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Wavelet Based EEG Analysis of Induced Emotion on South Indians

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ABSTRACT

Emotion is an affective aspect of consciousness in which different feelings such as joy, sorrow, fear, hate, or the like, are experienced that are distinguished from the cognitive and the volitional states of consciousness. The aim of this study is to determine whether the perceived and the induced emotions on the South Indians subjects are the same. The purpose of this study is to compare the perceived and the induced emotions on the south Indian subjects with the help of Self-Assessment Manikin (SAM) and Electroencephalography (EEG). Since emotions are complex and subjective, International Affective Picture System (IAPS) picture stimuli which were classified as positive and moderate arousal picture have been used to induce emotions. Healthy adult participants without any prior knowledge about the experiment were chosen for this study. The subjective rating of the picture was acquired using SAM scale and the brain activity was recorded using the EEG from every subject. The wavelet packet decomposition was performed to extract the EEG frequency bands. The subjective ratings and the relative component energies of the theta, the alpha, and the beta bands were considered for the analysis. When comparing the brain activity with the subjective rating (SAM scale), it is evident that the participants' perceived emotion and the induced emotion are the same. The results show that the theta component energy at the frontal lobes (F3, F4 and F8) and the temporal lobes (T4 and T6) during the presentation of picture stimuli is significantly high (p=0.043) when compared to the resting period when no stimulus was presented. Also it is observed that the subjects perceived pleasant pictures as pleased and the theta band activities at the frontal and the temporal lobes indicate that the induced emotion is pleasant. Based on these observations, this study concludes that the induced and the perceived emotions are the same in the south Indian subjects.

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INTRODUCTION

Analysis of different emotional states of the human brain has drawn tremendous attention in neuroscience (Bahar Guntekin and Erol Basar, 2010). Emotions are subjective and complex phenomenon that plays significant roles in quality of life for cognition, learning and decision making, motivation and creativity (Hosseini, S. A., and Naghibi-Sistani, 2011). The valence-arousal model, a two dimensional emotional space was presented by Russel (1980) having valence ratings on the horizontal axis and the arousal ratings on the vertical axis. Cuthbert, B. N *et al*. (2000) stated that emotionally arousing picture stimuli induce event related potentials in the scalp region. To analyse the emotion, different types of stimuli had been used and the induced changes were measured by examining the facial expressions and physiological signals of the participants. Izard C. E. (2007) defined that the physiological association of emotions probably originate in the brain rather than relying on the secondary physiological responses. The brain activity reproduces direct quantitative analysis of the induced emotion. Based on this fact, the current study mainly focussed on EEG to assess the induced emotion. L I Aftanas (2002) stated that the degree of emotional impact of the signal was significantly associated with the increase in evoked synchronisation of frequency bands.

EEG is the recorded electrical activity on the surface of the brain due to the collective action of millions of neurons firing together. In most cases, EEG signals are classified as non-stationary signal; hence developing an appropriate algorithm to extract the different bands of EEG signals plays a vital role. Most of the researchers tried EEG signal processing with Fourier transform but it offers only the spectral components in the EEG signals and it does not provide any time localization. Since the present work

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focused on evaluating the brain activation while viewing the positive and moderate arousal pictures, the time and frequency localization becomes very vital. This gives an insight, whether viewed series of pleasant pictures is able maintain the pleasantness throughout the period. So in the current work, discrete wavelet transform orthogonal Daubechies (db4) wavelets were chosen for optimal time-frequency localization. Wavelet transform, a multi-resolution analysis method which exhibits more precise temporal localization could bring solution to this problem. The pleasantness (valence) in the EEG was assessed by calculating the frontal theta power and arousal (activation) was assessed by measuring the beta power in all the electrode locations.

The objective of this study is to determine whether the perceived and induced emotions on South Indians participants are same using SAM Scale for subject ratings for perceived emotions and the physiological signal (brain activation) for induced emotions.

II Methodology:

2.1 Subject Selection:

Five healthy right-handed participants without any visual impairment pursuing Engineering were recruited for this study. The average age was 20 and the subjects volunteered for this study on their own interest. The experiment was conducted in sound attenuated room with appropriate lighting conditions. It was informed to the participants that they can stop the test at any time when they feel insecure during the test. The experiment was performed within the Biomedical Engineering Division, SSN College of Engineering, and Chennai, India. All volunteers read and signed an informed consent before participating.

