurements are taken at the significance level of 0.05. No significant change is observed in alpha asymmetry index, A1, in both conditions, after favorite music ($P=0.764$) and after relaxing music ($P=0.99$). Similarly, there is no significant change in asymmetry index, A2, after listening to favorite music ($P=0.516$). However, a significant change is observed in A2 after relaxing music ($P<0.05$).

2) EXPERIMENT 2

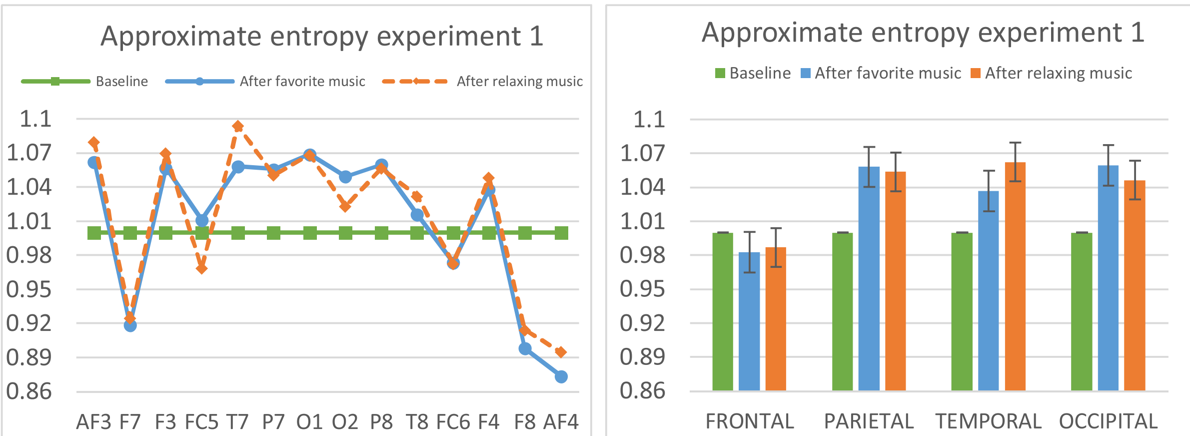
a: ABSOLUTE ALPHA POWER

Absolute alpha power for both control group and music listening group, is shown in Figures 9 and 10 respectively. Mean absolute power is calculated for all the subjects in each group and normalized w.r.t to the baseline data by dividing all three types of data (baseline, after first week and after second week) by baseline data. The results for both groups are plotted in Figures 9 and 10 for all channels and lobes. There is no consistency in the absolute power values for channels in the control group. In some channels the alpha power is increased



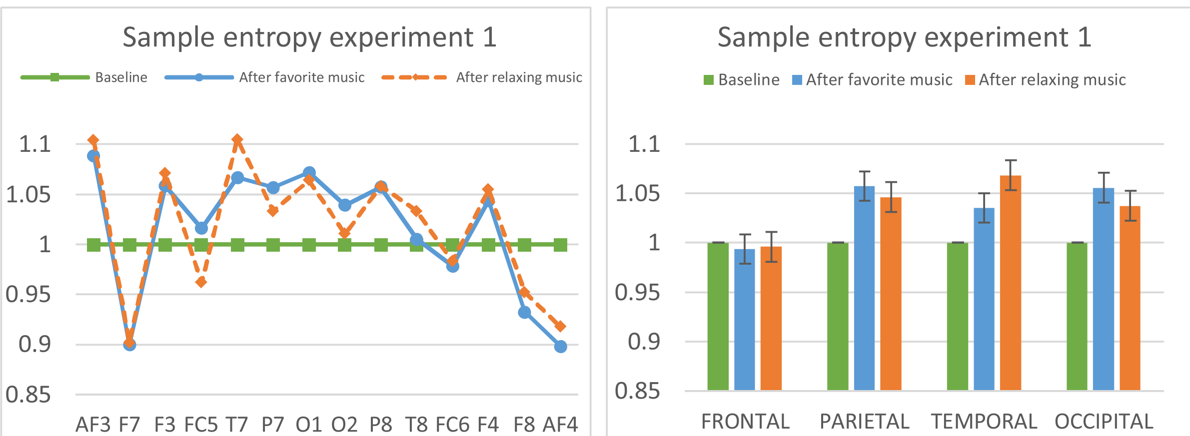
(a) (b)

FIGURE 6. Experiment 1; absolute alpha power (a) channels (b) lobes.



