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Impact of Music on Brain Function during Mental Task using Electroencephalography

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***Abstract*—**Music has a great effect on human body and mind; it can have a positive effect on hormone system. Objective of this study is to analysis the effect of music (carnatic, hard rock and jazz) on brain activity during mental work load using electroencephalography (EEG). Eight healthy subjects without special musical education participated in the study. EEG signals were acquired at frontal (Fz), parietal (Pz) and central (Cz) lobes of brain while listening to music at three experimental condition (rest, music without mental task and music with mental task). Spectral powers features were extracted at alpha, theta and beta brain rhythms. While listening to jazz music, the alpha and theta powers were significantly ($p < 0.05$) high for rest as compared to music with and without mental task in C_z. While listening to Carnatic music, the beta power was significantly ($p < 0.05$) high for with mental task as compared to rest and music without mental task at C_z and F_z location. This finding corroborates that attention based activities are enhanced while listening to jazz and carnatic as compare to Hard rock during mental task.

***Keywords*—**Music, Brain Function, Electroencephalography (EEG), Mental Task, Features extraction parameters

I. Introduction

THE basic and one of oldest socio-cognitive domains of Human species is music. Listening to music regularly helps to keep the neurons and synapses more active. Depending on the way sound waves are listened or pronounced, they have an impact in the way neurological (brain and nerve) system work in the human body. Neurological studies have identified that music is a valuable tool for evaluating the brain system [1]. Its observed that while listening to music, different parts of the brain are involved in processing music, this include the auditory cortex, frontal cortex, cerebral cortex and even the motor cortex [2]. Research findings indicate some of the cognitive tests are more influenced by exposure to music [3]. In 1993, Dr. Gordon Shaw of the University of California-Irvine found a temporary spike in the intelligence quotient in college students after they listened to Mozart music. Most of the school children prefer to study with a radio or television turned on [4] it improves verbal memory, creativity and memorizing of image material [5].

Each type of music has its own frequency, it can either resonate or it can be in conflict with the body's rhythms (heart rate). Each frequency bands of EEG rhythm relates to specific functions of brain, example Frontal midline theta rhythm (Fm theta) often appears on Electroencephalogram (EEG) during consecutive mental tasks [6].

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Beta activity relates to increased alertness and cognitive processes [7]. While listening to pleasant music there is decrease in alpha power at the left frontal lobe and unpleasant music produces decrease in alpha power at the right frontal lobe [8]. When subjects listen to the pleasant music the changes were reflected in the EEG and there was an increase in frontal midline (Fm) theta power [9]. Fm theta was observed during a large variety of tasks, such as mental calculation, working memory, learning [6], [10] and meditation [11].

Listening to music increases the power at theta and alpha frequencies of the human EEG [12]. Selecting the right type of music was important because the EEG spectral power depend on the intensity and style of music [13]. The psychological and physiological health of individuals can be improved by music therapy [14]. Neurological studies have identified that music is a valuable tool for evaluating the brain system [1]. The effect of Indian classical music and rock music on brain activity (EEG) was studied using Detrended fluctuation analysis (DFA) algorithm, and Multi-scale entropy (MSE) method [15]. This study concluded that the entropy were high for both the music and the complexity of the EEG increases when the brain processes music [16] monitored the brain wave variation by changing the music type (techno and classical) and the results showed when the music was switched from classical to techno, there was a significant plunge of alpha band and from techno music to classical there was an increase in beta activity.

Most of us listen to music of our choice during our leisure time or while working / studying. Music can be used as a tool to relieve tension/ stress, solitude, relax it also has an ability to enhance the listeners mood [17]. These changes are reflected clearly in physiological system for human body. Most of previous studies mainly focused on effect of music on brain functions without any mental workload. In the present study, we designed an experimental paradigm to see the effect of music on brain functions rate based on experimenter's choice of like music (Jazz, carnatic and Hard rock) during with / without mental workload.

II. Materials And Method

A. Subjects Summary

Eight unpaid young adults (2 men and 6 women) voluntarily participated in this study. The average age was 20 years (SD = 0.4 years) and average body weight was 68 kg (SD = 18 kg). All experiments were performed at the Biomedical Engineering Division, SSN college of Engineering, Chennai. The experiment was conducted in the morning with a normal diet in a sound proof room sitting on a comfortable chair and performed as per the guidelines of the Institutional Ethics Committee of SSN College for human volunteer research. All volunteers also read and signed an informed consent before participating.

