A STUDY TO CORRELATE SUBJECTIVE EMOTIONAL RESPONSES TO MUSIC WITH DIFFERENT EEG WAVES IN YOUNG ADULTS.

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ABSTRACT:

Background & objective: - Previous studies have reported EEG changes to music using parameters like alpha asymmetry index (AI) and frontal midline theta. While listening to pleasant music there is a right-biased alpha asymmetry while a left biased alpha asymmetry occurs in response to unpleasant one. The theta power in the frontal area significantly increases while listening to pleasant music. The present study focuses on studying these EEG variables while listening to music that induces positive (Happy, relax) Vs negative (Fear, Anger, Nervous, Sad) emotions and also correlate with DEQ scores. **Material & method:** - A cross-sectional study was done on 30 participants exposed to Classical Hindustani music and an annoying instrumental music with eyes closed while EEG was recorded. Subjective emotional responses were scored using Discrete Emotional Questionnaire (DEQ). **Results:** - ANOVA indicated statistically significant differences on comparing the two music conditions with Classical Hindustani music leading to right AI while Annoying music giving rise to left AI. **Conclusion**: - Differential hemispheric activation with music stimuli involves cortical circuits that are activated corresponding to the emotions induced. A noticeable relation seems to be present between music induced emotions and EEG wave pattern.

Key Words: - alpha asymmetry, frontal midline theta, DEQ scores.

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Introduction:

It is believed that music has the power to stimulate strong emotions within us which can range from happy, relaxed, calm and joyous to sad and nervousness also. A literature search reveals that EEG studies have been carried out in the past to know the EEG variables that are involved in emotional processing of music. One such variable is Alpha asymmetry index (AI) which is used to evaluate the individual differences of processed stimuli [1, 2, 3]. Studies show that alpha activity is more right biased in response to music that evoke positive emotions like happiness and joy while it is left biased in response to music that induces negative emotions like anger and sadness [4, 5]. Previous studies have reported that, positive emotions lead to a predominant activation of left brain regions which gives lower left cortical alpha activity indicated by low alpha power where as negative emotions are mostly related to the right brain activation and a higher corresponding left alpha power [2, 5, 6, 7, 8, 9, 10]. Overall, evidence reveals that high alpha power depicts inhibition whereas low alpha power depicts excitation of neural networks [2] Another EEG variable often analyzed in studies using music is frontal midline theta (FMθ) [1, 11, 12]. Generally, there is increase in the frontal midline theta power during exposure to the pleasant music or music that induces positive emotions compared to unpleasant music [1, 11].

Since music induced emotions are a subjective phenomenon, subjects may differ in their choice and liking for a particular music. And several studies have been carried out to analyze how subjects respond to and evaluate particular music stimuli [13]. Also, based on this a few subjective scoring systems have evolved. The dimensional scoring system, the Discrete emotional scoring and Geneva emotional music scale are often used scales. We use the DEQ scoring system to evaluate the subjective emotions felt after listening to music stimuli. So, the purpose of the current study is to investigate the emotions induced by music and to find out any significant relation with the EEG variables (AI and FM theta) in different brain areas and also correlation if any with the subjective emotions.

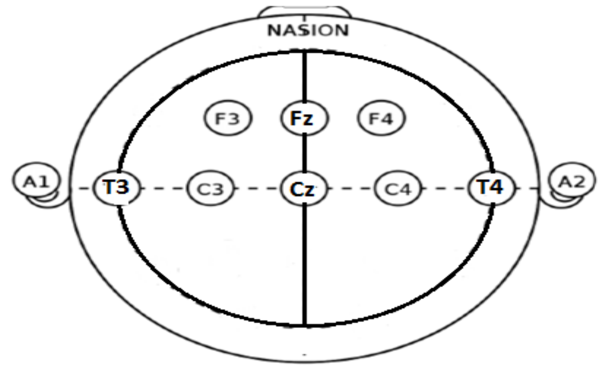
Material and Methods:

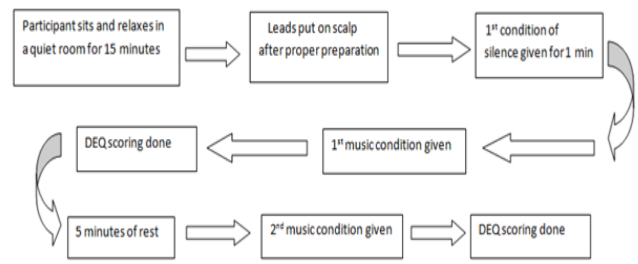
This study was undertaken after taking approval from 'The Institutional Ethics Committee, B. J. Medical College, Ahmedabad'. This was a cross sectional study done to analyse the effect of listening to two music stimuli namely a Classical Hindustani music and a hip-hop instrumental music on the EEG waves in subjects. For subject selection a detailed history was taken and subjects with history of addiction to smoking or alcohol, hearing illness, history of chronic psychiatric illness or neurological disorder with/without medication, history of doing yogasana or meditation were excluded from the study. A total of 30 participants were included in the final study (age range 18-35 yrs, 18 men, 12 women). The participants were explained in detail about the experiment and their consent was taken prior to the study.