2.2 Selection of Stimuli:

Eight pictures (Appendix A) were selected from the International Affective Picture System (IAPS; Center for the Study of Emotion and Attention [CSEA], 1999; Lang, Bradley, & Cuthbert, 1999) which is categorized as positive and moderate low arousal pictures (L I Aftanas, 2002). IAPS pictures were categorized into five subsets: i) emotionally neutral and low arousal pictures, ii) emotionally positive and moderate arousal pictures, iii) emotionally negative and moderate arousal pictures, iv) emotionally positive and high arousal pictures and v) emotionally negative and high arousal pictures (L I Aftanas, 2002). The current study incudes only positive and moderate arousal pictures for the analysis. The participants viewed the picture on the laptop using the windows moviemaker at the comfortable brightness and the quality level. The rating of picture is done according to the subjective feelings. The perceived emotion was assessed using a five point SAM scale by measuring the valence, the arousal and the dominance of the selected pictures.

2.3 Experimental Protocol:

Each experiments last for 6 minutes 45 seconds minutes, a baseline for eye blink, eye movement correction – 120 seconds, warning-5 seconds, and viewing-20 seconds for each 8 pictures and resting-120 seconds. The baseline and the resting period is also a silence period where no visual stimuli were presented.

Table 1: Experiment Protocol

Baseline	Warning	Viewing the picture	Resting
120 seconds	5 seconds	160 seconds	120 seconds

2.4 Experimental setup:

The participants were clearly explained with the experiment procedures so that they can perform without any distractions. The participants were asked to concentrate only on the picture shown. Nearly 2 meters distance was maintained by the participants from the screen on which the stimuli were displayed as shown in Figure 1. Each picture was presented for 20 seconds on a 15.6-inch (39.6cm) monitor. Silver-Silver Chloride (Ag/AgCl) electrodes and Ten20 EEG conductive paste were used to enhance the potential conduction and the impedance was kept below 5kΩ between the electrode and the scalp. Electrodes were placed in a 10-20 electrode placement system on all the cortical areas. Raw EEG signals were recorded using RMS EEG-32 Super Spec (RMS, India) with a 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 70 Hz. The power line interference noise (50 Hz) was eliminated using a notch filter.

Fig. 1: Experimental setup

Australian Journal of Basic and Applied Sciences, 9(33) October 2015, Pages: 156-161

2.5 Data Processing:

The EEG signals were recorded for 6 minutes 45 seconds of which the first 2 minutes were used for the baseline and eye blink correction. After two minutes, a warning was presented for 5 seconds indicating the onset of the experiment, followed by a presentation of 8 positive and moderate arousal pictures (each picture 20 seconds) and followed by 2 minutes of rest period. The recorded EEG signals for different conditions were pre-processed using wavelet denoising technique and the bandwidth of the EEG signal from 0 to 32 Hz was extracted at the third approximation level A (3,1). The component energy was calculated at each electrode location by squaring and summated logarithm of wavelet coefficients at the electrode location. The delta band was not considered in order to avoid slow electrode drift and eye movements. The offline analysis was performed using wavelet packet decomposition. The alpha band **(**8-12) Hz at A **(**6,2), beta band **(**16-32) Hz at D **(**4,1), and theta bands **(**4-8) Hz at D **(**6,1) decomposition level were extracted using wavelet packet decomposition. The relative wavelet component energy was calculated by dividing the particular bands (alpha, beta, and theta) absolute wavelet component energy by total wavelet component energy for a particular electrode location. The orthogonal Daubechies (db4) wavelets were chosen for optimal time-frequency localization. The entire analysis was performed by using LabVIEW, Version 10 (Wavelet Analysis Tool Kit).

2.7 Statistical Analysis:

The measured parameters relative alpha, beta, and theta component energies for nineteen electrode locations (F3, F7, F8, F4, T3, T4, T5, T6, C3, C4, P3, P4, FP1, FP2, O1, O2, Cz, Fz, and Pz) for two different conditions (viewing picture and Rest) were not normally distributed. Therefore non-parametric Friedman test was performed to evaluate the overall significance, $\chi 2$ (113) = 441.411; p = 0.05.

The Wilcoxon signed ranks was performed to measure the significant difference across the related groups and the significant value was set at p=0.05. The two experimental conditions (viewing picture and rest) were considered as independent variables. The measured relative component energies in alpha, beta, and theta bands were considered as dependant variables. The perceived emotion was measured using SAM scale ratings for valence and arousal. These subjective ratings were also considered as dependant variables. The analysis was performed using IBM SPSS Statistics for Windows, Version 20.0 (Armonk, NY: IBM Corp).

