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The relation between affective style of stressor on EEG asymmetry and stress scale during multimodal task

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Abstract

In previous paper, we founded that the affective style of subjects according to an auditory stressor existed. Subjects in the stress group compared to other groups reported a higher level of stress on physiological stress scale. The aim of the current study was to investigate the relation between affective style and stress scale under various stress conditions. This experiment consisted of three sessions such as auditory, movie, and unknot task. We used woman scream, horror movie, and unknot stimuli to evoke stress. We classified the affective style according to task based on EEG asymmetry. The stress scale in stress group was greater than that of other groups for all tasks. Also, a subject who in stress group for specific stimulus was not always in stress group for other stimuli. These results demonstrate that the subjects with the propensity to negative affective style are apt to be stressed.

Keywords: Frontal asymmetry, affective style, stress scale, EEG

1. Introduction

Stress is common in everyday life and is believed to affect happiness, health, and cognition. Although many studies have been made in uncovering the neuroendocrine and molecular processes mediating the cascade of reactions to stressor [1, 2], the central mechanism and neural correlates of psychological stress remain unknown. Indications of the fight-or-flight response under threatening situations suggest that the brain's response to stress may involve excitation of the emotion and vigilance systems. Although the majority of stress today is due to psychosocial factors and is not threatening, this brain-activation pattern may still take place during tasks such as test and impromptu speech [3]. There are some studies on brain activity pattern under stress environment such as word, examination, noise, and mental task stress [4, 5, 6, 7].

A major aspect of neurophysiological research on emotion is hemispheric specialization of emotion. These studies show that the left hemisphere is more involved in the processing of positive emotions and approach-related behaviors, whereas the right hemisphere is more involved in the processing of negative emotions and withdrawal behaviors [8, 9]. The model also suggests that the frontal cortex is particularly critical in emotional processing. There is an abundance of evidence supporting this model, from prefrontal ElectroEncephaloGram (EEG) alpha asymmetry studies. These studies show that positive moods or reactions are predicted relatively greater Left preFrontal Activity (LFA), whereas, negative moods or reactions predicted relatively greater Right preFrontal Activity (RFA) [10].

Also, recent neuroimaging studies suggest that negative affect generally elicits activation in the right prefrontal cortex, amygdala, and insula, whereas the left prefrontal cortex is associated with positive emotion [11]. The right prefrontal and cortex may play a key role in the brain's response to stress, because this brain area is a primary part of both the emotion and vigilance networks. Some studies suggest that high levels of right-sided prefrontal activation have been linked with negative affective style and suppressed immune function. Specially, Davidson suggests that individual differences in asymmetric frontal activity indicated individual differences in affective style [12, 13]. This brain area may be a common mediator of the relationship between psychosocial stress and its effects on mental and physical health [1, 2, 14, 15].

This study aims to investigate the possible effects of emotions which are associated with stress. There are many studies evaluating the stress state in stress disorder such as posttraumatic stress disorder [16]. Recent studies have highlighted the role of right-sided prefrontal activation during stress [17]. However, there

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are few studies on the affective style for normal stress response under natural stress. Also, yet no study has been performed on the Stress scale according to affective style during stress. For that purpose, we use woman scream (audio), horror movie (audio-visual), and unknot (audio-visual-motor) stimuli to evoke naturalistic stress and classify affective style according to different stimuli and then evaluate Stress scale. These results will be able to reveal the relationship between individual's affective style and stress scale under naturalistic stress. It is predicted that the stress group will result in relatively greater RFA than other groups. A greater stress scale will be associated with relatively greater RFA.

2. Materials and Methods

2.1. Participants

37 healthy, right-handed volunteers participated in the experiment. The subjects comprised 6 females and 31 males aged between 20 and 30 years. All subjects had normal auditory function; none of them had neurological disorders. All participants gave written informed consent.

2.2. Procedures

All subjects are tested during a rest state session and a stimulus session. During the rest state session, no stimulus was presented. EEG recordings in the rest state were performed over a period of 5 minutes. All subjects were instructed to keep their eyes closed in order to minimize blinking and eye movements.

