Psychological responses to sound stimuli

Joint consideration of AAE model and CV model

Xi Chen[1], Toshifumi Sugiura[2]

[1] *Graduate School of Science and Technology, Shizuoka University, Japan, f5245014@ipc.shizuoka.ac.jp*

[2] *Research Institute of Electronics, Shizuoka University, Japan, sugiura@rie.shizuoka.ac.jp*

Abstract: Psychological evaluation remains an important problem. Among the current objective methods, Anterior Asymmetry and Emotion model (AAE model) is widely accepted as a trait-related and state dependent measure. However, other inconsistent results suggested that the AAE model is more likely to reflect the motivational direction than the affective valence. Combination with another index to provide more credible evaluation is being considered. Comfort Vector model (CV model) proposed by Yoshida uses the characteristic of the frontal alpha wave fluctuations to evaluate the mood states from affective valence and arousal dimensions. In the present study, we evaluated the psychological responses to two kinds of sound (scary and soothing) in a group of eighteen healthy graduate students by AAE model as well as CV model. Then we discuss the relation between the results of these two models.

Keywords: AAE model, alpha wave fluctuation, Comfort Vector model, sound stimulus.

1. INTRODUCTION

Emotion includes a series of completed psychophysiological responses in the interaction with external stimuli or circumstances both in conscious and unconscious processes. Although various attempts in previous studies have been made to evaluate the psychological states, the objective evaluation still remains an important problem.

Because the psychological response is a substantial process occurring in the central nervous system, the electroencephalogram (EEG) which reflects these electrical activities could be used as the appropriate indices. The Anterior Asymmetry and Emotion model (AAE model) which uses the asymmetrical cortex activity between the left- and right-sided frontal lobes in the emotional experience and behavioral expression is widely accepted as a reliable index (Ahern & Schwartz, 1985; Davidson & Hugdahl, 1996; Hofmann, 2007; Jacobs & Snyder, 1996; Schmidt & Hanslmayr, 2009; Sutton & Davidson, 2000; Tomarken et al., 1992; Wheeler et al., 1993). According to the AAE model, the left frontal cortex is involved in the approach-related behavior and positive affect, while the right frontal cortex is involved in the withdrawal behavior and negative affect. However, the inconsistent result suggested that the frontal asymmetry is more likely to reflect the motivational direction rather than the affective valence if the motivation is not in accordance with the affective valence for some emotion (e.g., anger is approach-related but negative emotion) (Harmon-Jones & Allen, 1998). For a reliable evaluation, we consider that the combination use with other indices that mainly focus on capturing affective state become necessary.

Yoshida (2002) proposed a comfort vector model which is to use the frontal alpha-wave fluctuation to evaluate the mental mood from affective valence and arousal dimensions. 1/f fluctuation has been found in most natural events, like the birdsongs and the murmur of river. And the classic music which follows the 1/f fluctuation characteristic could reduce the negative mood (Levitin et al., 2012; Gough, 2000). Yoshida suggested that if the 1/f fluctuation characteristic is observed in the bio-physical rhythms, the individual is experiencing a positive mood state, otherwise is negative.

Based on the results of a great number of samples, Yoshida suggested the relation between the slopes of the alpha fluctuation power spectra and the emotional experience. The left prefrontal lobe is related to the affective valence, while the right is to the arousal (Yoshida & Iwaki, 2000). This method is to use the characteristic of the alpha-wave fluctuation in the left and right prefrontal lobes to estimate the psychological states as a point in a circle surface (Comfort Vector surface). This surface is comprised of two orthogonal axes: the affective valence and arousal.

In a previous study, we suggested the validity of CV model for evaluating the affective states (Chen et al., 2013). In this present study, we aim to investigate the psychological responses to sound stimuli by using the combination of AAE model and CV model, and discuss their correlation.

2. EXPERIMENT

2.1. Subjects

Subjects were 18 healthy university students, aged from 20 to 24. They were asked to have enough sleep before the experiment day, and to refrain from intense exercises, tobacco, coffee and alcohol.

2.2. Stimuli

Two kinds of affective sound clips were used in the experiment. One was a 5 minute "scary sound (including woman scream, gasping respiration, zombie scream)" which was selected to tense the body and elicit negative affect. The other soothing stimulus was a 5 minute classical music excerpt extracted from Pachelbel's Canon which was selected to elicit the positive affect.