III. Results:

The mean relative alpha, beta, and theta component energies were measured for the anterior and posterior hemisphere electrodes locations during experimental conditions (while viewing picture and rest). The relative theta component energies at frontal electrode locations give the measure of valence (pleasant /unpleasant). Arousal was calculated by measuring the relative beta component energy (low / high). The perceived emotion was measured using subjective rating by SAM scale and the results of perceived and induced emotions were compared.

3.1 Relative Theta Component Energy:

The relative theta component energy was significantly low at left frontal electrode location when compared to the right frontal electrode location.

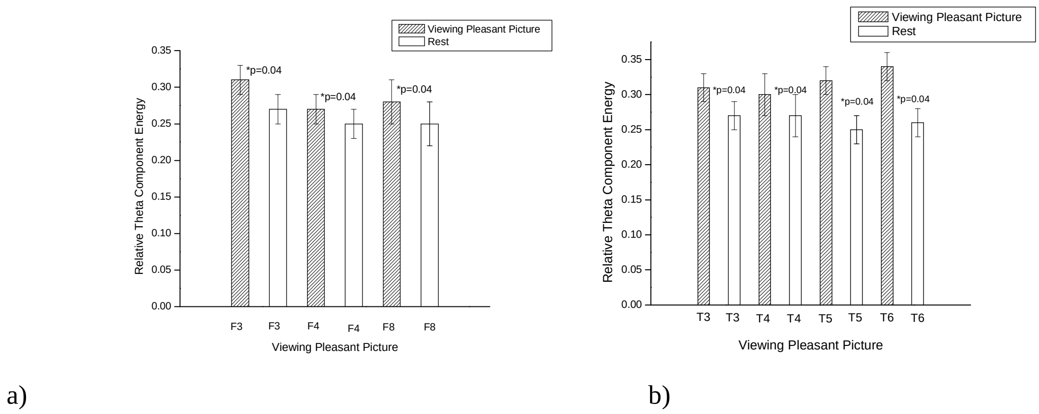


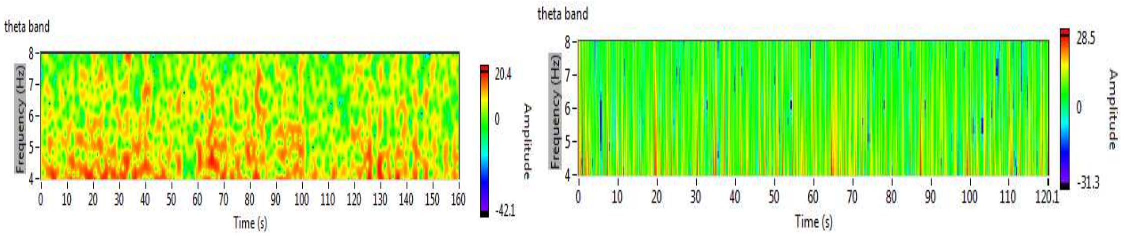
Fig. 2: a) Mean and standard error of Relative Theta component energy while viewing Pleasant pictures and Rest at frontal electrode locations b) Mean and standard error of Relative Theta component energy while viewing Pleasant pictures and Rest

The relative theta component was significantly high at frontal electrode locations (F3, F4 and F8) when compared with Rest (without viewing any picture) shown in Figure 2a. The mean relative theta component energy was high when compared with rest but it didn't elicit significant difference. The

Australian Journal of Basic and Applied Sciences, 9(33) October 2015, Pages: 156-161

increase frontal midline theta component energy increase when compared with rest indicates the viewed pictures induced pleasant emotion. The relative theta component energy in the frontal electrode locations while viewing Pleasant pictures and Rest revealed significant difference at F3, F4 and F8 (Z = -2.023, p = 0.043).

The extracted Theta band wavelet coefficients while viewing Pleasant pictures were visualized using time – frequency plot is shown in Figure 3a.