(a) (b)

FIGURE 7. Experiment 1; approximate entropy (a) channels (b) lobes.



(a) (b)

FIGURE 8. Experiment 1; sample entropy (a) channels (b) lobes.

whereas in other channels it is decreased after first and/or second week as shown in Figure 9(a). Mean absolute power in the frontal, parietal and occipital lobe is decreased after first week. However, there was an increase in alpha power for temporal lobe after first week as shown in Figure 9(b). Mean absolute power across all the subjects

TABLE 1. Summary of mean (M), standard deviation (SD), standard error (SE) and ANOVA (F-values and Pvalues) for alpha power at F3, F4, F7, F8 and alpha asymmetry (A1 and A2) for experiment 1.

	Condition	n	M	SD	SE	F-values	P-values
F3	After favorite music	27	2.0124	1.8547	0.3569	0.1017	0.7511
	After relaxing music	27	1.9460	1.5919	0.3063	0.2246	0.6375
F4	After favorite music	27	3.3727	2.5338	0.4876	0.1433	0.7065
	After relaxing music	27	3.3590	2.4246	0.4666	0.1587	0.6920
F7	After favorite music	27	2.0124	1.8547	0.3569	0.107	0.7511
	After relaxing music	27	1.9460	1.5919	0.3063	0.0264	0.8714
F8	After favorite music	27	5.0628	3.4799	0.6697	0.0258	0.8731
	After relaxing music	27	5.5423	4.1111	0.7912	0.0691	0.7936
A1	After favorite music	27	0.2521	0.3007	0.0579	0.0911	0.7640
	After relaxing music	27	0.2723	0.2953	0.0568	1.5×10^{-14}	0.9999
A2	After favorite music	27	0.1730	0.2712	0.0522	0.4273	0.5162
	After relaxing music	27	0.2172	0.2693	0.0518	-8.8×10^{-16}	**P<0.05**

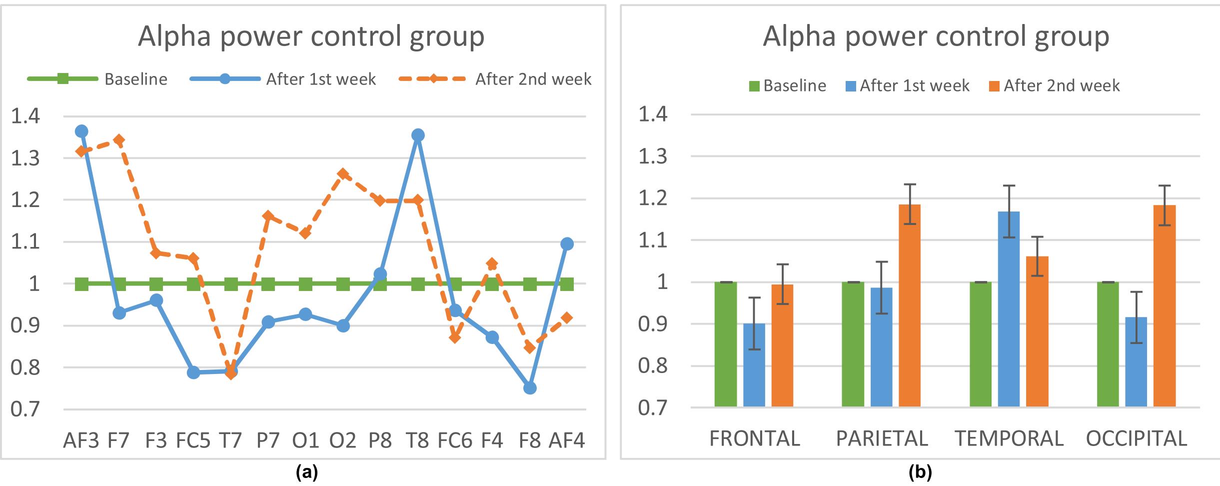


FIGURE 9. Experiment 2; absolute alpha power control group (a) channels (b) lobes.

in the music listening group is increased in all channels and all lobes. Results are plotted for the music listening group in Figures 10(a) and 10(b) for all channels and all lobes respectively.

b: APPROXIMATE ENTROPY

Approximate entropy is measured for both control and music listening group, in all channels and lobes. Figures 11 and 12 shows approximate entropy for control group and music listening group respectively.