2.3. EEG recording and processing

EEG was recorded according to the international 10-20 system from 19 referenced channels (Fp1,Fp2,F3,F4,C3,C4,P3,P4,O1,O2,F7,F8,T3,T4,T5,T6,Fz,Cz,Pz) linked to ear lobes, with ground electrode attached to the glabella. Data were digitized at 1 kHz (0.05-100 Hz). The impedances at frontal lobes: Fp1, Fp2, F3, F4 which were the main analysis positions in the study, were kept less than 5kΩ. A bipolar vertical electrooculogram (EOG) was recorded from supra- and infra-orbital positions of the right eye. After all the electrodes were attached, subjects were instructed to initially rest in a sitting position in a sound-dampened chamber. For each stimulus, EEG was recorded during twenty-five minute period, including ten minutes baseline, five minutes one stimulus presentation, and ten minutes recovery periods. After ten minutes break, the same EEG recording was carried for the other stimulus. During the whole EEG recording periods, subjects were instructed to maintain the eye-closed state to prevent the influence of eye-blinks.

The left- and right-sided alpha power (8Hz~13Hz) was calculated by the Fast Fourier Transform method (FFT method). Power values were then log-transformed, and the alpha power asymmetry values were calculated by subtracting left-sided alpha power from right –sided alpha power (In(Right) – In(Left)). Because the alpha power is inversely related to the cortical activation, positive values indicate relatively greater left frontal activity, while negative values indicate relatively greater right frontal activity.

3. METHOD

Comfort Vector model (CV model). We described the procedure to calculate the comfort vector in our previous study (Chen et al., 2013). Firstly, the recorded EEG data from Fp1 and Fp2 was passed through a band-pass filter (8Hz~13Hz) where the alpha-wave component was extracted. Next, we transformed the alpha wave into a time series of frequency fluctuation by zero-crossing method. Then the spectral power density of alpha fluctuation was calculated every twenty seconds. We took the frequency where the spectra changed most significantly for the inflection point. According to the inflection point, the spectra were divided into two part, lower frequency band field and higher frequency band field. The absolute slope obtained through regression curves of the lower frequency spectra in the left- and right-prefrontal lobe was used for the indicator of affective valence and arousal, respectively. Slope value approaching to 1 at Fp1 indicates more pleasant while approaching to 0 indicates more unpleasant. Slope value at Fp2 approaching to 1 indicates more calm while approaching to 0 indicates more excited.

The comfort vector is shown in algorithm (1), (2): where Fp1_slope and the Fp2_slope are the absolute values of slopes of regression lines of alpha fluctuation power spectra recorded at Fp1 and Fp2, respectively. The vector represents a point on the comfort surface shown in Figure 1. The surface consists of two orthogonal axes, pleasant-unpleasant and excited-calm, which makes four quadrants. The angle (θ) of the vector which is measured counterclockwise from the x-axis corresponds to the emotion valence while the length (*L*) of the vector which is the distance from the center represents the strength of comfort. One point shows the mood state of 20-second interval.

$$\theta = A\tan\left(\frac{Fp1\_slope - 0.5}{0.5 - Fp2\_slope}\right) \times \frac{180}{\pi} \quad (1)$$

$$L = 100 \times \sqrt{\frac{Fp1\_slope^2 + Fp2\_slope^2}{2}} \quad (2)$$

In the present study, we treated the upper half surface (the first and the second quadrants) as the pleasant filed while the lower one as unpleasant field, and the left half surface as clam field while the right side as excited (Figure 2). To quantify the mood states, we calculated the ratios of points lying in these respective fields as the indices of psychological states.

