Brain Function Connectivity Analysis for Recognizing Different Relation of Social Emotion in Virtual Reality

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Abstract. Social emotions are emotion that can be induced from human social relationships when people are interacting with others. In this study, we are aim to analyze a brain function connectivityin terms of different relations of social emotions. The brain function connectivity can be used to observe the neural responses with features of EEG coherences during a cognitive process.In this study, the EEG coherence is measured according to different social emotion evocations. The auditory and visual stimulus for inducing social emotions was presented to participants during 20.5 sec (±3.1 sec). The participants were asked to imagine and explain about similar emotion experience after watching each video clips. The measured EEG coherencewas grouped into two different social emotion categories;the information sharing relation and emotion sharing relation, and compared with the results of subjective evaluation and independent T-test.The information sharing relation was related with the brain connectivity oftherighttemporo-occipitalposition associated with a language memory. The emotion sharing relation was related with the brain connectivity of the left fron-to-right parietal position associated with a visual information processing area.

Keywords: Emotion, Social emotion, Emotion relation, EEG coherence, Brain function connectivity.

1 Introduction

In this study, social emotions are emotion that can be induced from human social relationships when people are interacting with others. Social emotion makes notice the intention of others and thus helps a more fluent information interaction to SNS (social networking service) user.

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The objective of this study is to analyze the brain functional connectivity by the different relation of a SNS. The cerebral activity that responds to cognitive function is

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able to analyze by brain functional connectivity, so it is important to the new HCI method.

EEG coherence has been used in the analysis of cognitive function. Rietschel(2012) used brain functional connectivity to analyze and to assess the cognitive process. Differences of task difficulty were compared in brain functional connectivity using EEG coherence. According to the result, the brain functional connectivity in the sensory motor increased when the given task was more difficult [1].

The EEG coherence has been used in order to observe the cognitive function in response to the motion of an object using brain functional connectivity. Experiment was to show visual simulating the collision of moving objects. Connectivity of the left sensory motor circuitthat is between the left occipital lobe and the parietal lobe increased when visual focus was needed [2]. So, according these studies results, EEG coherence was useful to analyzing cognitive function.

Reiser(2012) used the video and voice which expressed an actor's emotion for evoke social emotion. Variation of brain functional connectivity was analyzed using EEG coherence. Connectivity between the prefrontal cortex and the posterior cortical regions was recorded. The social emotion stimuli such as sadness, anxiety and neutrality represented to the subjects. According to the result, decrease of the brain connectivity in some subjects meant a lower degree of attention on emotional information. For other subjects, increase of the brain connectivity in the right hemisphere showed the focus on the social emotional information [3]. Thus brain functional connectivity changed between the prefrontal cortex and the posterior lobe area was related with emotional recognition.

Ye(2011) analyzed brain functional connectivity change by social relation.The images of persons who were different social relation with participants were presented and the subjects were instructed to recognize them. According to the result, frontotemporal connectivity was activated when social emotion was evoked [4].

Through these studies, the right cerebral hemisphere associated with emotion by the social relation was able to know how the brain reacts. Especially, connectivity between the frontal and temporal lobes was correlated with emotion by the social relation. However, the previous studies were difficult to see as a reaction to the process such as acquisition of information, emotion evoking, and emotion expression that occur within the SNS. Therefore, the objective of this paper is to analyze connectivity of brain function using EEG coherence in different relation with a similar situation within a SNS.

2 Method

2.1 Independent Variable and Dependent Variable

The independent variables were consisted as conformation as information sharing relation and emotion sharing relation. To evoke social emotion, the scenarios defined as visual stimuli (text and representative images) and auditory stimuli (prerecorded audio of a scenario) were presented simultaneously. Research of social emotion has been undertaken with a variety of independent variables such as image, text and recorded sounds noted. [4-10].

For the dependent variable, EEG was measured at eight points (F3, F4, T3, T4, P3, P4, O1, O2) shown as figure 1 and the sampling rate was 400Hz. An EEG100C (Biopac, USA) was used for measurement and impedance was less than 5kΩ.