There is no apparent change in the approximate entropy for the control group in channels, AF3, F7, F3, FC5, T7, P7, O1, O2, as shown in Figure 11(a). Also, there is no visible change in the parietal and occipital lobe in the control group, but a noticeable change is observed in the frontal and temporal lobe after second week as shown in Figure 11(b). Conversely, for music listening group approximate entropy is decreased in all the channels after second week except AF3, as shown in Figure 12(a). Also, there is a decrease in approximate entropy after first week and second week in all lobes except frontal. In the frontal lobe there is slight increase after first week but after second week it is decreased, as shown in Figure 12(b).

c: SAMPLE ENTROPY

The mean sample entropy for control group across all channels and lobes is measured and shown in Figures 13(a) and 13(b) respectively. There is a slight

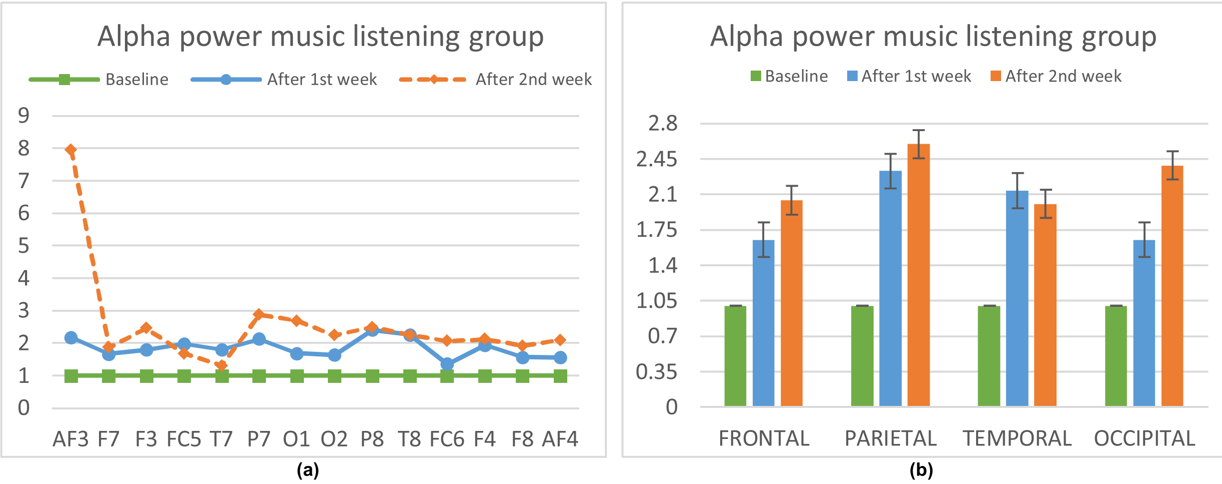


FIGURE 10. Experiment 2; absolute alpha power music listening group (a) channels (b) lobes.