The musical stimuli for the study were so chosen so as to reflect extremes of subjective emotional response in most subjects [1]. For this a prior study was conducted wherein a group of 50 volunteers listened to three music conditions (1 excerpt of Classical Hindustani, 2 excerpts of hip-hop instrumental music) and rated the emotions on the DEQ score.(Graph.1). DEQ scale was used as it is relatively easy to understand and score compared to the dimensional scale. Out of the 2 hip-hop instrumental musical excerpts, the 1st excerpt evoked much larger negative emotional response and so it was used for the current study. Music 1 was a 1 minute excerpt of Hindustani classical Vrindavani-sarang on sitar-tabla (https://youtu.be/TXSb_OIMNQg) while Music 2 was a 1 minute excerpt of annoying hip-hop instrumental Music (https://youtu.be/_kdvlXNJ01Y). Half the subjects listened to Classical Hindustani music as 1st music while the remaining half listened to Annoying music as 1st music.

The DEQ scale is very easy to use and understand [14]. The emotions we used for Discrete Emotional Questionnaire (DEQ) scoring system were- Happy, Relax, Sad, Fear, Anger and Nervous. After listening to each music stimuli the subject scores each of the above emotions on a scale of 1 to 7 as follows (1 - not at all, 2 - slightly, 3 - somewhat, 4 - moderately, 5 - quite a bit, 6 - very much, 7- at extreme amount).

This study was carried out in the Electroencephalography laboratory of department of physiology at B. J. Medical College, Ahmedabad. Instruments used were EEG system - Neuromax 32 version 3.0.0.5 software by Medicaid, Chandigarh, 1 computer, acquisition box, EEG leads & a ground electrode. The standard operating protocol for EEG acquisition was followed. The leads used and electrodes positioned is shown in the diagram below.





<u>EEG processing</u>

The EEG tracings were filtered using a 0.5 Hz high pass filter and a 35 Hz low pass notch filter, through which a 50Hz notch filter was in place. Impedances were checked with an electrode impedance checker and kept below 5 kΩ. A sampling rate of 256Hz was applied to the raw EEG data and it was band-pass filtered at 1-45Hz and re-referenced to an average reference. EEG artifacts such as eye blinks, lateral eye movement, muscle activity or cardiac artifacts were excluded from further analyses.

Statistical Analyses:

The pre-processed data (absolute alpha power and midline theta at Fz) was then tabulated in MS-EXCEL. Following this, all statistical analyses were carried out using Graph Pad version 3.06.

<u>1. Alpha asymmetry index</u>

Alpha asymmetry indices in the frontal, parietal and temporal cortical regions for both the music conditions as well as the silence conditions were calculated.

The absolute power values of ‘α‘waves in the Frontal (F3/F4), Central (C3/C4) and Temporal (T3/T4) electrodes were used to obtain the Alpha asymmetry index as per the following formula [2].

$$AI = P_{right} - P_{left}$$

$\overline{\quad P_{baseline} \quad}$

$P_{baseline}$ is the average of alpha waves obtained from all electrode sites of both the left and right hemispheres. This equation shows that a positive AI is associated with a right-biased alpha rhythm distribution. Because neural activity is negatively correlated with alpha power, it is expected that the larger AI would be found in the positive emotional condition compared to the negative emotional condition [1].

Following this, a 3 x 3 repeated measures ANOVA (2 factors, 3 levels; Factor 1: brain lobes-frontal, central and temporal and Factor-2: Music condition-Silence, Classical music and Annoying music) was carried out with AI at different brain sites as the dependent variable [1].

2. Correlation with the DEQ score for emotions (Happy, relax, fear, sad, anger, Nervous)

Since happy and relaxed reflect positive valence emotions, we used the score of happy and relax (reflecting positive emotions) to correlate it with the AI at frontal, central and temporal regions (for Classical music). Similarly we used the score of fear, sad, anger and nervous (reflecting negative emotions) to correlate with AI at frontal, central and temporal regions (for annoying instrumental music) [2]. For all the calculations spearman's correlation was used.

