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EEG BASED NEUROPHYSIOLOGICAL RESPONSES TO MUSIC AMONG SLEEP DISORDER PATIENTS

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ABSTRACT

In this study, the effect of music listening was examined among sleep disorder patients using electroencephalography (EEG). The categories of music chosen were Kapi, Kalyani and Neelambari (South Indian classical ragas). Sixteen participants were chosen and placed into two groups (with and without sleep disorders) based on Epworth Sleepiness Scale (ESS) questionnaire. EEG signals were recorded from the two electrode locations (Fp1 and Fp2) while listening to three music. Wavelet packet decomposition technique was used to analyze the acquired EEG signals and relative wavelet packet energy (RWPE) features were extracted from the theta, alpha and beta bands. Results showed that the RWPE at beta2 band was significantly ($p < 0.05$) high for Kapi raga as compared to Kalyani and Neelambari. While listening to Kapi raga, sleep disorder patients have increased alertness and decreased arousal level. The findings of the study suggest that Kapi raga can be used as an optimum therapy/ rehabilitative tool for sleep disorder patients.

INTRODUCTION

Music plays an indispensable role in reducing stress and anxiety. It promotes physical changes that support people struggling with sleep problems (Shapiro and Flanigan, 1993). Sleep is a behavioral state of every individual's life. Several factors such as stress, pain, illness, ageing and environment influences sleep (Kramer *et al.,* 1999). Sleep disorders involve abnormal behaviors associated with sleep (Bae and Golish, 2006). This disorder may lead to depression, fatigue, tiredness, and problems in daytime functioning. Lack of sleep not only impacts the overall quality of life and productivity of a person's life, but also leads to serious health issues such as increased risk of diabetes, weight gain, high blood pressure and irregular heartbeats (Benson and McDevitt, 1989). Many literatures demonstrate that music can aid in treatment of chronic sleep troubles like insomnia (Harmat *et al.,* 2008; Lai and Good, 2005). Music has a complete effect on hormone system and elevates brain's learning and information intake. It assimilates more information in less time, thereby, increasing cognitive skills (Harmat *et al*., 2008).

Music listening has a great effect on body and mind (Adalarasu *et al.,* 2011). It can alleviate sympathetic nervous system activity, blood pressure, heart and respiratory rate and may have absolute effects on sleep through muscle relaxation and distraction from thoughts (Roy *et al.,* 2009). Research has found that the silence between two musical note triggers brain cells and neuron which are responsible for the development of sharp memory. Music therapy is one of the flourishing fields of healthcare which uses music to heal. Many diseases are being cured using music like lowering blood pressure, epilepsy, stroke etc, make body calm, easing pain and so on. Moreover, the fact that music can be used to increase the effectiveness of many occupational activities that justify the usage of music. Pavlygina *et al.,* (2004) studied the effectiveness of music on a cognitive activity of human. Music-assisted relaxation may improve sleep quality and had a moderate effect on the sleep quality of patients with sleep complaints (Hanser, 1985). Other research signifies that music listening may help lengthening sleep duration, reduce the number of night-time awakenings, shorten the time it takes to fall asleep and enhance daytime functioning in people with sleep problems (Jourdain, 1997). The Epworth Sleepiness Scale (ESS) is generally used for subjective measurement by means of self-rating scale of daytime sleepiness (Johns, 1991). The Epworth sleepiness Scale indicates how one is likely to doze off or fall asleep, in contrast to just feeling tired. This resort to one's usual way of life in recent times the maximum total score is 24, and a score greater than 10 signifies daytime sleepiness (Johns and Hocking, 1997).

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This scale can be an appropriate tool to assess the effectiveness of a music therapy.

Different techniques have been used to study the effect of music on brain function. Most widely used technique is electroencephalography (EEG). Great reduction in feelings of stress and an increased sense of physical relaxation was observed under the influence of alpha music (Vijayalakshmi *et al.,* 2010). Verbal learning with a musical template increases the frontal EEG coherence (Peterson and Thaut, 2007). A number of signal processing techniques to analyze EEG signals have been suggested in recent times, such as wavelet analysis (Geva and Kerem, 1998), neural networks etc. Hirshkowitz *et al.,* (1978) computed alpha asymmetry for linguistic, atonal and musical stimuli using bilateral EEG recordings between musicians and non-musicians. Subjects listened to each of the four 2-min segments of auditory stimuli - a radio newscast (verbal), silence (baseline), electronic guitar feedback (noise), and a popular song (music). Result showed no significant differences for any type of stimulus (music, noise, baseline and verbal). Bhattacharya *et al.,* (2001) found the interdependency between different brain regions of musicians and non-musicians while listening to music and in rest condition through EEG signals. Musicians showed significantly higher degrees of interdependency than non-musicians while listening to different pieces of music over multiple cortical areas like central posterior temporal, parietal and right occipital.