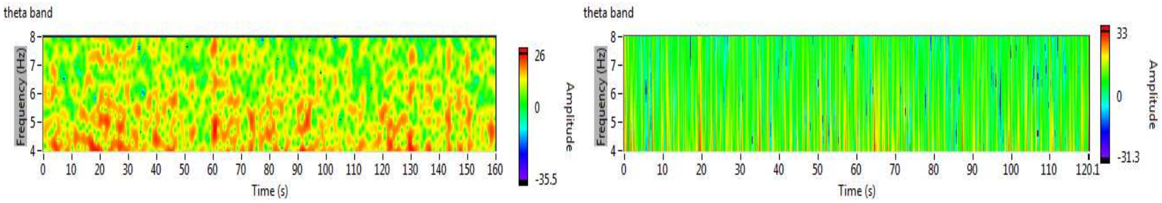
a) b)

Fig. 3: a) Time-frequency plot of Theta band (4-8) Hz while viewing Pleasant pictures at Frontal lobe (F3) b) Time-frequency plot of Theta band (4-8) Hz during Rest at Frontal lobe (F3).

The relative theta component energy increased for the whole time 2 minutes 40 seconds (160 s) viewing pictures for all the frontal lobe electrode locations only F3 electrode location was shown in the Figure 3a and the extracted Theta band wavelet coefficients during rest (without viewing any pictures) were visualized using time – frequency plot is shown in Figure 3b. The relative theta component energy decreased throughout 2 minutes (120 s) during rest this was noted at all the frontal lobe electrode locations only F3 electrode location was shown in the Figure 3b.

The relative theta component was significantly high at Temporal electrode locations (T3, T4, T5 and T6) when compared with Rest (without viewing any picture) shown in Figure 2b. At this location there were no changes in beta and alpha component energy. The relative theta component energy in the frontal electrode locations while viewing Pleasant pictures and Rest revealed significant difference at T3, T4, T5 and T6 (Z = -2.023, p = 0.043).

The extracted Theta band wavelet coefficients while viewing Pleasant pictures were visualized using time – frequency plot is shown in Figure 4a.



a) b)

Fig. 4: a) Time-frequency plot of Theta band (4-8) Hz while viewing Pleasant pictures at Temporal lobe (T6) b) Time-frequency plot of Theta band (4-8) Hz while Rest at Temporal lobe (T6).

The extracted Theta band wavelet coefficients during rest (without viewing any pictures) were visualized using time – frequency plot is shown in Figure 4b. The relative theta component energy decreased throughout 2 minutes (120 s) during rest this was noted at all the temporal lobe electrode locations only T6 electrode location was shown in the Figure 4b..

3.2 Relative Beta Component Energy:

At the same time, the relative beta component energy decreased at F3 and F7 when compared with rest shown in Figure 5. The beta component energy decrease was noted only at left frontal electrode locations. The relative beta component energy in the frontal electrode locations while viewing Pleasant pictures and Rest revealed significant difference at F3 and F7 (Z = -2.023, p = 0.043).

Australian Journal of Basic and Applied Sciences, 9(33) October 2015, Pages: 156-161

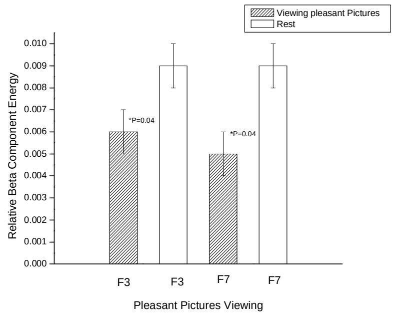
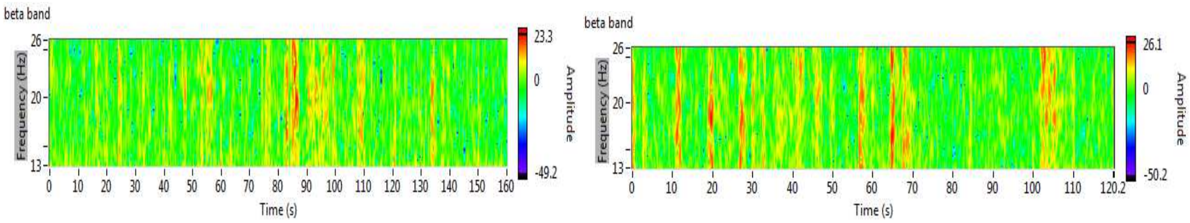


Fig. 5: Mean and standard error of Relative beta component energy while viewing Pleasant pictures and Rest

The extracted beta band wavelet coefficients while viewing Pleasant pictures were visualized using time – frequency plot is shown in Figure 6a.



a) b)

Fig. 6: a) Time-frequency plot of Beta band (13-30) Hz while viewing pictures at Frontal lobe (F3) b) Time-frequency plot of Beta band (13-30) Hz during Rest at Frontal lobe (F3).