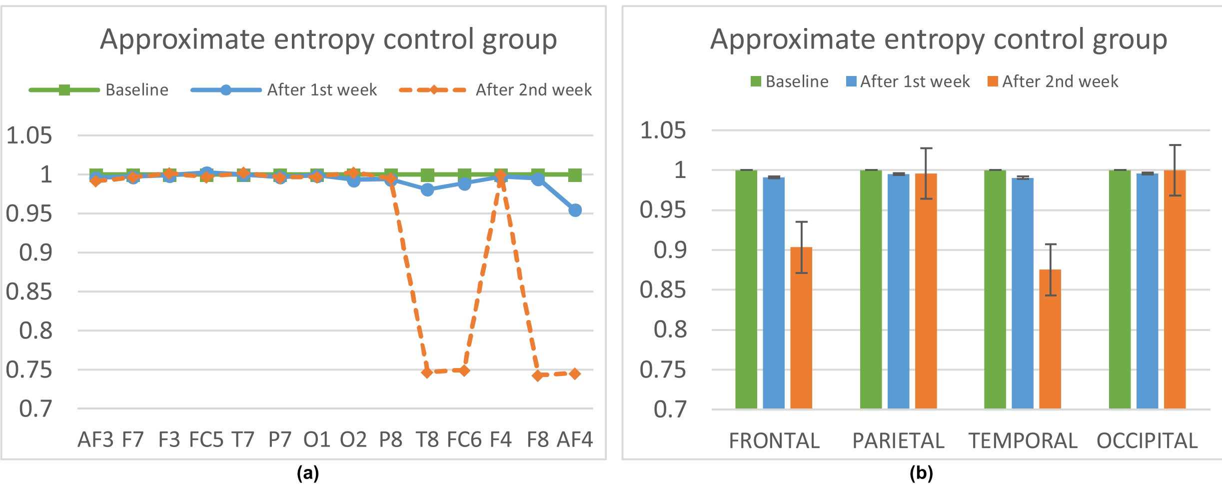
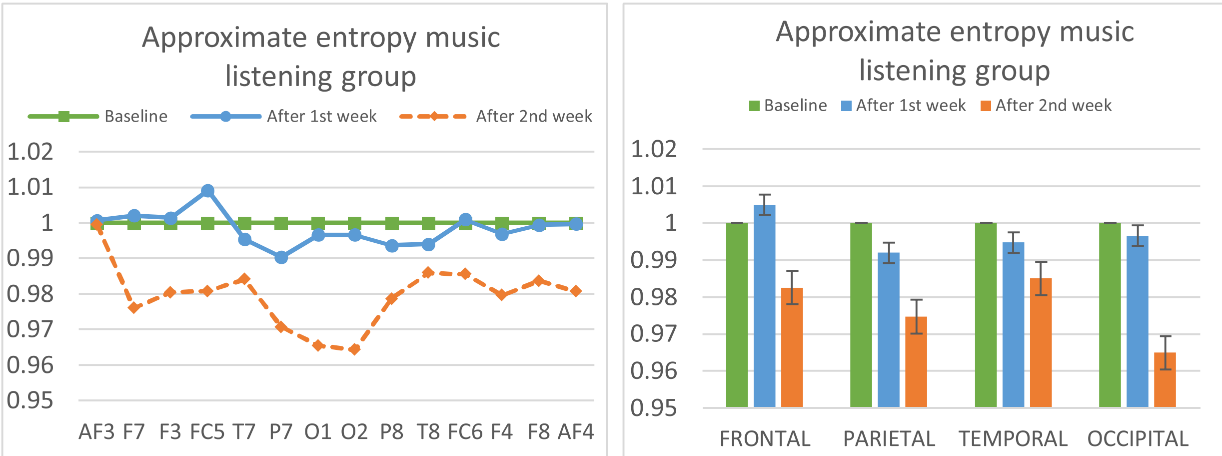


FIGURE 11. Experiment 2; approximate entropy control group (a) channels (b) lobes.

increase in two channels, F7 and F8 after first week in the control group. Conversely, there is a small decrease in seven channels, P7, O1, O2, P8, T8, FC6 and AF4 after first week in the control group. Whereas the remaining channels, T8, FC6, F8 and AF4 show large decrease in the sample entropy after second week in the control group as shown in Figure 13(a). However collectively there is no change in sample entropy in all lobes for the control group, except the frontal lobe. In frontal lobe there is an increase after first week but after second week it is decreased as shown in Figure 13(b). On the other hand, in music listening group there is a decrease in sample entropy in all channels except, AF3 as shown in Figure 14(a). Similarly, there is a decrease in sample entropy in all lobes after first week and also after second week as shown in Figure 14(b).