Sakharov *et al.,* (2005) presented the asymmetry in the pattern of coherence (Coh) of the cortical activity of listeners to classical music of three intensities and rock music of medium and high intensities. Listening to classical music of a low intensity produced intra-hemispheric in the alpha and gamma frequency bands, classical music of a medium intensity in the alpha, beta and gamma bands and EEG Coh increased between the temporal and central occipital areas of the right hemisphere in all frequency bands for classical music of high intensity. During listening to rock music, changes in Coh of EEG took place in the theta, alpha and gamma frequency bands. Lin *et al.,* (2005) examined the EEG responses to sonata music, metal music and favorite music using frequency distribution analysis and Independent component analysis (ICA). The proportion of the high correlation coefficient was high during listening to metal music than that of sonata music.

Lahiri and Duncan (2007) used the Mozart music for treatment of epilepsy disorders. Harmat *et al.,* (2008) investigated the effects of music on sleep quality in young participants (aged between 19 and 28 years) with sleep complaint. Participants listened either to relaxing classical music or an audio book. Results showed that music statistically significantly improved sleep quality. Sleep quality did not improve statistically significantly in the audio book and the control group. Depressive symptoms decreased statistically significantly in the music group, but not in the group listening to audio books. Lai and Good (2005) studied the effects of soft music on sleep quality in older community. Results evident that experimental group had significantly better sleep less sleep disturbance and daytime dysfunction.

The aim of this study was to examine the neurophysiological responses of sleep disorder patients to various types of South Indian classical music genre of ragas like Kapi, Kalyani and Neelambari. This study used both subjective analysis and objective assessment on the effect of different ragas.

MATERIALS AND METHODS

Participants

The study group consisted of eight male and eight female with a mean age of 23.8(±2.3) years and body mass of 63.7(±3.7) kg. The participants chosen for this study were required to have normal hearing for a period of 6 months or more prior to taking part in the study. They were instructed not to participate in any heavy training or mental activity 24 hour prior to their experiment day. All participants were made aware of the experimental details prior to assuming their involvement in the study and signed an informed consent that conformed to the ethical guidelines of the university. Before commencing the experiment, participants were explicitly instructed to take their comfortable posture. Once this posture was determined by the participant, experiments were performed.

Experimental Design and Analysis

Participants were tested on an Epworth Sleepiness Scale to identify the control group and sleep disorder group. This questionnaire was administered to evaluate the experience of participants suffering with sleep disorder. After the self assessment questionnaire, participants were asked to listen to three different South Indian classical ragas namely Kapi, Kalyani and Neelambari through headphone. The order of listening to raga was randomized. Each raga was presented to the participant for three minutes with a break of two minutes between two ragas. At the end of each raga a cognitive task (simple mathematical calculations) was given to participants through PSYTASK software for 30 seconds. EEG was used to evaluate the neurophysiological responses of the participants while music listening. Fig. 1 shows the experimental setup and data acquisition of EEG signals. Electrodes were placed on two locations of frontal lobe (Fp1 and Fp2) as per 10–20 configurations for electrode placement. EEG signals were recorded using single channel digital electroencephalograph amplifier at a sampling frequency of 500 Hz. After the experiment, participants were asked to rate the three music they listened according to six-point scale (1 - Unpleasant, 3 - Average, 6 - Pleasant). Raw EEG signals were filtered using a low and high pass filter with cut-off frequencies of 0.4 and 48 Hz. The filtered signals were analyzed using wavelet packet decomposition technique to assess the brain activity between control and sleep disorder group during music listening. Daubechies 4 (db4) family was adopted as the mother wavelet. After eight-octave wavelet packet decompositions, the EEG components of the following three frequency bands were obtained: theta (4 –

7Hz), alpha (8 – 12 Hz), and beta (13 – 30 Hz). For all EEG data, the relative wavelet packet energy (RWPE) indices in three frequency bands were calculated. EEG signals were analyzed off-line using Matlab™ 2009b software (Mathworks, Inc., USA).

Fig. 1 Experimental set up and data acquisition of EEG signals

Statistical Analysis

Friedman test was performed to identify significant differences among three classical ragas between control and sleep disorder group. This analysis was performed for alpha, theta and beta (beta1 and beta2) activities for frontal region of the brain. Post-hoc Newman-Keuls Multiple Comparison analysis was performed for the cases where Friedman test result showed significant difference. Results are reported as mean and standard error. The significant level was set at $p < 0.05$. Winks SDA 6.0.93 was used for statistical data analysis.

