Frontal Asymmetry Analysis of Theta Wave in the Audio Emotional Experiment Revealed by Event-related Spectral Perturbation

Ruoyu Du[1], Hyo Jong Lee[1,2]
[1]Division of Electronics and Information Engineering, Chonbuk National University
[2]Center for Advanced Image and Information Technology

Abstract

Hemispheric asymmetry in prefrontal activation have been proposed in two decades ago, as measured by electroencephalographic (EEG) power in the theta band (4-8Hz), is related to reactivity to affectively pleasure audio stimuli. In this study, we designed an emotional audio stimulus experiment in order to verify frontal EEG asymmetry by analyzing ERSP results. Thirty healthy college students volunteered the stimulus experiment with the standard IADS affective sounds. These affective sound clips are classified in three emotion states, happy, neutral and fear. ERSP image results revealed that there are the stronger responses of high arousal (fear and happy) in the left pre-frontal lobe, while the stronger responses of low arousal (neutral) in the right pre-frontal lobe. However, the high pleasure emotions (happy) can elicit greater relative right EEG activity, while the low and middle pleasure emotions (fear and neutral) can elicit the greater relative left EEG activity. Additionally, the most response differences of theta band have been found out in the medial frontal lobe, which is proved as the frontal midline theta.

1. Introduction

Pre-frontal hemispheric asymmetries have become widely accepted as a correlate of approach and feedback related motivation in basic research [1-3], with more and more studies extending the frontal asymmetry methodology to diverse fields in related applied psychology. Recent researches on a differentiation of valence and approach-withdrawal motivation suggests that only the latter is lateralized in frontal and pre-frontal brain regions [4] [5]. Theta waves (4-8 Hz) have been associated with drowsiness, daydreaming, creative inspiration and meditation, arousal [6], sensorimotor processing and mechanisms of learning and memory [7]. One type of theta waves is named frontal midline theta. The theta waves exist during the various tasks which need the correlation of the increased mental effort and sustained concentration. The theta wave is widely used in the auditory research [8]. The ERSP reflects the influence of the stimulation on the power spectrum, and can prove the evoked response theory [9]. These ERSP features exhibit certain patterns in the time-frequency domain and contain relevant and complementary information, and might have the potential to provide new or extra features to increase the performance. In this paper, we aim to find out the EEG response features of frontal theta band during the emotional audio stimulation using ERSP maps.

2. Data Collection

2.1 Subjects

Thirty males in the age group of 20-26 years were employed as subjects. They are all right-handed and have correct visions. All the subjects were healthy and none of them had prior history of neurological or psychiatric disorders. All of them gave informed consent. Once the consent forms were filled-up, the subjects were given a simple introduction about the research work and stages of experiment. The subjects were still instructed to wear the headphone and seat in the semi-upright position, and were instructed to remain still and to blink or move their eyes and body as little as possible.

2.2 Stimuli and procedure

There are 42 sound clips from IADS in this experiment. They were characterized by both levels of arousal and pleasure namely: high pleasure-high arousal, low pleasure-high arousal and middle pleasure-low arousal. These affective states are commonly defined as happy, fear and neutral separately. During the experiment, the selected sounds were classified two equal sets, each of which have 21 sound clips from three states. Specially, Set1 have more excessive affective sounds. These sounds were selected from uniformly distributed clusters along the pleasure and arousal axes. Audio stimuli were 42 affective sounds with different emotional pleasure, presented randomly for 6s following another 4s for resetting emotion with no sound. It is also necessary to reset emotional status before the projection of the first sounds. Thus, fixation mark (cross) was projected for eight seconds in the middle of the screen to attract the attention of the subject. The EEG signals from each subject were recorded during the whole projection phase.

2.3 EEG recording

The EEG was recorded using a Brain Vision amplifier system. Silver-silver-chloride-electrodes (Ag/Gal) were used in association with the ‘‘Easy Cap System’’. In this research, eighteen electrodes (Fp1, Fp2, F3, F4, Fz, F7, F8, C3, C4, Cz, T7, T8, P3, P4, P7, P8, O1, and O2) were inserted to record EEG signals using the Easy Cap which refer to Figure 1. The circles shows the selected channel in this study. These selected channels (Fp1, Fp2, F3, F4, F7 and F8) belonged to the frontal lobe region and they were distributed in the left and right hemisphere.