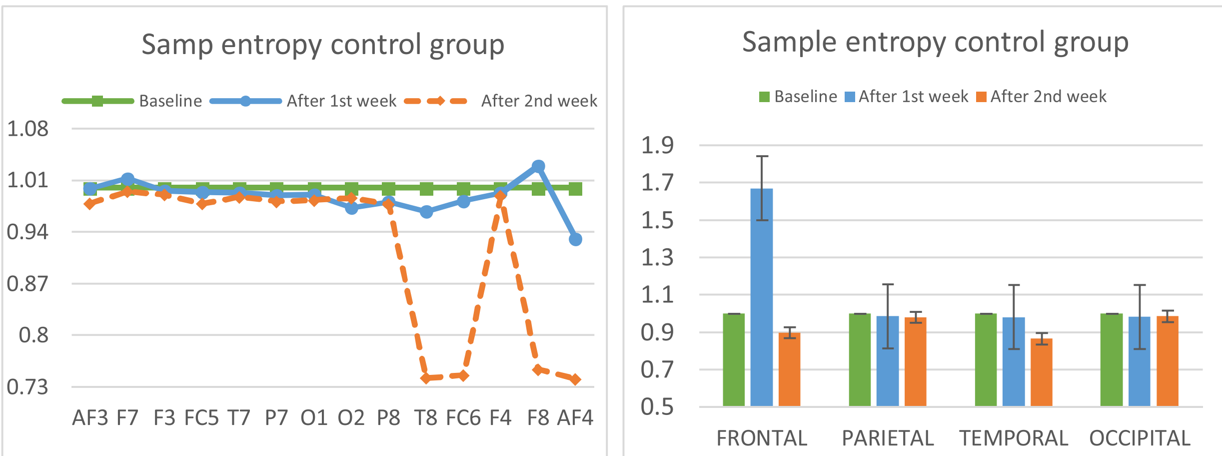
d: ALPHA ASYMMETRY

The results of alpha asymmetry in experiment 2 are summarized in Tables 2 and 3 for control group and music listening group respectively. It is clear from ANOVA P-values in Table 3 that there is no significant change in the alpha asymmetry after 1^{st} week and after 2^{nd} week against the baseline in the control group. The difference is measured at a significance level of 0.05. Similarly, there is no significant change in the alpha asymmetry in music listening group between the baseline versus first week and second week. However, the alpha power at electrodes F3 and F4 show significant change after listening to the music for two weeks, which is shown in Table 4, with *p*-values 0.0308 and 0.0298 for F3 and F4 respectively.



(a) (b)

FIGURE 12. Experiment 2; approximate entropy music listening group (a) channels (b) lobes.



(a) (b)

FIGURE 13. Experiment 2; sample entropy control group (a) channels (b) lobes.

C. STATISTICAL ANALYSES

Summary of the statistical analyses for three features, alpha power, approximate entropy and sample entropy, in both experiments, in the form of p-values is given in Table 4.