RESULTS

Self Assessment Questionnaire

When the sleep score is greater than 10 (Maximum score - 24) according to Epworth Sleepiness Scale, participant has impact on sleep problem. In this study, sleep score for sleep disorder group was in the range of 10.5 - 13 and for control group in the range 6 - 7.5 (Fig. 2). According to the rating given by the participants (control and sleep disorder groups) to each Indian classical raga (Kapi, Kalyani and Neelambari), the ragas Kapi and Neelambari showed a significant difference on sleep disorder group (Fig. 3).

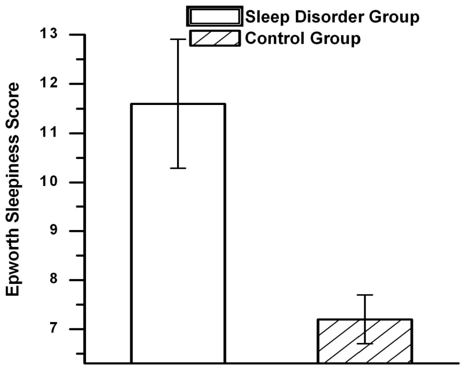

Fig. 2 Mean and standard error values of Epworth Sleepiness Scale for control and sleep disorder groups.

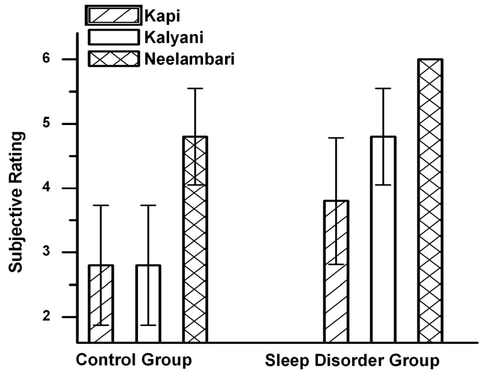

Fig. 3 Mean and standard error values of participants' rating (sleep disorder group and control group) for Kapi, Kalyani and Neelambari ragas. Note: Level of significance p < 0:05.

EEG Assessment

Fig. 4 showed that the relative wavelet energy at beta 2 band for sleep disorder group was significantly ($p < 0.05$) high for Kapi raga as compared to Kalyani and Neelambari raga. Between Kalyani and Neelambari raga, Neelambari raga made beta activity significantly ($p < 0.05$) high. From the fact that beta band is dominant when person is in active state (increased alertness), we can infer from the results that among the three ragas, Kapi raga made person's brain more active, increased alertness and decreased daytime sleepiness level since study was carried out on sleep disorder group having daytime sleepiness. Fig. 5 showed that Kalyani raga increased beta activity in control group as compared to sleep disorder group but no significant difference was found. This infers that Kalyani raga boosts the active state of the control group, i.e., who are already in alert (active) state.

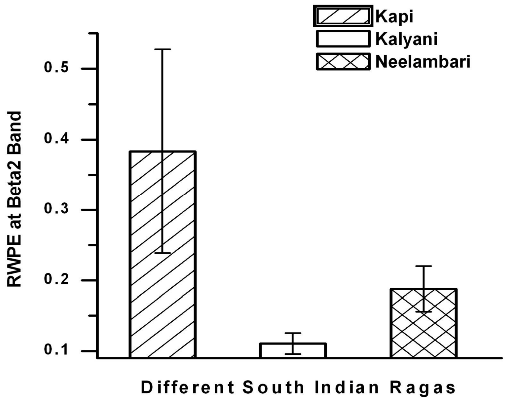

Fig. 4 Mean and standard error values of relative wavelet packet energy (RWPE) in beta2 band for sleep disorder group while listening Kapi, Kalyani and Neelambari ragas.

DISCUSSIONS

This study demonstrates the effect of South Indian ragas (Kapi, Kalyani and Neelambari) on neurophysiological response of people with sleep disorder. Sleep disorder participants were identified using self assessment questionnaire.

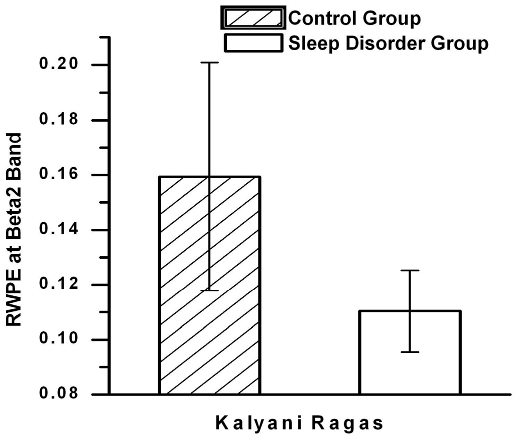

Fig. 5 Mean and standard error values of RWPE in beta2 band for control and sleep disorder groups while listening Kalyani raga.