B. Mental Task using PSYTASK Software

PSYTASK is a program for preparation and carrying out both psychophysics and psychophysiology investigations. The subject should respond to presentation of stimuli (both visual and acoustic) by pressing a buttons or ignore them in dependence on the subject task. The Mental task was given through PSYTASK software that gives visual/auditory stimuli presentation for psychophysiology investigation tasks, such as mental arithmetic (addition, subtraction, multiplication and division) operation is stimulated and the task performance parameters (like omission and commission errors) are recorded to build-in database for evaluating the subjects mental performance as shown in fig 1. In the present study, all the subjects selected medium level of Mathematics. The Mathematical task is GoNogo task.

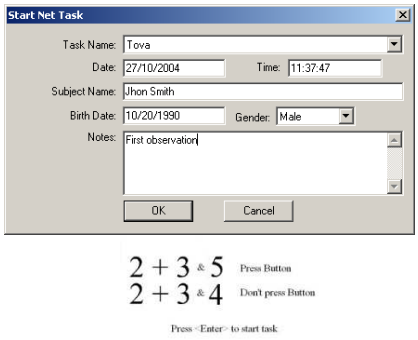


Fig. 1 Screen Shot of Psytask – Mental workload

C. Experiment Protocol

In present study three types of music was selected (Jazz, Carnatic and Hard rock) and mental workload was given through Psytask while listening music. The experiment was conducted in the morning (around 8 AM) in a sound proof room sitting in a comfortable chair. Mini Mental Test (MMT) [18] was conducted before the starting experimental protocol to check whether the subject was mental competent to sit for the test. Subjects who scored 23 out of 26 were selected for recording. Scores of 25 - 30 out of 30 are considered normal; NICE classify 21 - 24 as mild, 10 - 20 as moderate and < 10 as severe impairment.

Each experiment lasted for 13 minutes, of which 30 seconds each for eye open and eye close and 12 minutes for three combination of music (Carnatic, Hard rock, Jazz) each 2 minutes of fixed volume as shown in table 1. The music combination was randomly decided based on the tossing of an unbiased coin. EEG was recorded for three conditions, With Music and No Mental task (Condition 1), With Music and With Mental task (Condition 2), Rest (No Music and No Mental task, Condition 3).

TABLE I
EXPERIMENTAL DETAILS

Duration (Mins)	Task
1	30sec (Eyes open)&30sec (Eyes close)
1	With Music and No Mental task
1	With Music and With Mental task
2	Rest
1	With Music and No Mental task
1	With Music and With Mental task
2	Rest
1	With Music and No Mental task
1	With Music and With Mental task
2	Rest

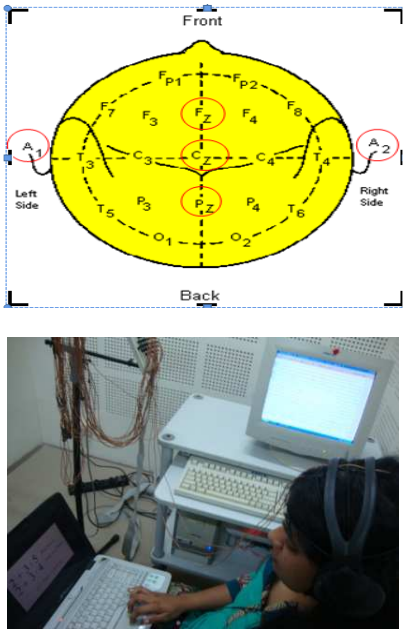


Fig. 2 Locations of the EEG electrodes on the scale using 10-20 system of electrode placement (Frontal - F; Central - C; Parietal - P and a subscript reflecting its position relative to the midline. Even and odd numbers refer to the right and to the left hemisphere respectively, and the *z* refers to an electrode placed on the midline)

D. Electrode Placement

The present study was to examine the effect of music during mental workload. So we consider Frontal, Parietal and Central lobes for this study. Ag/AgCl was used to avoid potential shift due to electrode polarization. In order to have good contact impedance between electrodes and scalp the participants were asked to take head bath and the scalp skin was cleaned with sprit. Ten -20 electro gel was used to improve potential conduction (i.e. with impendence below 10 kilo Ohms) between the electrode and the skin surface. Electrodes were placed on three locations namely, F_Z, C_Z, P_Z, $A_1 + A_2$ (reference) ear lobe and Ground with monopoles montage 10 – 20 standard EEG surface electrode placement configuration as shown in fig 2.

EEG signals were recorded using RMS EEG-32 Super Spec (RMS INDIA) with the sampling frequency of 256 Hz/channel. Raw EEG signals were filtered using a low and high pass filter with cut-off frequencies of 0.1 to 40 Hz.

The electrical interference noise (50 Hz) was eliminated using notch filter. Muscle artifacts were removed by selecting the EMG filter.

