Characterization of the changes in electroencephalogram power spectra due to sound stimulation

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Abstract. Music has an important role in our life nowadays. Music can affect emotions and brain activity that can be measured through brain waves as electrical signals produced by neurons to carry sensory and cognitive information. In this study, brain waves for 10-12 normal male-non musician undergraduate students under three kinds of treatment are read using wireless electroencephalography (EEG) with 14 channels. For the first treatment, EEGs data are recorded when the subjects are in relax condition, i.e. rest and listening music. For the second treatment, subjects were stimulated with music in two loudness levels and for the last treatment subjects were stimulated with two different tempos of a song. From all subjects of this work, it was obtained that the right brain hemisphere is more active when listening music (significance level of 0.02). The average power spectra slightly increase with increasing music loudness (significance level of 0.35-0.45). Changes in musical tempo cause a decrease of the power spectra of alpha and beta bands (significance level of 0.25-0.30).

1. Introduction

In our daily life, some activities (such as sports, meditation and therapy) are often accompanied by music with different tempo, for example $\approx 60$ bpm (adagio) for yoga and taichi, $\approx 180$ bpm (presto) for treadmill and 120-156 bpm (allegro) during aerobic [1]. Music can affect emotions and brain activity that can be measured through brain waves as electrical signals produced by neurons to carry sensory and cognitive information. Music is classified as a right-brain activity. It means that music awareness is on the right hemisphere of the brain [2-4] and the right brain’s signals were higher than the left brain’s signals when listening to music [5]. In addition, the variation in brain wave patterns is also influenced by the tempo and intensity of the music [6,7]. Loudness is the perception of sound intensity, it can be changed by adjusting the volume knob of the music player.

The aim of this research is to characterize the EEG power spectra due to sound stimulation. First, it is to identify which hemisphere of the brain is more active when listening to music due to neuro-electrical signal. The second is to investigate the influence of loudness of the music to the power
spectra in alpha and beta bands and the third is to study the brain's perception when the tempo of a song is increased.

2. Method
The music for this study is instrumental music. Its loudness is adjusted from its volume using software Audacity 2.2.1 and the tempo is determined using software MixMeister BPM Analyzer as shown in Table 1.

| Music | Song Title | Volume | Tempo (bpm) |
|-------|------------|--------|-------------|
| A     | Shape of You (Ed Sheeran) | 50%    | 90 (Andante) |
| B     | Indonesia Raya (WR Soepratman) | 50% and 20% | 109 (Moderato) |
| C     | Red Cap Assault (Ashane) | 50%    | 162 (Presto) and over 200 (Prestissimo) |

The subjects are 10-12 normal non-musician undergraduate students (male, age of 21-24 years). All subjects have normal audition and no pre-existing neurological problems. The experiment was conducted in a quiet room where subjects were instructed to relax and listen attentively to the music. The scalp of the subject should be clean and free from the use of any hair cream or gel. Each subject was recorded under three treatments using wireless EEG with 14 channels. For the first treatment, the EEGs of subjects in rest condition with closed eyes were recorded for 30 sec. Then, subjects were stimulated with music A for 120 sec. For the second treatment, subjects were stimulated with music B in various loudness level (20% and 50%) for 105 sec. For the last treatment, subjects were stimulated with two different tempos of the music C (presto for 105 sec and prestissimo for 105 sec). The time interval between two treatments was about 240 sec. All musics were delivered by a computer through an earphone.

Subjects were recorded using wireless EEG with 14 electrodes (AF3, F7, F3, FC5, T7, P7, O1, AF4, F8, F4, FC6, T8, P8, and O2) plus 2 reference electrodes (CMS and DRL) which are placed according to the international standard system 10-20 as shown in Figure 1 with a sampling frequency rate of 128 Hz. The software will indicate the signal quality of each electrode. After all the electrodes are in good signal then its get ready for brainwave recording. The EEGs in musical conditions were all recorded with closed eyes.

![Figure 1. Electrode Channel Placement](image)

The method of research that was conducted was depicted in the Figure 2 below:
The algorithm of power spectra and brain mapping has been described in the previous study [8]. Data recording results from EEG were in European Data Format (.edf) and then were converted into American Standard Code for Information Interchange (ASCII). This data then extracted by centering in order to remove the DC offset of each electrode. The data were then filtered from the noise and artifacts.

3. Results and Discussion
The alpha power spectral density versus frequency from the right hemisphere and left hemisphere and brain mapping for non-musician undergraduate students for stimulation condition when listening music are shown in Table 2.

Table 2. Alpha Power Spectra and Brain Mapping when the subject is in resting and listening music (treatment 1)

| Condition         | Alpha Power Spectra | Brain Mapping |
|-------------------|--------------------|--------------|
| Rest              | ![Graph](image1)   | ![Graph](image2) |
| Listening music   | ![Graph](image3)   | ![Graph](image4) |
When the subjects are at rest (not listening music), the power spectral density of right hemisphere slightly greater than the left hemisphere. When listening music, it is found that the right hemisphere is even more active than the left hemisphere since the right hemisphere has much higher power spectral density (the significance level of 0.02). It is also confirmed by the visual inspection of brain mapping that the right hemisphere has more region with red colour. This result is in accordance with the previous studies [4,5] that music awareness is on the right hemisphere of the brain. All subjects are accustomed to using the right ear while on the phone. Therefore, there seems to be a relationship between the brain dominance and the ear which is usually used to listen the mobile phone.

The increase in loudness from 20% to 50% increases slightly the mean values of alpha band (the significance level of 0.45) and increases slightly the mean values of beta band spectra (the significance level of 0.35) as shown in Figure 3. From the brain mapping, it can be seen that the power spectra of all channels increases simultaneously as the loudness increases.

![Alpha Band](image1)

![Beta Band](image2)

**Figure 3.** The effect of loudness in the alpha and beta power spectra (treatment 2)

![Alpha Band](image3)

![Beta Band](image4)

**Figure 4.** The increase in the tempo of a song (treatment 3): (a) Alpha Band and (b) Beta Band

The increase in the tempo from its original value of a song seems to decrease the power spectra of the alpha band (the significance level of 0.25) as shown in Figure 4a. The indication that the power
spectra of the alpha band decreases from original tempo is also reported by other study [9]. However, the music tempo do not affect the alpha power significantly [10] as this study shows that the probability of rejecting the lowering of alpha power is larger than the standard value of 0.05. Figure 4b shows that the power spectra of beta band decreased with significance level of 0.30 if the music tempo is increased. This result is in contrast to the other study [10]. This study obtains that the power spectra of the brain waves decreases when the tempo of the song increases. Altering music tempo of a song will make the song less natural so that reduce the interest to listen the song.

4. Conclusions
This study discusses on the characterization of the changes in EEGs power spectra due to sound stimulation by analyzing the effect of music loudness and tempo on the alpha and beta bands. Our results indicate that the right brain hemisphere is more active when listening music. The average power spectra from all subjects slightly increase when the music loudness is increased with significance level 0.35-0.45. The increase in loudness may produce individual differences in response to music. The power spectra of alpha and beta bands decreases from original tempo to higher tempo with significance level 0.25-0.30.

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