2.2.1. Multimodal tasks. We investigated the effect of stressor according to multimodal stimuli on frontal EEG asymmetry. We used a woman's scream, horror movie, and unknot to induce negative emotion as stressor, and landscaped movie and the sound of birds in a peaceful forest to induce positive emotion. The human ear is less sensitive to low frequency sound than high frequency sound [18]. We are most sensitive to high frequency sounds, such as a child's scream. A human scream is within the range 2,000Hz to about 4,000Hz [19]. The auditory stimuli consisted of a woman's scream and the sounds of a bird. A woman's scream was presented in the form of an auditory stimulus of -93dB to -36dB intensity, in the range 65 to 2,0000H. The sound of birds was presented as an auditory stimulus of -103dB to -56dB intensity, in the range 130 to 20,000Hz. During the auditory session, a woman's scream and the sound of birds are repeated 30 times. These stimuli lasted for 2 seconds and the time interval of the stimuli is 3 seconds. Also, anxiety, fear, and stress increased cortisol in the brain. A cortisol is the important stress hormone. Cortisol level increased while subjects were watching a horror film [20]. We used horror film as an audiovisual stressor. These audiovisual stimuli lasted for 3 minutes. Also, we put to use unknot stimulus to induce stress under the multimodal condition. Unknot stimulus is to untie a thread with four knots as soon as possible. Unknot stimulus lasted for 4 minutes. The information of time was provided with headphones.

2.3. EEG recording

We used 4 positions; Fp1, Fp2, F3, and F4; according to the Modified Combinatorial Nomenclature (MCN) system. In many studies on FA, these positions were chosen to detect prefrontal activity [21, 22]. We usually analyzed frontal EEG alpha asymmetry at the F3, F4, Fp1, and Fp2 positions. EEG was recorded using Ag-AgCl disc electrodes placed at 4 positions. Additionally, EEG recordings from the left earlobe (A1) and back of the neck (Iz) were used to obtain the reference and ground potentials, respectively. The sample rate of the EEG acquisition device was 256Hz, and the resolution of the A/D converter was 12 bits. The EEG measurement software system recorded the EEG value of subjects by emitting the auditory stimulus at defined times.

2.4. EEG asymmetry analysis and stress scale

All EEG recordings were filtered using band-pass FFT filtering of 4 to 30 Hz, in order to eliminate the influence of artifacts in the theta (4-8Hz), alpha (8-13Hz), and beta (13-30Hz) response components.

Asymmetry scores represented the difference between log alpha density in the right hemisphere electrodes of interest, and log alpha density in the left hemisphere electrodes of interest, or ln(Right)-ln(Left) alpha power [23]. The difference score provides a simple scale representing the relative activity of the right and left hemispheres, with higher scores indicating relatively greater left frontal activity. Alpha asymmetry results in lower scores in greater right frontal activity, assuming that alpha power is inversely related to activity. We performed alpha band to all band power spectrum analysis for stimuli, then, calculated frontal alpha asymmetry in the Fp1/2 and F3/4 sites.

The brain waves are represented in different frequency bands. Every band mirror a number of recognized mind conditions. Beta is usually split into low Beta (12-15 Hz), midrange Beta (15-18 Hz) and high Beta (>18 Hz). Beta is associated with the fully

awake, fully focused mind. High beta without alpha is associated with stress, anxiety, high blood pressure, and similar issues [24]. Also, alpha waves are dominant waves when a person is in a state of relaxation which enhances focused inner concentration. Thus, we used high beta/alpha relative power as a stress scale to evaluate stress.

2.5. Statistical analysis

The alpha asymmetry values were analyzed in a two-way ANOVA with the following factors: "affective style" (non-stress, stress, normal), "stimulus type" (woman scream, bird sound, horror movie, landscaped movie, unknot, rest). The type of stimuli were selected by task: woman scream and bird sound (audio), horror movie and landscaped movie (audio-visual), and rest state and unknot (audio-visual-motor). All statistical analyses were performed using the statistical software package SPSS PC (version 12.0). Results were considered as significant at the level of $p<0.05$.

3. Results

3.1. Alpha asymmetry and affective style

Some may perceive the same sound stimulus as noise, whereas, others may not. The reception of stimulus is influenced by two kinds of cognitive characteristics; current transient influences and enduring individual qualities [25]. For this reason, we assumed that there is an individual affective style with respect to stimuli and classified according to frontal alpha asymmetry. This consisted of three groups; stress, non-stress, and normal. A relatively greater RFA was demonstrated with a number of distinct negative mood states or behaviors, including depression, fear and withdrawal [10]. Stress was empirically related to the region of right prefrontal cortex [26]. In order to understand the relationship between the affective style according to stimuli and RFA, we assumed that the stimuli inducing negative emotion results in a relatively greater RFA than that of the stimuli inducing positive emotion. For that purpose, the natural log alpha relative power values of electrodes at Fp1, Fp2, F3, and F4 were calculated and alpha asymmetry was obtained in the Fp2/Fp1 and F4/F3 sites. Table 1 shows the basis of classification of affective style based on alpha asymmetry. However, some subjects exhibited relatively greater RFA in the stimuli inducing positive emotion compared to the stimuli inducing negative emotion.