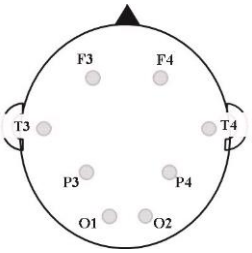

Fig. 1. Eight points of EEG measurement

2.2 Participants and Procedure

Twenty seven right-handed normal subjects (male: 13, female: 14) performed this experiment. The average age was 24.8(±1.3). The Subjects were paid about $50 for participation. They were instructed to have a deep sleep before the experiment, and were also instructed not to drink any caffeinated beverages, in order to limit natural arousal stimuli. When the subjects arrived in the experiment room, they were given 10-minutes rest in order to accustom them to the environment. Afterwards, they were informed about the experiment objective and process of test.

The EEG data was measured during the experiments of social emotion evocation. Stimulus within the experiment is a scenario which is the explanation of relation. This auditory and visual stimulus was presented to the participants during 22.5 sec. (±2.1 sec.). The participants were asked to imagine and describe a similar experience. The average time of imagination was 18.8 sec. (±2.5 sec.) and the vocal expression was 31.3 sec. (±3.1 sec.).

This experimental protocol is an improved method on the existing experimental protocol which has been used in various research purposes for the reaction according to the social emotion [9-14].

3 Analysis and Results

3.1 The Coherence of EEG

By using 8 measuring points, a total of 28 coherences (between the points) were analyzed (e.g. F3-F4, F3-T3, F3-T4...). EEG coherence measured the synchronization of two signals as a value between 0 and 1. If the coherence value was one, the two signals were identical. EEG coherence between two points can be measured with formula (1). In formula 1, R_x (w) and R_y (w) represents the spectrum power of each signal, and R_{xy} (w) represents the cross spectrum power. The FFT method was used for spectrum analysis, by applying a sliding window. The window size of the sliding window consists of 1600 (4 sec) samples, while the interval in which the slide progressed forward is at a rate of 800 samples (2 sec).

The EEG coherence result, divided as spectrum: delta(0.5~4Hz), theta(4~7Hz), alpha low(8~10Hz), alpha high(10~12Hz), beta low(12~15Hz), beta mid(15~18Hz), beta high(18~30Hz), and Gamma(26~100Hz).

$$C_{xy} = \frac{|R_{xy}(w)|^2}{R_x(w) \times R_y(w)} \tag{1}$$

3.2 Normalized EEG Coherence

Normalized EEG coherence was used in a number of studies as a way to clarify the comparison between the stimuli [15- 17]. Entire individual coherence measurements without the distinction of social emotional stimuli were normalized using formula 2. In Figure 2, the normalization of the results before and after the F3-F4 alpha high coherence values can be compared.

As shown in Figure 2, the maximum value of coherence and the top 5% of the value of individual differences were not significant when normalization was not applied. Also shown in Figure 2, it can be seen that a decrease in the top 5% of the value of individual differences, but maintains the maximum change in the value of the data when normalization was applied. In addition, the mean value is fixed at 0. So, Normalized EEG coherence gave the advantages of easier analysis of the pattern of response to stimulation by the individual subject.