3. Frontal midline theta

Theta power change was calculated as natural logarithmic function of baseline and emotional eliciting power. Theta power at Fz (frontal site) was used.

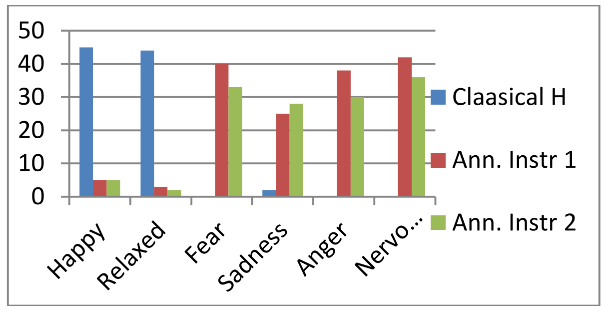
For the theta power analysis, a 3 x 3 repeated measure design two factor ANOVA, theta power at different brain areas (frontal, parietal and temporal electrodes) and different music stimuli (silence, classical and annoying music) was conducted [1].

Results:

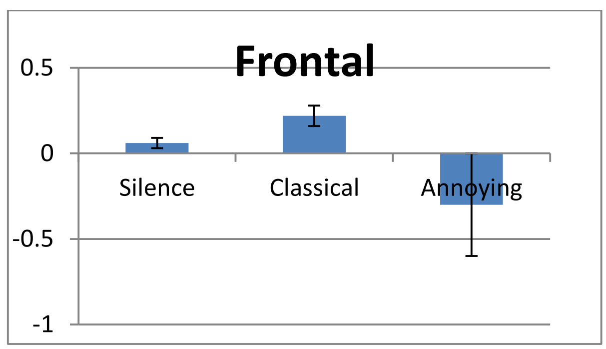
Alpha asymmetry index

The ANOVA result showed a significant main effect of brain site (N=30, F=11.23, p<0.01) and also the music condition (N=30, F=124.37, p<0.01). There was a significant interaction between brain lobes and music condition (N=30, F=5.27, p<0.01). Post hoc tukey HSD analysis revealed a larger AI index in frontal area (N=30, F=63.35, p<0.01) and temporal area (N=30, F=54.57, p<0.01) for all comparisons between music conditions (silence Vs classical music, silence Vs annoying music and classical Vs annoying music). For central area, comparison of silence Vs annoying music did not reveal a significant effect. Overall the mean AI for classical music differed significantly from that during silence at all brain sites while for annoying music, it differed significantly from silence at only the frontal and temporal sites. Also between classical and annoying music the mean AI differed significantly at all sites. (Graph.2, 3 & 4)

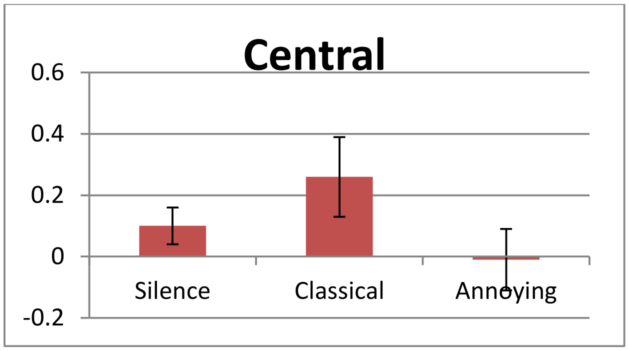
Graph.1 : No. of subjects with DEQ scores ≥ 3 for all the 3 music conditions.



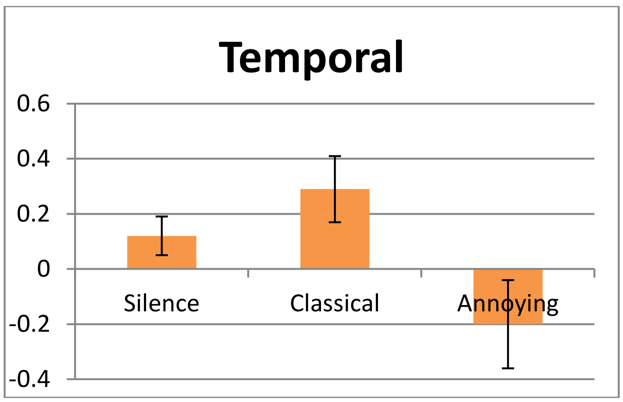
Graph.2: Mean difference and standard deviation of the absolute power (log (dB)) changes in the alpha band in each of the songs related to the baseline for the frontal leads collected.