E. Data Processing

Each set of music was played for 2 minutes and while listening to each type of music subject performed one minute mental task through PsyTask. Data analysis 30th to 40th sec epoch (10 sec) was taken (assuming, it takes 30 sec for the brain to adapt to each set of music). The EEG signal was smoothened using moving average rectangular window and signal was band limited to 4 - 32 Hz. The delta band was not considered for analysis in order to avoid the slow electrode drifts and eye movements. Brain rhythms alpha (8 - 13 Hz) beta (13 - 32 Hz) and theta (4 - 8 Hz) were separated using LabVIEW 8 (DFD Toolkit). Each segment, power spectra were computed via Fast Fourier Transform (FFT) and mean power spectrum feature were extracted. Individual power spectrum was calculated for each type of music at three brain rhythms.

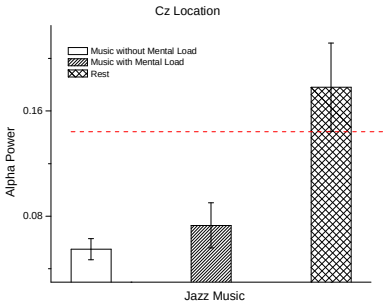
F. Statistical Test

A one way analysis of variance (ANOVA) test was performed on three conditions for with and without mental task while listening to music three different type of music. Post-hoc analysis was performed using the Tukey's Honestly Significant Difference (HSD) test and the significance level was set to be $p < 0.05$ for all analyses performed. SPSS 15.0 for Windows (SPSS Inc, Chicago, IL) was used for the statistical calculations.

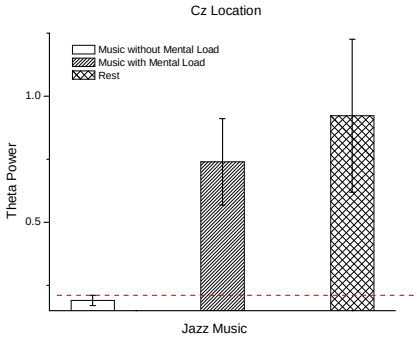
III. Results

A. Jazz Music

At C_z location, while listening Jazz music there is a significant difference in the alpha power in the three different experimental conditions, F (2, 21) = 9.083, ($p < 0.05$). The Post hoc analysis of Tukey multiple comparisons test revealed that there was a significant difference ($p = 0.002$) in spectral power of alpha for condition 1 (with music and no mental load) and condition 3 (Rest) when compared with condition 2 (with music and mental load) and condition 3 ($p = 0.008$) as shown in fig 3a. The increase in alpha power at rest condition indicate that subject vigilance and attention level was low, but listening Jazz music increase vigilance and attention level with and without mental task.



(a)



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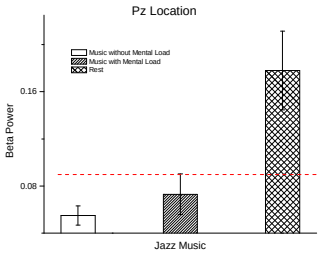


(c)

Fig. 3 Shows mean and one SEM of (a). Alpha power at C_z (b). Theta power at C_z (c). Beta power at P_z at three different experimental conditions for the entire subjects during jazz music

There is a significant difference in the theta power in the three different experimental conditions at C_z while listening jazz, F (2, 21) = 3.611, ($p < 0.05$). Post hoc analysis of Tukey multiple comparisons test revealed that the spectral power of theta was significantly different ($p = 0.004$) condition 2 (with music and mental load) and condition 3 ($p = 0.004$) as shown in fig 3b. Similarly there is significantly ($p < 0.05$) increase in theta power during jazz music with work task as compared to listening music without mental task. Alpha and theta was closely related with each other, significantly increase in theta shows that subjects concentration level reduced during rest.

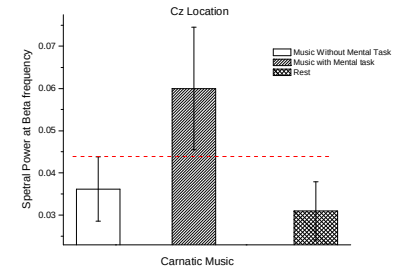
Beta power was significant difference in three experimental condition while listening to jazz at P_z location F (2, 21) = 4.418, ($p < 0.05$). The Post hoc analysis of Tukey multiple comparisons test revealed that there was a significant difference ($p = 0.025$) in spectral power of beta for condition 1 (with music and no mental load) and condition 3 (Rest) as shown in fig 3c. There is no significant difference in Theta power for all the three conditions at P_z.