Table 1. Individual affective style with respect to stimuli

Affective style	Basis of classification
Stress	Scream and bird sound alpha asymmetry < 0 Landscaped and Horror movie alpha asymmetry < 0 Rest state and Unknot alpha asymmetry < 0
Non-stress	Scream and bird sound alpha asymmetry > 0 Landscaped and Horror movie alpha asymmetry > 0 Rest state and Unknot alpha asymmetry > 0
Normal	Scream alpha asymmetry>0 and bird sound alpha asymmetry < 0 or Scream alpha asymmetry<0 and bird sound alpha asymmetry > 0 Landscaped movie alpha asymmetry>0 and Horror movie alpha asymmetry < 0 or Landscaped movie alpha asymmetry<0 and Horror movie alpha asymmetry > 0 Rest state alpha asymmetry>0 and Unknot alpha asymmetry < 0 or Rest state alpha asymmetry<0 and Unknot alpha asymmetry < 0

3.2. Alpha asymmetry and stressor

We found the difference of individuals with respect to the stimuli. Frontal EEG alpha asymmetry varied according to individual's affective styles. The extent of alpha asymmetry changed with the negative tasks such as woman scream, horror movie, and unknot was investigated through a series of paired sample t-tests. Significant differences were observed for horror movie ($t=-2.766$, $p=0.009$), and unknot tasks ($t=-4.364$, $p=0.000$). In both cases, lower scores were observed during negative task than during rest state. It means that horror movie and the unknot stimuli act as stressors properly. However, there was no significant difference during woman scream. Since our primary interest was the effect of affective style on alpha asymmetry, we will restrict reporting of the results of the effect of the affective style and stimuli type. There was significant difference in alpha asymmetry across the three affective styles in all sessions. However, the type of stimuli showed no significant effects on alpha asymmetry for all tasks. The average of alpha asymmetry in stress group was lower than that of other groups ($F=19.369.000$, $p=0.000$) in audio session and ($F= 25.831$, $p=0.000$) in audio-visual session and ($F=18.192$, $p=0.000$) in audio-visual-motor session. There were significant interaction between stimuli type and affective style in audio-visual ($F=7.167$, $p=0.000$) and audio-visual-motor ($F=6.003$, $p=0.004$). Also, the

average of alpha asymmetry in normal group was lower than that of non-stress group for all sessions. These results indicated that stress group was more relative to greater RFA compared to other groups. It means that stress group revealed a significant effect with greater right-sided activation at frontal sites. Also, the alpha asymmetry under stress environment is influenced by not stimulus type but affective style. The affective style acts as a major factor for stress response. Figure 1 indicates the average of alpha asymmetry according to affective style for negative sessions at F3 and F4 sites. As is clear from Figure 1, the average of alpha asymmetry in stress group is lower than that of other groups and the average of alpha asymmetry in non-stress group is the greatest among groups. Also, the averages of alpha asymmetry for horror movie and unknot session are greater than that of the woman scream session.

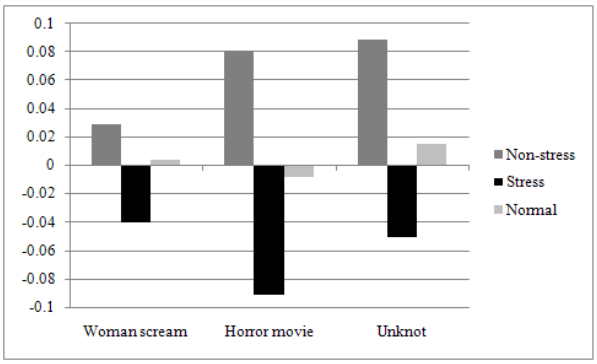

Figure 1. The average of alpha asymmetry according to affective style

3.3. An affective style and stress scale

We hypothesized that correlations exist between the stress level and the affective style. The stress metrics included high beta relative power/alpha relative power as stress scale. The high beta power (20-30Hz) relative to alpha power is widely known as a factor relative to stress [24]. As illustrated in Table 2, the mean of stress scale in stress group was the greatest compared to other groups for all sessions. Specially, although there was no significant difference for t-test in case of woman scream task, the mean of stress scale in stress group. This implied that subjects in the stress group were more sensitive to stress than that of other groups and have relatively greater RFA. Also, the stress scale of auditory stimuli was the lowest compared to stress scale of other groups. We assumed that stress scale has to do with the complexity and validity of stimuli.