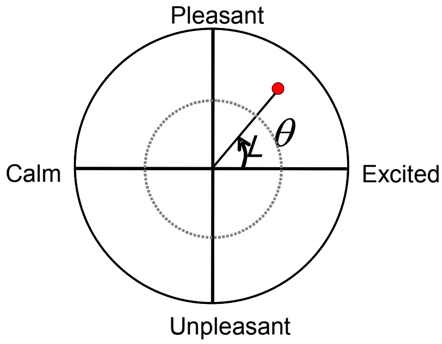

Figure 1: Comfort Vector surface

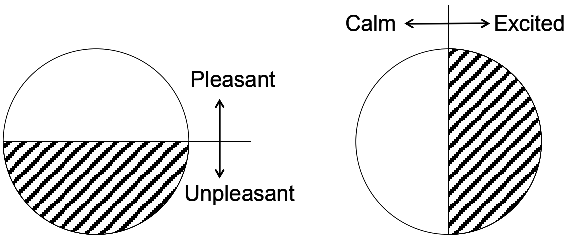

Figure 2: Classification of mood states

Table 1: Changes in frontal asymmetry in response to scary sound

Group	Baseline	Sound	Recovery	Subjects
I	-0.06 (0.04)	-0.14 (0.08)	-0.08 (0.04)	A,B,C,H,J,Q
II	-0.08 (0.07)	0.04 (0.01)	0.02 (0.08)	E,F,G
III	0.09 (0.08)	0.05 (0.08)	0.08 (0.08)	D,K,L,M,N,O,P,R,T

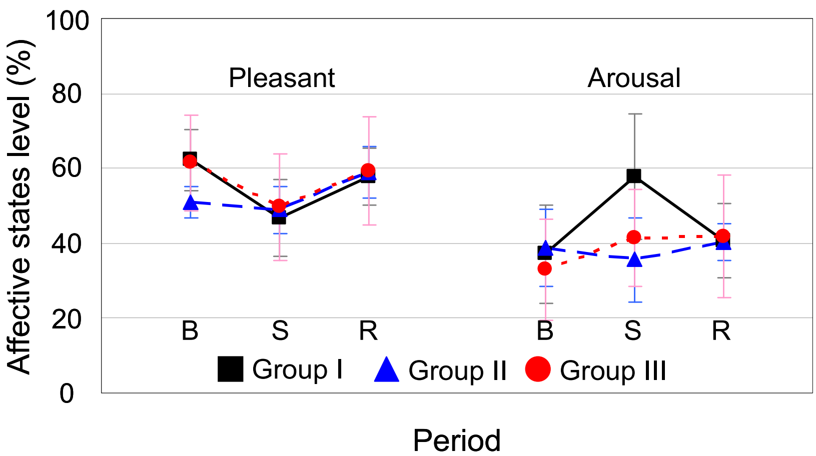

Figure 3 Changes in affective states (pleasant and arousal) to scary stimulus evaluated by CV model (B: Baseline; S: Sound presentation; R: Recovery)

4. RESULTS

In this present paper, we mainly focus on showing and discussing the results of the AAE model and CV model of the scary sound stimulus. And discuss the results of the soothing sound stimulus at the final section. The results of AAE model and CV model in response to the scary sound are shown in Table 1 and Figure 3.

As shown in Table 1, subjects were divided into three different groups (Group I, II, and III) according to their baseline frontal asymmetry and their sound stimulus-elicited changes. Six subjects who had negative values of frontal asymmetry at baseline displayed more negative values in response to the stimulus (Group I). Three subjects in Group II had negative values at baseline and showed positive values while listening to the scary sound. And Group III had positive values at baseline while presented the decrease in these values during the sound presentation period.

To discuss the relation between AAE model and CV model, we investigated and compared the results of CV model among Group I, II and III. Figure 3 shows the pleasant and arousal states of these three groups at baseline, sound presentation, and recovery periods. Indices for pleasant and arousal states of CV model were the ratios of the number of the points located in the upper and right part of the CV surface (Figure 2) for three different periods (baseline, sound presentation and recovery).

As shown in Figure 3, these subjects in Group I and III who displayed decreased values in frontal asymmetry (AAE model) showed significant decrease in the pleasant affective states and increase in the arousal (more excited affective states), compared to baseline (Group I: ΔPleasant = -15.56%, $t(5)=-2.51, p<0.05$, ΔExcited=20.55%, $t(5)=2.29$, $p<0.05$; Group III: ΔPleasant=-11.85%, $t(8)=-2.33, p<0.05$, ΔExcited=8.52%, $t(8)=2.55, p<0.05$). During the resting period after the stimulus presentation, the pleasant affective states of these two groups recovered to the baseline level. While these subjects in Group II who displayed positive values of frontal asymmetry (AAE) showed non-significant changes neither in pleasant nor arousal states.