B. Carnatic Music

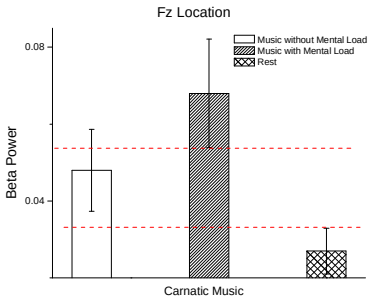
At C_z location, during carnatic music there is a significant difference in the beta power in the three different experimental conditions, F (2, 21) = 2.252, ($p < 0.05$). The Post hoc analysis of Tukey multiple comparisons test revealed beta power was significantly ($p < 0.05$) high for carnatic music with mental work task as compared to rest and music without mental task as shown in fig 4a. Similarly there is significantly ($p < 0.05$) decrease in beta power during music without mental task as compared to music with mental task.

At F_z location, there is a significant difference in the beta power in the three different experimental conditions, F (2, 21) = 3.738, ($p < 0.05$) as shown in fig 4b. The Post hoc analysis of Tukey multiple comparisons test revealed when carnatic music was played the spectral power of beta was significantly high during condition 2 and condition 3 ($p = 0.049$). The frontal lobe is associated with decision-making, problem solving, and planning and the Pattern of high beta activity in normal person indicates the subjects were engaged in processing information during music with mental task moreover it also clearly indicates rapid or excessive thinking while performing mental calculations.

There is a significant difference in the beta power in the three different experimental conditions at P_z, F (2, 21) = 0.171, ($p < 0.05$) in fig 4c. The Post hoc analysis of Tukey multiple comparisons test revealed that beta power was not shown any significantly different between three experimental conditions. There is no significant difference while listening to hard rock for all the three conditions at all the three locations.



(a)



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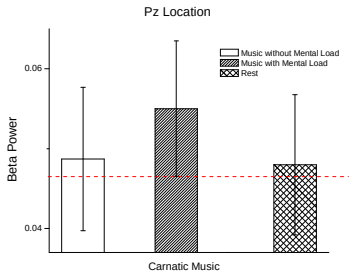

(c)

Fig. 4 Shows mean and one SEM of Beta power at (a) C_z (b). F_z (c). P_z three different experimental conditions for the entire subjects for carnatic music

IV. Discussion

It is evident from the results of our study shows that Jazz and Carnatic music significantly improves brain function as compared to hard rock during mental task. Our results reinforce earlier related reports on brain wave variation by changing the music type [16], when the music was switched from classical to techno, there was a significant plunge of alpha band. Techno music to classical there was an increase in beta activity; theta and delta rhythms were neglected in [16] study. In present study the spectral power for alpha, beta and theta band was calculated for the three sets of music (carnatic, jazz and hard rock). The results showed a significant increase in theta power while listening to jazz when compared to other music (carnatic and hard rock). Brain activity while listening to Sankarabharanamraga was studied using fMRI [19]. Similarly the brain function during listening to Persian classical music was study using fMRI techniques [20]. Both the studies could be carried out at hospital set up, which have a MRI Scanner and mental task was not given along with music. Moreover it gives only the spatial resolution. The present study aimed to analyze the effect of three types of music on brain function at different time scales in natural working condition.

While subjects listen to the pleasant music the changes were reflected in the EEG signal and there was an increase in frontal midline (Fm) theta power [9].In our EEG study, when Jazz music was played the spectral power of theta band was significantly ($p < 0.05$) high at C_Z location when compared to Carnatic and hard rock. This finding supports their conclusion [9]. The alpha power is inversely related to the brain activity [9]. In our study, at C_Z location the alpha power was significantly high during rest which indicates the brain activity is less. Harmon et al., [21] used three groups, one group listened only to Mozart music and the other group listened only to Rock music. The third group without any music and the participant were asked to read a book review during the experiment. They were subsequently asked to answer ten multiple choice questions after the experiment and concluded that they were unclear whether music will increases cognitive abilities. EEG or fMRI study was not done to support their conclusion. Moreover the selected groups were exposed to only set of the music (either Classical or Rock). In this work all the participants were exposed to all the three sets of music in a random order. When Jazz music was played the spectral power of alpha band was significantly high at C_Z location which indicates the subjects were more relaxed while doing the mental task. When carnatic music was played there was a significantly high beta activity in all the three locations which indicates the subjects were actively thinking to know whether Jazz or Carnatic will improve the mental task we need to find the task performance for with and without music condition.

V. Conclusions

This study investigated the effect of music on brain functions during three experimental conditions (rest, without mental task and with mental task). Our study concludes that while listening to carnatic music the beta activity was high during mental task in all the three locations when compared to Jazz and hard rock.

This indicates the subjects were actively thinking while do the mental task. When Jazz music was played the spectral power of theta band was significantly high at C_Z location when compared to Carnatic and hard rock. This indicates Jazz music is pleasant and it can induce positive emotion and reduces mental stress. Hard rock doesn't show any significant different for any locations or conditions. To support our study further , to know whether Jazz or Carnatic will improve the mental task we need to find the task performance for with and without music condition.

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