Graph.3: Mean differences and standard deviation of the absolute power (log (dB)) changes in the alpha band in each of the songs related to the baseline for the central leads collected.



Graph.4: Mean differences and standard deviation of the absolute power (log (dB)) changes in the alpha band in each of the songs related to the baseline for the temporal leads collected.



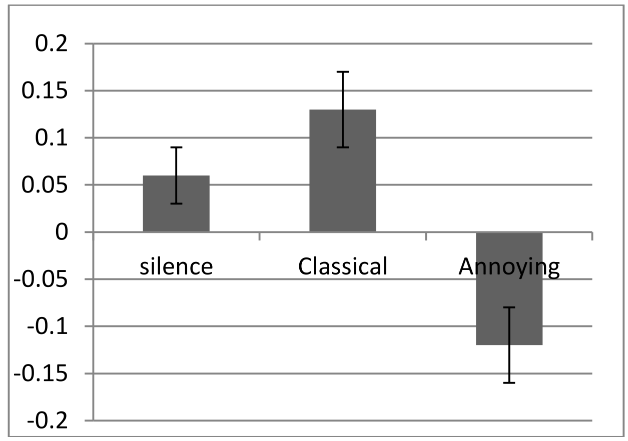
<u>Frontal midline theta</u>

For the theta power analysis, a 3 x 3 repeated measure design two factor ANOVA, theta power at different brain areas (frontal, parietal and temporal electrodes) and different music stimuli (silence, classical and annoying music) was conducted. A significant main effect was found for brain area (N=30, F=3.82, P<0.05) and music condition (N=30, F=7.59, P<0.01). There was no significant interaction between the two factors. There was a statistically significant difference between the mean differences of FMθfor the 3 conditions, showing a greater theta power at Fz for Classical music compared to that during silence and during listening to annoying music**.** (Graph.5)

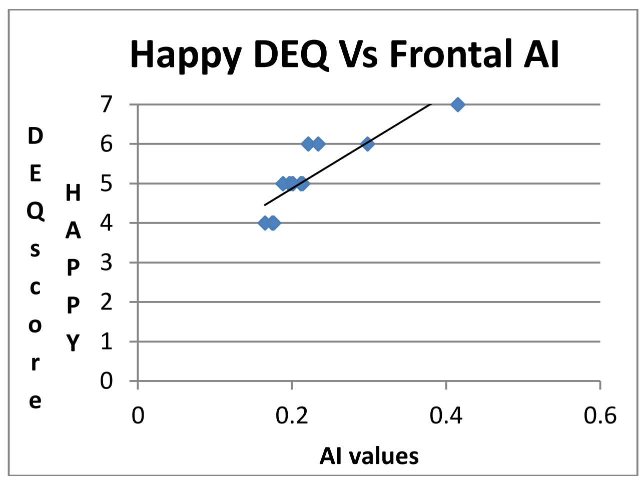
<u>Correlation between AI and DEQ scores</u>

The study found a significant correlation for right sided Frontal alpha asymmetry and DEQ score for both happy (ρ: 0.92, p-value <0.01) and relax (ρ: 0.79, p-value <0.01) emotions which was absent for parietal AI. Only the DEQ score for relax correlated well with the temporal AI (ρ: 0.53, p-value <0.05) Similarly DEQ score for the emotion of nervous (ρ: –0.81, p-value <0.01) and anger (ρ: –0.74, p-value <0.01) correlated with the AI values at only the frontal site. Correlations between other emotions and brain sites were statistically insignificant. (Graph.6)

Graph.5: Mean differences and standard deviation of the Frontal midline theta power (log).



Graph.6 : Graph of correlation between DEQ score for happy and frontal AI



Discussion:

The current study was undertaken to study the effects of Music on human brain waves in terms of certain quantitative variables like AI and midline theta and also to measure correlation between the subjective emotional responses and the derived brain wave parameters. Overall the mean AI for classical music differed significantly from that during silence at all brain sites while for annoying music, it differed significantly from silence at only the frontal and temporal sites. Also between classical and instrumental music the mean AI differed significantly at all sites.

