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Global EEG synchronization as an indicator of emotional arousal and its application for tracking emotional changes during video watching

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Abstract

In the present study, we investigated whether global EEG synchronization can be a new index to track emotional changes during continuous EEG recording. Global synchronization index (GFS), a measure known to reflect human cognitive process, was evaluated to quantify the global synchronization of multichannel EEG data recorded from a group of participants (n=20) while they were watching two short video clips. The two video clips were about 5-min long each and designed to respectively evoke happy and fearful emotions. Other participants (n=21) were asked to select two most impressive scenes in each clip, and the questionnaire results were then compared to the grand averaged GFS waveforms. Our results showed that beta-band GFS value was decreased when people experienced high emotional arousal regardless of the types of emotional stimuli, suggesting that the GFS measure might be used as a new index to track emotional changes during video watching and would be potentially used for evaluating movies, TV commercials, and other broadcast products.

1 Introduction

Understanding human emotional process has been regarded as an important research topic in neuroscience as emotion plays a key role in communication or interaction between humans. Many different neuroimaging modalities have been used to study the neural substrates of emotion, such as electroencephalography (EEG), magnetoencephalogram (MEG), and functional magnetic resonance imaging (fMRI) (Peyk et al., 2008). Among these, EEG has been considered the most suitable tool to study the temporal dynamics of emotion thanks to its high temporal resolution and reasonable cost (Millan et al., 2008). In particular, decoding individual emotional states from EEG is attracting increased attention because of the recent popularization of low-cost, wearable EEG systems and their potential applications in affective brain-computer interfaces (BCIs).

Two representative methods have been most widely used to evaluate or recognize individual emotional states, which are frontal alpha-asymmetry and event-related potentials (ERPs) elicited by emotional stimuli (Degabriele et al., 2011). Despite a number of studies based on these methods, only a few studies have attempted to continuously track or monitor the emotional changes using EEG data recorded while continuous and complex emotional stimuli (e.g., movies and video clips) are presented.

In this study, we tried to search for a new index that can effectively estimate temporal changes in emotional states of a group of individuals while they were watching video clips designed to evoke different types of emotions, which can be potentially applied to the evaluation of various cultural

contents including movies, TV commercials, and music videos. Among various possible indices, we tested the feasibility of EEG synchronization as an index of emotional states because some previous studies reported that functional connectivity is generally increased during cognitive processing and decreased during emotional processing especially in beta & gamma frequency bands (Harding et al., 2012, Northoff et al., 2004). Beta-band global field synchronization (GFS), a well-known measure shown strong correlation with human cognitive process (Koenig et al., 2001, Lee et al., 2010), was evaluated to quantify the global synchronization of multichannel EEG data recorded from a group of participants while they were watching two video clips. Our study hypothesis was that decreased GFS values might be observed when stimuli eliciting high emotional arousal are presented because dominant emotional processing would act as a distractor of cognitive processing in the brain. To verify our hypothesis, results of simple questionnaires inquiring two scenes that were most impressive and memorable in each clip and the grand-averaged GFS waveforms were compared.

2 Methods

2.1 Experimental conditions and paradigm

EEG data were recorded using a multichannel EEG system (ActiveTwo, BioSemi) with 22 active EEG channels (Cz, C3, C4, T7, T8, Pz, P3, P4, P7, P8, Fp1, Fp2, Fz, F3, F4, F7, F8, AFz, AF7, AF8, O1, and O2) and two EOG channels (VEOG and HEOG). A 17-inch LCD monitor was used for the presentation of visual stimuli. The subjects were seated in a comfortable armchair placed in front of the monitor. The distance between the monitor and subjects was set to 70 cm. Two short video clips were presented to the subjects. One clip used to evoke happy emotion was a short video clip titled 'Isaac's Live Lip-Dub Proposal', which was watched by more than 25 million people in YouTube (http://youtu.be/5_v7QrIW0zY) (referred to as a *positive clip*). In the video of 5:13-min long, a man named Isaac surprised his girlfriend with the world's first live lip-dub marriage proposal. The other clip used to elicit negative emotion was edited from a famous movie 'The Grudge'. In the video of 4:36-min long, sudden appearances of ghosts made subjects feel fearful (referred to as a *negative clip*).

Twenty-five healthy subjects initially participated in our experiment. The *positive clip* and *negative clip* were presented to the participants one after another, between which a short break time of about two minutes was given. To investigate the general feeling about each video, another group of participants (n=21) was recruited and asked to select two most impressive scenes in each clip. They watched each video clip twice without recording EEG, and then asked to mark two time points during the second play of each clip.

2.2 Data Analysis

Principal components analysis (PCA) was used to remove EOG artifacts from EEG data. The preprocessed data were then filtered using a band pass filter with cutoff frequencies of 1 and 55 Hz. EEG data from five participants were excluded from the analysis because these data were severely contaminated by noises and artifacts. The data were then segmented into 2-s epochs with a 50% overlap to continuously evaluate GFS values along time. The GFS, a method to measure the overall functional connectivity of the brain, has been generally used to investigate cognitive decline in patients with psychiatric disorders (Koenig et al., 2001, Lee et al., 2010). To evaluate the GFS values, EEG signals recorded from different scalp locations are first transformed into frequency domain using the Fast Fourier Transform (FFT), and then the FFT-transformed signals at each frequency are mapped onto a complex plane. The GFS value of a frequency is defined as the normalized difference between two eigenvalues representing the point distribution in the 2-D complex plane (Koenig et al., 2001). According to Lee et al.'s study (2010), the average GFS value in beta band (14~25Hz) showed

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strong correlation with Mini-Mental States Examination (MMSE) scores that reflected cognitive process in the brain. The GFS time-series of each participant was filtered using a ten-second moving-average filter, and then grand averaged across all participants.