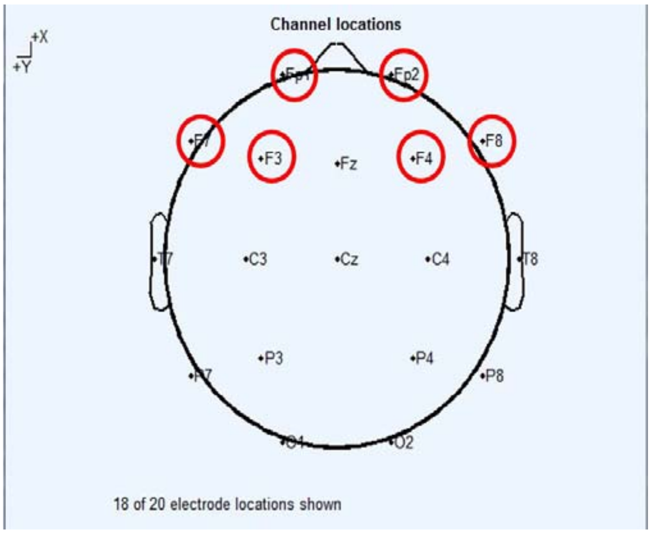


Figure 1. The montage used in this research based on 10-20 system of electrode placement, the circles denoted the selected channels in this study.

3. Event-related Spectral Perturbation Analysis

In EEG research, the event-related potential model often proves to be a limited method to study complex brain dynamics. For this reason, event-related spectral perturbation (ERSP) techniques adapted from signal processing have been used in the recent years. They represent average spectral changes in response to a stimulus. ERSP measures the mean event-related changes in the power spectrum at a data channel or component. They generalize the narrow-band event-related de-synchronization and synchronization [10]. Calculating an ERSP requires computing the power spectrum over a sliding latency window then averaging across data trials. The color at each image pixel then indicates power (in dB) at a given frequency and latency relative to the time locking event. Typically, for n trials, if, $F_k(f, t)$ is the spectral estimate of trial k at frequency f and time t, then ERSP is given by

$$ERSP(f,t) = \frac{1}{n}\sum_{k=1}^{n}\left|F_k(f,t)\right|^2$$

To compute spectral density, EEGLAB uses either the short-time Fourier transform or a sinusoidal wavelet (short-time DFT) transform that provides a specified time and frequency resolution [5].

4. Experiment Results

Results demonstrated that the three different pleasure-arousal emotional states performance related changes on brain activities in the frontal lobe were revealed by ERSP. Figure 2 shows the theta ERSP map in the pre-frontal lobe. More ERSP maps of theta band around frontal lobes are thumb nailed in the Fig. 3 for three emotions: happy, fear and neutral. In the Fig. 2, the range of power (dB) was quantified from 2.0 to –2.0. We chose the first 1500ms to analyze the first response of different emotion when the subject received the sound stimuli. There were obvious differences in the responses between high arousal emotional stimuli and low arousal emotional stimuli in the whole pre-frontal lobes, which were indicated in the Fig.2. In the left pre-frontal lobe, there were the stronger response in the high arousal (fear and happy) stimulus than in the low arousal (neutral) stimulus.