The graph of mean & standard deviation suggests that AI values were positive or right biased at frontal, central and temporal sites for classical music and since the difference was significant on comparison with both silence and annoying music, it can be interpreted that classical music induced a higher activation of left brain cortical networks resulting in lower activity in the upper alpha bands and also increased coherence between the frontal, parietal and temporal regions on left side and subsequently a right biased alpha asymmetry. This particular finding is supported by many studies done in the past in this area [1, 6, 15]. In one such study, 4 different types of musical stimuli each eliciting a particular kind of emotion strongly was used and their effect on the AI were studied [15]. In another study functional coupling between temporo-parietal regions in left hemisphere in response to positive music was identified in fMRI too [6].

In contrast it was found that Annoying music led to significant difference from resting AI values at only frontal and temporal regions. Also the difference between classical and annoying music was significant at all brain sites. The mean values of AI for annoying music were in the opposite direction than for classical music. This difference is noteworthy because it is associated with a left biased alpha asymmetry or a higher right sided brain activation with coherence in right cortical regions. These findings are supported by previous studies done in this area which have shown an increased frontal activity in the right hemisphere of the human brain associated to music that generates negative emotions [5, 16, 17, 18].

Previous literature has suggested that approach related positive emotions is associated with relatively greater left frontal activity (giving rise to low alpha power on left side) whereas relatively greater right frontal activity (and corresponding right low alpha power) is associated with withdrawal related negative emotions [8]. The prefrontal cortex is a large brain region that covers most of the frontal lobes. The left prefrontal cortex sub serves positive emotional functions during listening to light, happy and joyful music, whereas the right prefrontal cortex sub serves negative emotional functions during aversive music presentations [19, 20, 21].

We also analyzed correlation between the reported emotions (DEQ scores) and the alpha asymmetry to see if a higher DEQ score of a particular emotion is associated with a higher alpha asymmetry. This may help to understand the relation between the subjective emotions and neural correlates better. The study found a significant correlation for right sided frontal alpha asymmetry and DEQ score for both happy and relaxed which was absent for parietal AI. The temporal AI index correlated with only the DEQ score for relaxed. Similarly DEQ score for the emotion of nervous and anger correlated with the AI values at only the frontal sites. Correlations between other emotions and brain sites were insignificant. In a similar study done previously, correlation between AI measure during rest and enjoyment rating scale was done to predict the evolution of affective response of the subjects to different music stimuli [2]. Our finding of significant correlation between positive emotions and right biased AI at fronto-temporal and between negative emotions and left biased frontal AI corroborates the results of ANOVA. This may imply that the right biased asymmetry increases with increasing quotient for happiness as indicated by DEQ score. Whereas the left sided frontal activation is associated with emotions of anger and nervousness.

Finally, the frontal midline theta difference calculated at frontal Fz electrode site showed a significant difference indicating that this parameter is affected by the type of music stimuli. The study showed a significant difference between the mean of FMθ between classical Vs annoying music with a larger theta power at frontal electrode during listening to classical music. This finding is supported by many research articles which have shown that during listening to positive emotion music compared to negative music, there is a greater frontal midline theta power [12, 22]. Modulation of the frontal midline theta power is linked to activity of Anterior cingulated cortex which is involved in emotional and attention mechanisms [23, 24].

Classical Hindustani music provides a beautiful appraisal of melody, rhythm and harmony. It is contemplative in nature and focuses mainly on melodic development. It renders an aesthetic feeling as it progresses with its notes. Compared to this annoying instrumental music which was used had notes and tones which were desynchronized. There was absence of harmonious progression plus the loud beats may have interrupted the attention which many subjects may have perceived as obnoxious and irritating.

Conclusion:

The current study contributed to reinforce the relation that exists in the activation of the cortical networks in the left hemisphere when hearing songs that trigger positive emotions and the right hemispheric neural circuits in the negative emotions. The study also supports the approach withdrawal model of emotion processing which states that emotions associated with approach behaviours are processed by left anterior brain regions and emotions associated with withdrawal behaviours are processed within right anterior brain regions.

In spite of persistent research in the field of music and EEG, we are far from reaching the exact precise physiological mechanisms behind music induced emotions and their neurological substrates. Research in this field must continue to evolve and be able to use music to our advantage. This study also presented a few limitations. First, the number of subjects was less. Second, more musical excerpts could have been taken each reflecting a precise emotion. However since we used musical excerpts evoking extremes of emotions (Happy Vs Anger) in most subjects as stimuli, our findings can be considered for further studies. On behalf of future studies, it would also be interesting to have comparison between musicians and non-musicians as well as considering a wider number of EEG channels on display, aiming to validate cerebral hemisphere physiologic functionality and correlation with musical perception. Further research should throw more light on how musical excerpts change the cerebral blood flow and whether that is associated with any EEG change or even how music affects memory consolidation and sleep.

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