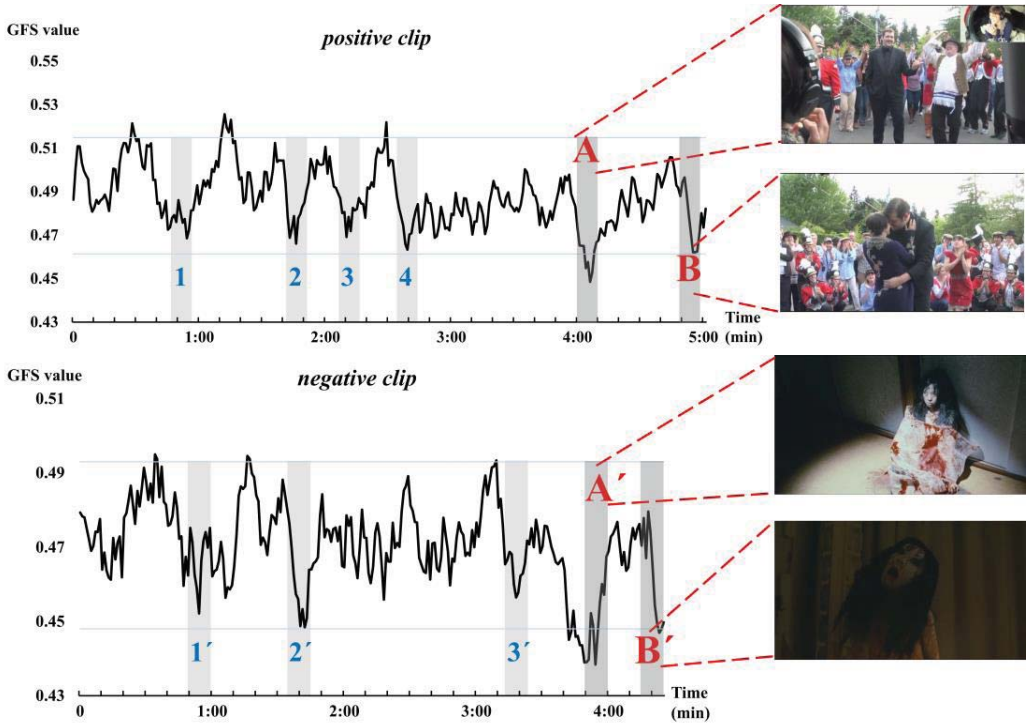

Figure 1: Grand averaged GFS waveforms

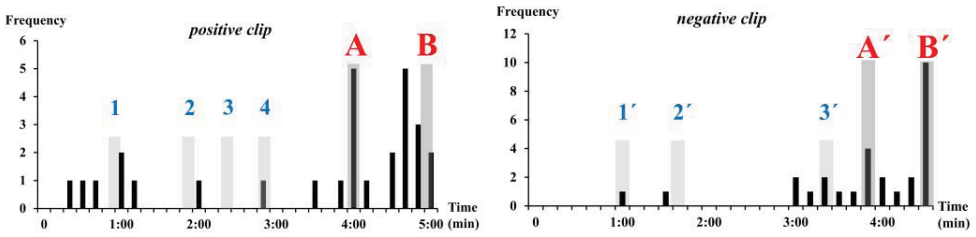

Figure 2: The questionnaire results on two most impressive scenes in each clip

3 Results

Figure 1 shows the grand-averaged GFS waveforms of each video clip and Figure 2 shows the results of questionnaire (two most impressive scenes in each clip). Horizontal lines in Figure 1

represent 1.96 standard deviation values ($p < 0.05$). Interestingly, two time periods in each video clip at which the GFS values dropped below the lower horizontal line (denoted by A, B, A', and B') matched fairly well with the time periods most frequently selected in the questionnaire. In the time periods A and B, the woman was finally proposed by the man, and in A' and B', sudden advent of the ghost made the subjects feel most fearful. In Figure 1, there are some other time points showing sudden drops of GFS values to around the lower horizontal line (denoted by 1, 2, 3, 4, 1', 2', and 3', which were chosen objectively), at which time some reported high emotional arousal, as shown in Figure 2. The average GFS values for all emotional events marked in Figure 1 were compared with the GFS values averaged over all time points not marked as emotional events using paired t-test. The statistical analysis results showed significant differences between two conditions (positive clip: $p = 0.0068$; negative clip: $p = 0.0059$).

4 Conclusion

The purpose of the study was to continuously track the changes in emotional arousal using a global EEG synchronization measure. As expected in our study hypothesis, decreased GFS values were observed when stimuli eliciting high emotional arousal are presented. It is noteworthy that the decreased GFS values were commonly observed regardless of the types of stimulus valence, which supports our main hypothesis that emotional processing might act as a distractor of cognitive processing and thus the GFS value, an indicator of cognitive processing, would decrease during emotional processing. The results of questionnaires could be elucidated fairly well with the grand-averaged GFS waveforms, suggesting that our study design would be potentially applied to practical applications to evaluate various cultural contents or broadcasting products. Further studies need to be conducted in future studies in order to generalize our hypothesis using more experiments and investigate individual variability in the GFS waveforms.

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