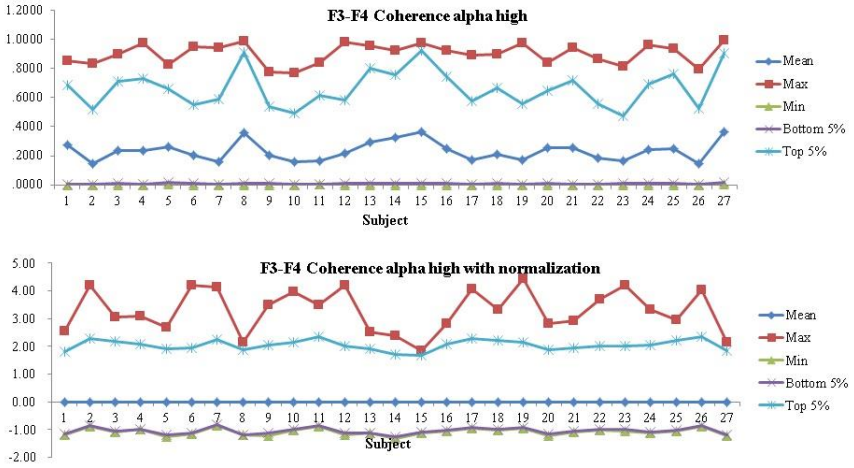

Fig. 2. Normalized EEG coherence of F3-F4 alpha high by individual (Top: Non normalized EEG coherence, Bottom: Normalized EEG coherence)

$$\mathrm{Z-normalization}(x_i) = \frac{x_i - Mean}{Standard\ Deviation} \tag{2}$$

3.3 Statistical Verification and Results

According to the experiment process, Normalized EEG coherence data was divided as stimulus, imagination, and expression and each individual data was separated as the emotion sharing relation or information sharing relation. The separated results were compared using an independent T-test by SPSS 19. Some normalized EEG coherence showed significant differences and is displayed in figure 3($p<0.01$). Only the common responses of the three processes from the experiment (stimulus, imagination, and expression) were arranged. Because of the result, one process had a chance of response, except an emotion response such as a difference of visual stimulus or an auditory volume.

As shown in figure 3, right temporo-occiptalipsilateral connectivity changed at alpha low(8~10Hz) and translateral connectivity between left frontal and right parietal changed at alpha high(10~12Hz). When the social emotion of emotion sharing relation was evoked, alpha low was decreased and alpha high was increased during stimulation, imagination and expression process.Otherwise, alpha low was increased and alpha high was decreased when the relation was information sharing.

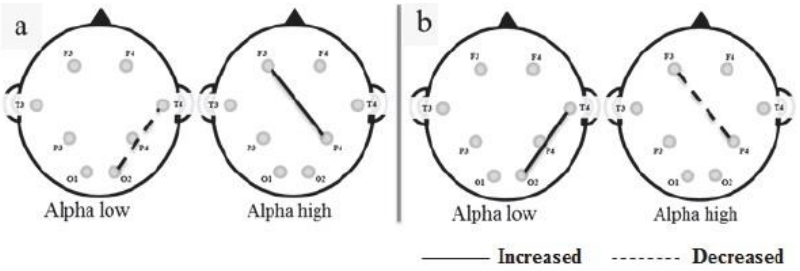

Fig. 3. Significant EEG coherence of relation (a: Emotion sharing relation, b: Information sharing relation)

4 Conclusion and Discussion

The research of social emotion within a SNS is invaluable because social emotion helps fluent information transaction and also gives a clue to the invention of a new HCI method. But less is known about the body's reaction of social emotion and basic emotion. So the purpose of this study was to find a central nervous response by relation of social emotion.

The method of relation stimuli such as the information sharing and the emotion sharing was used visuals and audio.And three steps such as stimulus, imagination, and expressions were performed by the participants. During stimulus, 8ch EEG was recorded and converted as EEG coherence. EEG coherence was transformed as normalized value to decrease individual difference. The central nervous response by relation was compared using an independent T-test.

According to the result, when the social emotion of emotion sharing relation was evoked,the translateral connectivity between left frontal and right parietal was increased during stimulation, imagination and expression process.Otherwise, right temporo-occiptalipsilateral connectivity was increased when the relation was information sharing.

This connectivity was related to language memory process and the visual information processing. The information sharing response which is right temporo-occipital connectivity was associated with the language memory [18, 19]. And reaction of emotion sharing which is the connectivity between left frontal and right parietal was associated with the visual information processing area [20].Therefore, language memory was enhanced when the relation was information sharing. And visual information process was activated when emotion sharing relation.

Using this coherence result of this paper, the relation between persons in SNS could be recognizable. Furthermore, we could figure out the dominant cognitive process when social emotion was evoked.

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