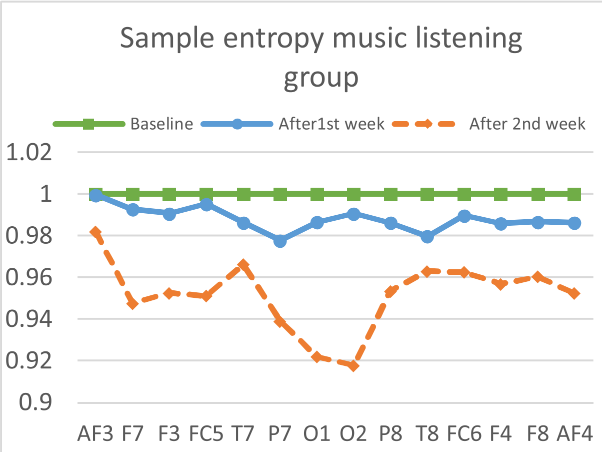
1) EXPERIMENT 1

We assessed alpha absolute power, approximate entropy and sample entropy, in lobes and channels, for two conditions, baseline versus favorite music and baseline versus relaxing music. For (a) Alpha power; we observed that there is no significant change in alpha power in lobes for baseline versus favorite music (F=0.61, P=0.43) and relaxing music (F=0.32, P=0.57). Next, we examined alpha power across channels. We found that there is no significant change in both conditions, baseline versus favorite music (F=0.27, P=0.60) and baseline versus relaxing music (F=0.48, P=0.49). For (b) Approximate entropy; there is no significant change in approximate entropy across lobes for both conditions, baseline versus favorite music (F=1.60, P=0.20) and baseline versus relaxing music (F=2.26, P=0.13). Also, there is no significant change across channels for the two conditions, baseline versus favorite music (F=108, P=0.29) and baseline versus relaxing music (F=2.02, P=0.15). For (c) Sample entropy; there is no significant change in the sample entropy for both conditions across lobes, baseline versus favorite music (F=1.35, P=0.24) and baseline versus relaxing music (F=2.01, P=0.15). However, significant change is observed across channels for both conditions, baseline versus favorite music (F=3.98, P=0.04) and baseline versus relaxing music (F=5.10, P=0.02).

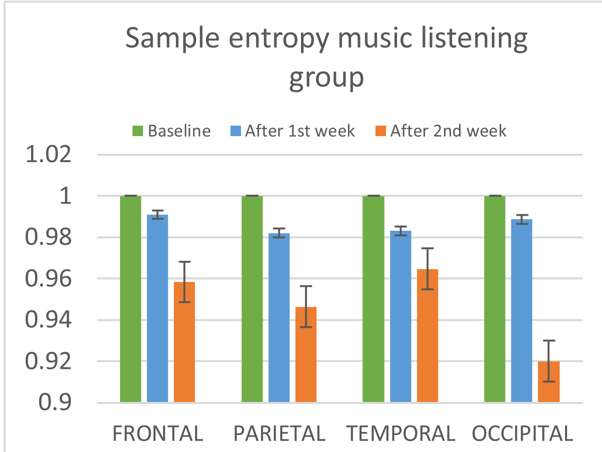
2) EXPERIMENT 2

a: CONTROL GROUP

For control group, no significant change is observed for the alpha power in lobes for both conditions, baseline versus



(c)



(d)

FIGURE 14. Experiment 2; sample entropy music listening group (a) channels(b) lobes.

TABLE 2. Summary of mean (M) and ANOVA (F values and P-values) for alpha power at F3, F4, F7, F8 and alpha asymmetry (A1 and A2) for experiment 2 control group.

	Condition	M	F-value	P-value
F3	After 1st week	3.2228	0.0085	0.9293
	After 2nd week	3.6017	0.0356	0.8565
F4	After 1st week	4.0394	0.1227	0.7380
	After 2nd week	4.8557	0.0217	0.8875
F7	After 1st week	2.9143	0.0578	0.8180
	After 2nd week	4.2032	1.3509	0.2892
F8	After 1st week	4.7485	0.7964	0.4065
	After 2nd week	5.3485	0.1814	0.6850
A1	After 1st week	0.1178	0.8482	0.3925
	After 2nd week	0.1595	0.4746	0.5166
A2	After 1st week	0.2211	3.7701	0.1002
	After 2nd week	-0.0415	1.4280	0.2771

TABLE 3. Summary of mean (M) and ANOVA (F, P-values) for alpha power at F3, F4, F7, F8 and alpha asymmetry (A1 and A2) for experiment 2 music listening group

	Condition	M	F-value	P-value
F3	After 1st week	5.1134	0.7223	0.4280
	After 2nd week	4.1422	7.8938	**0.0308**
F4	After 1st week	5.1134	0.9762	0.3613
	After 2nd week	5.6096	8.0269	**0.0298**
F7	After 1st week	4.1792	0.9644	0.3640
	After 2nd week	4.6879	0.9539	0.3664
F8	After 1st week	6.2908	0.6381	0.4548
	After 2nd week	7.7178	4.0857	0.0897
A1	After 1st week	0.2370	0.0689	0.8017
	After 2nd week	0.1507	1.3403	0.2910
A2	After 1st week	02065	0.0706	0.7993
	After 2nd week	0.2773	0.1930	0.6758