The relative beta component energy decreased for the whole time 2 minutes 40 seconds (160 s) viewing pleasant pictures for left frontal lobe electrode locations only, F3 electrode location were shown in the Figure 6a. The extracted beta band wavelet coefficients during rest were visualized using time – frequency plot is shown in Figure 6b.

Meanwhile the relative beta component energy increased for every 10 s till 70 s then again increased at end of the rest period 100 s (120 s). This was noted only at left frontal electrode location, F3 electrode location was shown in the Figure 9. There were no changes reported in alpha component energy.

Discussion:

Emotion is slanted and it varies across culture. In order to induce emotion, very strong stimulus is necessary. Lang *et al*. (1999) and Bradley and Lang (2000) used International Affective Picture System (IAPS) and International Affective Digitized Sounds (IADS) as a stimuli to induce emotion. In the current work, IAPS images grouped as positive and moderate arousal was observed to study the perceived and induced emotions on the south Indian subjects. Justlin and Laukka (2004); Bradley and Lang (1994) used Self-Assessment Manikin (SAM) scale to assess the affective dimensions of valence and arousal and dominance. Based on the previous findings, the perceived emotion was measured using the SAM scale. Our south Indian participants were reported the mean valence 6.89±1.55 and mean arousal for the same pictures as 3.09±2.11 for the positive and moderate arousal pictures. Based on the participants' rating the viewed stimulus is rated as Pleasant or Low arousal.

The current study hypothesized that the perceived and the induced emotions would be the same where the induced emotion will be reflected in the physiological signals. Sammler *et al*. (2007) stated that Electroencephalogram (EEG) provides high temporal resolution and can be used to study the emotional states at various time scales. Based on this, current work employed EEG for the emotion analysis.

Sammler *et al*., (2007) observed that the participants listen to consonant music there is an increase in the frontal midline (Fm) theta power when compared with the dissonant music. The induced pleasantness to the stimuli will be reflected as increase in the frontal midline theta band power which was observed in the present study. The increase in the relative theta component energy was noted only at the frontal and the temporal lobe electrode locations while viewing pleasant pictures whereas the decrease in the relative beta component energy was observed only at the left frontal electrode location. There were no changes in any other electrode locations and in the relative alpha component energy. The theta band variations were noted at the anterior (F3, F4 and F8) and the posterior (T3, T4, T5 and T6) parts of the brain.

The beta band variation was noted only at the anterior (F3 and F7) parts of the brain. The EEG component energies were noted only in the theta and the beta bands that supports the findings of B.L. DeLaRosa *et al* 2014 which stated that the theta and the beta band activities play a prominent role in synchronizing information processing at different time scales during an inherent visual intimidation processing task. G Bahar and E Basar (2010) analyzed the event related beta oscillation in contrast to the presentation of IAPS picture stimuli and stated that negative emotions are related to the increased beta response in humans.

The positive aspects of pleasing appreciation have been linked to the arousal in the left frontal areas, while the negative emotions involve the arousal in the right frontal areas (Schmidt & Trainer, 2001). Alpha and beta waves have been shown to be inversely related when encountering a stressor, with alpha bands decreasing while the beta bands increase in energy (Sulaiman *et al*., 2010). The beta component actually decreased while viewing the pleasant pictures at the left frontal lobe electrodes when compared to the rest period. This clearly indicates that the viewed stimulus did not elicit any arousal. There was no change in the alpha component energy for any of the electrode location. The EEG band component energy changes were noted only at the frontal and the temporal lobes of the brain. To strengthen the study further, the pleasant pictures with high arousal, the unpleasant pictures with various arousal levels and the neutral pictures will be observed from the same IAPS database and the sample size would be increased.

Conclusion:

In the two dimensional affective emotion space (valence and arousal), the south Indian participants perceived and induced emotion were measured. The induced emotion was measured using EEG and perceived emotion by using SAM scale. In the current study based on brain activation, the theta component increased at all frontal lobe electrode locations, this indicates the viewing pictures are pleasant and beta component energy decreased at left frontal electrode locations when compared with Rest. This suggests the viewed pictures are positive and moderately arousal matches the perceived emotion rating. There was no alpha oscillation at the frontal lobe so the induced emotion cannot be interpreted as positive or negative Emotion. The viewed list of IAPS positive and moderate arousal perceived valance rating similar to western population whereas the changes were noted in arousal ratings.

Appendix A:

The following IAPS pictures formed pleasant category: 2010, 2345, 2501, 2530, 2540, 5200, 5760 and 5780.

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