People feel brisk while listening to fast music and feel sad to pathos music. Without even understanding the language, people respond differently while listening to different genre of music. Hence, sound waves are identified depending on the way they are listened or pronounced, having an impact in the neurological (brain and nerve) system in the human body (Levin, 1998). Music has multidimensional nature that influences the individual's physical and psychological levels of consciousness (Nilsson, 2008). In recent years, complementary therapies have been widely used as a medical treatment in health care. Reports have documented the effect of music on important physiological variables such as blood pressure, heart rate, respiration frequency, body temperature, and galvanic skin response (Myskja and Lindbaek, 2000). Music therapy as a medical intervention modality has been used in patients of all ages, and has been applied in various health care settings such as coronary care, cancer care, intensive care units, maternity units, rehabilitation, peri-operative areas and palliative care (Evans, 2002). Studies proved that adequate sleep is very important for our body and mind to work in a normal health environment (Tan, 2004). Sleep disorders can cause anxiety, depression, mood swings and relationship problems which can possibly extend up to accidents and death.

Music therapy has shown tremendous impacts on the patients with sleep disorder by making them listening to certain ragas for an advised period. Certain ragas have been identified in curing sleeping disorders by working on the nervous system of the patients. The classical ragas have sleep promoting qualities and induce sleep in people with sleep disorder problems (Gitanjali, 1998). It is an incredible fact that all lullabies are based on south Indian classical music. There are a numerous studies investigating the impact of music to promote relaxation or induce sleep (Mornhinweg and Voignier, 1995; Bonebreak, 1996; Loewy *et al.,* 2005). However, several of these studies use subjective self-assessment measures as the primary outcome index (Tan, 2004; Lai and Good, 2005). This self-assessment index does not always correlate with objective physiological measures of sleep (Armitage *et al.,* 1997; Baker *et al.,* 1999). In this study, both the subjective as well as objective measurements were carried out to determine the effect of classical ragas between controls and sleep disorder groups. Studies also use polysomnography (PSG) measures which compared a back massage condition with a music/ muscle relaxation/ mental imagery and a control condition, among critically ill patients. Results showed no significant improvement was found in sleep efficiency (Richards, 1998). In this study, EEG was used to evaluate the neural activities while listening to the three ragas.

EEG is the electrical pattern records on the surface of the brain formed by the aggregate of synchronized neural activities from millions of neurons acting together (Lal and Craig, 2001). In most cases, it has been showed that EEG is a classical nonstationary signal. Wavelet transform is a new two dimensional time-scale processing method for non-stationary signals (Mallat, 1989). Its main advantage is to provide simultaneous information on frequency and time location of the signal characteristics in terms of the representation of the signal at multiple resolutions corresponding to different time scales. Recently, wavelet packets have appeared to be a powerful tool to match the time varying characteristics of bio signals. In the research of the EEG rhythm, a more accurate frequency band is required. In order to extract specific frequency band which we are interested in, wavelet packet transform can be applied to generate spectral resolution fine enough to meet the problem requirement (Sun *et al.,* 2006). A discrete wavelet transform (DWT) analysis may not adequately partition some neuroelectric waveforms into functionally distinct scales. Wavelet packets are linear combination of wavelets and they form bases to retain orthogonality, smoothness, and localization properties of the parent wavelets. Wavelet packet decomposition algorithm decomposes gradually both the low frequency and high frequency contents of the signal. This decomposition also chooses corresponding frequency band in accordance with the feature of the analyzed signal, and makes a good match with the spectrum of the signal, which can improve the time-frequency resolution. In the present study, results conclude that Kapi raga increases the brain activity of sleep disorder participants and proves to be an efficient tool in treatment of sleep disorder.

A study by Steriade and Hobson (1976) supports this study which tells that widely distributed EEG beta activity is thought to be related to increased alertness and cognitive processes. The present study is also corroborated with Sakharov *et al.,* (2005) study which determined increase in spectral power of beta2 band when listening to low and moderate classical music. The results of this study indicate that Indian classical ragas have a significant effect on sleep disorder patients. The present study supports Harmat *et al.,* (2008) and Lai and Good (2005) study which investigated the effects of music on sleep quality in young participants and older adults respectively. They found out that classical music is an effective treatment for sleep problems. In summary, there is evidence that music has a beneficial effect on sleep parameters in normal young participants, although the effectiveness of music to improve sleep in clinical populations remains to be determined.

CONCLUSION

From the study, it is shown that listening to South Indian ragas may act as a useful intervention to overcome sleep disorders. However, due to small number of population, we could consider this study as a preliminary pilot report and further study should proceed by recruiting more participants. The findings of this study may help health-care professionals to build complementary therapeutic relationships with sleep disorder patients. In practice, health-care professionals can encourage sleep disorder patients to listen to specific ragas to enable them to release their negative feelings and improve poor sleep quality. Thus, music listening can act as an alternative self-care skill for sleep disorder patients in their daily lives.

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