1st week (F=0.01, P=0.925) and baseline versus 2nd week (F=0.31, P=0.58). Also, change in alpha power for channels is not significant for both conditions, baseline versus 1st week (F=0.26, P=0.60) and baseline versus 2nd week (F=0.21, P=0.65). Approximate entropy change in lobes is significant for one condition, baseline versus 1st week (F=3.36, P=0.07), but not significant for other condition, baseline versus 2nd week (F=2.21, P=0.14). However, the change in approximate entropy for channels is significant in both conditions, baseline versus 1st week (F=4.72, P=0.03) and baseline versus 2nd week (F=4.41, P=0.03). Change in sample entropy across lobes is not significant for both conditions, baseline versus 1st week (F=1.15, P=0.324) and baseline versus 2nd week (F=1.27, P=0.303). On the other hand, change in sample entropy across channels is significant in both conditions, baseline versus 1st week (F=4.22, P=0.04) and baseline versus 2nd week (F=5.66, P=0.01).

b: MUSIC LISTENING GROUP

In the music listening group, a significant change is observed in all three features calculated across lobes. For, (a) absolute alpha power: baseline versus 1st week (F=4.59, P=0.04) and baseline versus 2nd week (F=18.87, P<0.05). For (b) approximate entropy: baseline versus 1st week (F=1.97, P=0.17) and baseline versus 2nd week (F=30.62, P<0.05). For, (c) sample entropy: baseline versus 1st week (F=4.75, P=0.03) and baseline versus 2nd week (F=38.37, P<0.05).

Similarly, the change across channels for both conditions is significant. In (a) absolute alpha power: baseline

TABLE 4. All three features and their P-values across channels and lobes with different conditions

		P-values					
		Alpha power		Approximate entropy		Sample entropy	
Experiment ID	**Condition**	Lobes	Channels	Lobes	Channels	Lobes	Channels
Experiment 1	Baseline vs favorite music	0.23	0.60	0.20	0.29	0.24	**0.04**
	Baseline vs relaxing music	0.57	0.49	0.13	0.15	0.15	**0.02**
Experiment 2 Control group	Baseline vs 1st week	0.92	0.60	0.07	**0.03**	**0.01**	**0.04**
	Baseline vs 2nd week	0.58	0.65	0.14	**0.03**	0.09	**0.01**
Experiment 2 Music listening group	Baseline vs 1st week	0.41	**0.001**	0.17	0.30	**0.03**	**0.002**
	Baseline vs 2nd week	P<0.05	P<0.05	P<0.05	P<0.05	P<0.05	P<0.05

versus 1st week ($F=11.04$, $P=0.001$) and baseline versus 2nd week ($F=43.61$, $P<0.05$). In (b) approximate entropy: baseline versus 1st week ($F=1.01$, $P=0.3$) and baseline versus 2nd week ($F=77.14$, $P<0.05$). In (c) sample entropy: baseline versus 1st week ($F=10.12$, $P=0.002$) and baseline versus 2nd week ($F=97.76$, $P<0.05$).

V. DISCUSSION

Examination of different features, alpha power, approximate entropy, sample entropy, and asymmetry measurements for both experiments produced results showing different patterns. Alpha waves in the brain are associated with relaxed state [41]. Alpha power analysis within experiment 1 using three different measures (baseline, after favorite music and after relaxing music) suggest that participants were not able to alter their alpha activity. Thus, instead of exhibiting an increase in their alpha activity to enhance their relaxation using musical stimulation it seems that undergoing such stimulation led to a decrease in alpha waves. There may be a number of reasons why alpha waves exhibited a falling-off pattern. For instance, alpha activation can be suppressed with the intervention of new situation or new task [42]. Also, a short passive music activity (listening to music) can be regarded as non-effective intervention to improve the emotional relaxation. Thus, we believe that such a short-time musical stimulation is not beneficial to the participants to enhance their relaxation level.