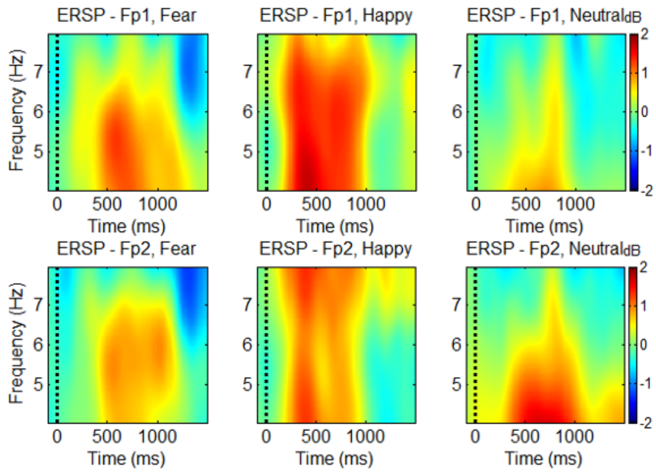
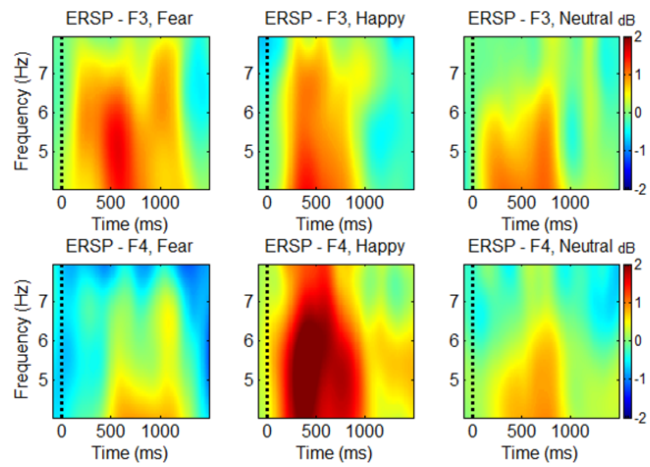
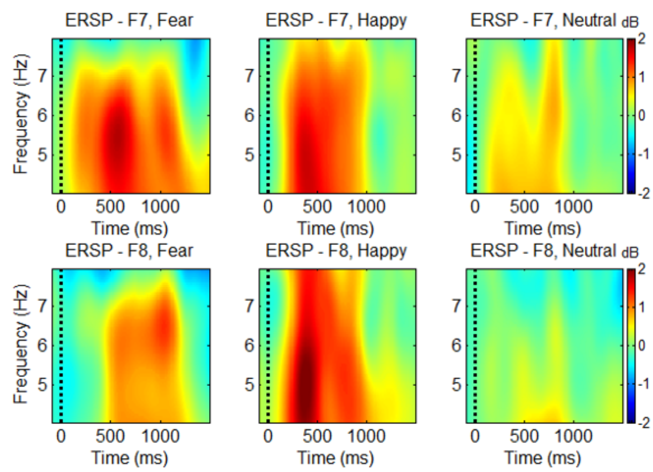


Figure 2. ERSP maps of different emotion states in channels of pre-frontal lobe



(a)



(b)

Figure 3. ERSP maps of different emotion states in channels of frontal lobe

Moreover, the different emotion responses result of ERSP maps in the channels of frontal lobes were shown in the Fig. 3. The ERSP result windows have the same scale calibration as the Fig. 2. Figure 3(a) showed the result maps in the medial frontal region. Figure 3(b) showed the result maps in the lateral frontal region. F3 and F7 belongs to the left hemisphere of frontal lobe. There is a stronger response of theta band in the left frontal hemisphere than the right hemisphere in the fear and neutral. However, the greater responses in the happy stimuli were elicited in the right frontal hemisphere than that in the fear and neutral, which shown in the F4 and F8 electrodes of Fig.3. In addition, the most obvious difference and the strongest responses of happy state were elicited in the medial frontal region.

5. Conclusion

In this paper we investigate how the brain activity changes in the frontal theta band according to three classical audio emotional stimuli. There have 42 IADS sound clips were selected as the stimuli. While those emotion statuses changed, the range of 4 to 7 Hz (theta band) is extracted and the ERSP maps were calculated and revealed in the whole frontal lobe region. The intensity difference were found in the different frontal regions, where emotional changes were dominant. First, there are stronger response for the high arousal stimulus in the left pre-frontal hemisphere. While the stronger response for the low arousal (neutral) stimulus were found out in the right hemisphere. Secondly, the high pleasure (happy) emotional states were elicited greater relative EEG activity in the right hemisphere. While the low (fear) and middle (neutral) pleasure emotions have the stronger responses in the left frontal lobe region. Finally, the most obvious differences were elicited in the medial frontal region. In other words, the frontal midline theta was also found in this research. The greatest response in the happy stimulus proved the theta band have the correlation with the change of emotional states. Moreover, theta asymmetries in the frontal lobe observed in the different affective picture and the related conclusion may have the more important role in emotion processing than previously believed and should be more carefully considered in future studies.

Acknowledgement

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