5. DISCUSSION

In this study, we investigated the psychological responses to two kinds of sound stimuli by using AAE model and CV model. However, the significant results were only observed for the scary stimulus. Group I as well as III showed significant decrease in their asymmetry values as well as the pleasant level. Their arousal level in sound presentation period also increased compared to baseline. From these results, it seems that this scary stimulus aroused pronounced withdrawal motivation (relatively increased right frontal activation), more negative mood and more cautiousness in these subjects. This result is consistent with a previous study suggesting that we react more significantly to the negative stimuli compared with the positive stimuli, perhaps as a consequence of evolutionary pressures to avoid harm (Davidson et al., 2000). Group II displayed non-significant change in affective state while listening to the scary sound. According to the opponent-process theory (Kline et al., 2007), affective and motivational states are modulated by two opposing processes: the initial reaction to stimuli and a compensatory process which tends to regulate the affective states. According to the result of the CV model, subjects in Group II did not express so much negative affect or withdrawal motivation in response to the scary sound stimulus. For this reason, the initial reaction which is related to the right frontal activation (negative affect and withdrawal-related motivation) in this case disappeared early while the opposite regulatory process became dominant, thereby leading to greater relative activation on the left frontal side (Davidson, 2004). From the results above, we considered that there was a correlation between the AAE model and CV model for scary stimulus.

Nevertheless, no correlation was observed for the soothing sound stimulus. These subjects who showed the similar changed patterns of their affective states (CV model) displayed different change direction of frontal asymmetry (AAE model). Some subjects showed increased positive affect as well as frontal asymmetry. This pleasure in classical music may activate the rewarding system of the brain (Salimpoor et al., 2009), which is considered to be related to greater left frontal activation. However, some other subjects displayed increased pleasant affect but decreased frontal asymmetry. According to a previous study (Davidson, 1998), not all positive affects are related to left frontal activation, only those accompanied by goal-pursuit motivation. Some other positive affective states, such as relaxation, calm and other post-goal affects may inhibit the approach-related behavior, i.e., appeared withdrawal behavior. The difference between these two kinds of pleasure might be distinguished by jointing the AAE model and CV model. The joint consideration would evaluate the psychological states from affective valence as well as motivation dimensions, thereby may provide the multifaceted evaluation.

Although the ‘Pachebel’s Cannon’ which was used as the soothing stimulus is generally considered as a pleasant sound, nevertheless, the positive affects were not necessarily elicited in all subjects in the present study. Salimpoor et al. (2009) suggested that, music emotions are based on aesthetic stimuli, and do not have an obvious adaptive or survival value, thereby the emotional experience of music would not be universally similar, but depends on personal preference and previous experience. Also, the affective states while listening to music may be affected by some external factors such as the listening environment. These effects are highly individualized, and are thereby difficult to estimate. More significant result would have be expected if we could use some simple but distinct stimuli with positive valence, such as laughing sounds, or select the proper stimuli according to personal preference.

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BIOGRAPHY

Xi Chen was born in Beijing, China on January 15, 1988. She received the B.A. degree in Biomedical Engineering from Southeastern University, Nanking, China, in 2009, and the M.E. degree in Electrical and Electronics Engineering from Shizuoka University, Hamamatsu, Japan, in 2012. She is currently a second year doctoral student at the Graduate School of Science and Technology, Shizuoka University. Her research interests include Kansei evaluation by EEG. Xi Chen is a student member of Society of Psychophysiological Research (SPR) and Japan Society of Kansei Engineering.

Toshifumi Sugiura was born in Iida, Japan on April 13, 1951. He received the Ph.D. degree in semiconductor materials from Shizuoka University, Hamamatsu, Japan, in 1979, and the Ph.D. degree in Medicine from Hamamatsu University School of Medicine, Hamamatsu, Japan, in 1993. He is currently a professor at the Research Institute of Electronics, Shizuoka University. His research interests include Kansei (or mood state of mind) and stress evaluations by EEG and HRV, and brain temperature measurement by microwave radiometer system. Dr. Sugiura is a member of IEEE Engineering in Medicine and Biology Society, the Society of Psychophysiological Research (SPR), and the Japan Society of Kansei Engineering.