However, in experiment 2 a significant change in the alpha power after listening to the relaxing music indicated a link between music and mood enhancement. The participants in the music listening group were able to increase their alpha waves. Even though, the increase after first week was not significant, still it indicated that music were synchronizing the brain signals to alpha waves. However, a significant increase is observed after second week. Such exhibition of alpha waves may be due to the possibility that initial exposure of the participants to the new activity have a suppressing effect on the alpha activation and that over the time the participants learned to habituate with the task [43]. This indicated that the participants in the music listening group may have experienced more relaxed and joyful emotions during the course of second week. This finding is consistent with others [4], who have reported similar changes in the mood of the participants after music therapy. The statistical features, approximate entropy and sample entropy [34], [36], [37], quantify the complexity of the signals. More complex signals have higher values of entropy than less complex signals [24]. The participants in experiment 1 exhibited an increase in approximate entropy and sample entropy after listening to the music. This increase in the entropy values are indication of the engagement of the brain into some function, for instance, the participants focusing on the lyrics of the music. Instead, when the participants in experiment 2 listened to relaxing music for two weeks, approximate entropy and sample entropy is decreased. The decrease in the entropy values indicated that the participants in the music listening group were able to reach to a calm and relaxed emotional state. This calmness and relaxation may have the effect on the brain to lower the activation that resulted in the lowering of complexity of the brain signals.

To evaluate the assumption that frontal alpha asymmetry may indicate some neural mechanism [44], we measured two alpha asymmetries A1 and A2 to evaluate the neural changes in the participants brain activation after listening to the music. No significant change is observed in the alpha asymmetries A1 and A2, after listening to the favorite music in experiment 1. Similarly, a non-significant change in A1 after listening to the relaxing music is noted. However, there was a significant change in A2 after listening to the relaxing music in experiment 1. On the basis of these results, it may be suggested that the favorite music stimuli in experiment 1 does not produce appreciable effect in order to change the mood level.

The significant change in A2 after relaxing music may be linked to the change of emotional state to approach oriented state (positive emotions) and joyful experience of the participants. A likely explanation for these results is that the relaxing music produces more pronounced affective changes than the favorite music. This may be related to the composition of the relaxing music, which is more effective in synchronizing the brain signals to the alpha state.

The observed asymmetries A1 and A2 in experiment 2 in the music listening group were non-significant. After listening to the music, a non-significant change in the EEG asymmetry may be related to insufficient engagement of the participants to the music listening.

VI. CONCLUSION AND FUTURE RECOMMENDATION

This research study is conducted to investigate the short term and long term effects of two different types of music on the human brain in normal healthy adults. We used music as stimulus intervention for normal healthy adults, and utilized physiological measurements i.e., EEG recordings to explore the effects. The subjective analysis of the music on the participants' mood, in the form of a questionnaire, indicated that music produce soothing effects on the participants' mood. According to the questionnaire results from experiment 1 as shown in Figure 3, before the music 56% of the participants reported neutral mood, 21% (relaxed), 9% (pleasant), 6% (depressed) and 3% (stressed and low mood). After listening to their favorite music, more than 50% of the participants reported that they are relaxed, 28% participants recorded their mood as pleasant and 18% said that they are in neutral mood. After listening to relaxing music, 78% of participants reported to be in relaxed mood and 12% said they are neutral. Neurophysiological results of experiment 1 indicated that, in contrast to favorite music, relaxing music has more soothing effect on the human brain in terms of increase in alpha power and reduced complexity. It is concluded that relaxing music, which is composed of alpha binaural beats, is helpful in acquiring more relaxation as compared to the favorite music of the listener. In experiment 2, the effectiveness of the relaxing music in the music listening group is compared to the control group. The results indicated that relaxing music induced more alpha waves in the participant's brain and the change in alpha power was significant. The relaxing music used in this study is an effective intervention for enhancing the emotional relaxation and cognition improvements, which is measured in terms of absolute power of alpha band in the EEG recordings. The findings of this study are helpful for those people who usually feel stressed after routine tasks or difficult circumstances faced in the daily life. The number of participants employed in this research study were limited and only two weeks of music listening practice is tested. The authors believe that the use of longer practice of music training could produce deeper level of soothing effects on the cognition level. Increasing the number of participants will help in discriminating the effects to a better extent. Future studies, with increased number of participants, will help in investigating and examining the effect on a deeper level using more in-depth data.

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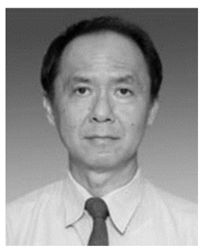

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