Table 2. Stress scale with respect to negative stimuli

Stimuli	Channel	Stress	Non-stress	Normal
Woman Scream	Fp1	0.379	0.253	0.279
	Fp2	0.419	0.261	0.305
	F3	0.247	0.255	0.242
	F4	0.266	0.217	0.227
Horror movie	Fp1	1.476	1.11	0.49
	Fp2	1.477	1.298	0.602
	F3	0.515	1.009	0.606
	F4	0.667	0.794	0.558
Unknot	Fp1	1.646	1.273	1.343
	Fp2	2	1.155	1.071
	F3	0.949	0.814	0.829
	F4	1.146	0.642	0.773

4. Discussion

In the previous study, we found the relation between the affective style and the alpha asymmetry of auditory stress [27]. Four major results were observed in the present study. First, F3 and F4 sites were major positions evaluating the affective style under various stress conditions and had to do with emotion. Alpha asymmetry in these positions was able to use as factor classifying the affective style. Also, the alpha asymmetry of an individual was more influenced by the affective style than stimuli type. Second, subjects in stress group exhibited a relatively greater RFA and a relatively lower score of alpha asymmetry than that of other groups. Third, stress scale is greatest in the stress group compared to other groups. Also, a subject who in stress group for specific stimuli was not always in stress group for other stimuli. This result implied that there was more sensitive stimulus according to subject. Finally, the EEG stress scale of unknot and horror movie was greater than that of auditory stimuli in all affective style. Thus, we analyzed that it was due to the complexity and validity of stimulus.

Numerous studies demonstrated a shift toward greater right frontal activity during exposure to negative valence stimuli, or conditions that generally trigger a withdrawal response. Stress was empirically related to relatively greater RFA, especially in rodents [28]. Especially, Lewis investigated the effect of examination stress on frontal EEG asymmetry, psychological stress, hormonal stress, and negative health [7]. In the present study, generally, relatively greater RFA was exhibited during audio-visual and audio-visual-motor stimuli as well as auditory stimuli. However, some subjects exhibit the contrary with respect to RFA.

Frontal EEG alpha asymmetry was extensively studied as a correlate of individual differences in emotional response [13]. The effects of emotional significance in the negative stimulus varied between individuals. The present study presents the relation

between an individual's affective style and frontal alpha asymmetry with respect to audio, audio-visual, and audio-visual-motor stressor. Especially, a woman's scream and unknot resulted in the lowest alpha asymmetry (greater RFA) and highest levels of stress scale in the stress group. Although a correlation was exhibited between variation in frontal asymmetry and variation in any of the stress metrics, the relationship underlying this association remains obscure. Future studies are clearly needed in order to further investigate the underpinnings of these relationships. The present findings have an interesting implication for understanding the relationship between stress and frontal alpha asymmetry.

F3 and F4 are the most commonly used positions for examining alpha activity, as they are located above the dorsolateral prefrontal cortex [29]. The prefrontal lobe plays a crucial role in emotion regulation and conscious experience [30, 31]. Thus, we analyzed the data with fewer electrodes, involving mid frontal electrodes (e.g., F3/4), and more anteriorly located electrodes (e.g., Fp1/2). These two analyses led to different conclusions regarding an individual's affective style. We found that there is an individual affective style with respect to frontal alpha asymmetry in F3/4 sites, but not in Fp1/2 sites. Our findings argue for a comprehensive sampling of frontal sites in EEG asymmetry studies.

Our study demonstrated that stressor was associated with variation in frontal alpha asymmetry, caused by an increase in right frontal activity. Also, this variation in frontal alpha asymmetry was associated with an individual's affective style with respect to stimuli. A woman's scream, horror movie and unknot inducing negative emotion were associated with variations in frontal alpha asymmetry, caused by an increase in right frontal activity. These serve as natural stressor. Variations in frontal alpha asymmetry with respect to a stressor were greater in the stress group with higher stress scale. These results imply that there are differences in an individual's affective style for the same stimulus. An individual's affective style affects frontal alpha asymmetry with respect to emotional response. Therefore, it is a major aspect of emotional response. Our study shows that an individual's affective style is relative to stress level. Thus, the mechanisms mediating stress level with respect to affective style need further investigation.

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