Measuring Affective Sharing between Two People by EEG Hyperscanning

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ABSTRACT

Empathy plays an important role in human social interaction such as promoting stronger relationships and collaboration. In this study, we measured affective sharing, one of the main components of empathy, from EEG signals. To elicit affective sharing, we conducted an experiment in which participants communicated using facial expressions of joy, sadness, and neutrality. EEG signals were simultaneously recorded from both participants during the experiment. The result showed the correlations of the EEG powers were significantly higher under the joy and sadness conditions in the alpha-mu band. This result demonstrates that it is possible to measure affective sharing in response to emotional faces from the correlation of EEG powers. To our knowledge, this is the first EEG hyperscanning study that investigates affective sharing in response to emotional faces.

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Figure 1: Photograph of experimental setting. The target's seat was placed on the right side and the observer's on the left. Seats were separated by a partition. A web camera was installed on the target's monitor.

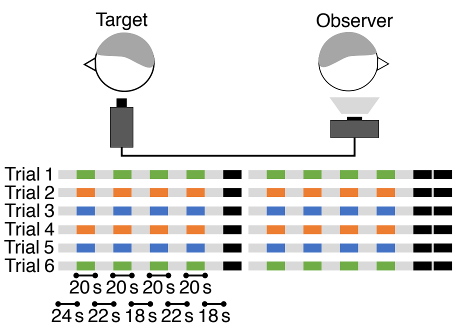

Figure 2: Outline of the experiment. Each color indicates the kind of emotions instructed to a target. The order of emotions was determined by the participant before starting the experiment. The grey boxes indicate the rest. The black boxes placed at the end of each trial indicate the SAM.

CCS CONCEPTS

• **Computing methodologies** → **Cognitive science**.

KEYWORDS

empathy, affective sharing, electroencephalogram, facial expression

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INTRODUCTION

Empathy plays an important role in human social interaction. For example, It promotes stronger relationships and collaboration [11]. In much of the research, empathy is evaluated by subjective evaluation [19]. However, It has been argued that subjective evaluation of empathy has less than ideal reliability [3] and low consistency among participants [6][14]. Therefore, the necessity of psychophysiological measurement of empathy has been pointed out [20].

Empathy involves bottom-up information processing and top-down information processing [23]. Here, affective sharing is the main bottom-up information process [23]. Affective sharing is an affective response to another person that often, but not always, entails sharing that person's emotional state [5]. It is known that affective sharing relies on inter-brain synchronization [5]. A previous study measured the inter-brain synchronization during observation of emotional faces by functional magnetic resonance imaging (fMRI) hyperscanning [1]. In this case, hyperscanning was the simultaneous recording of cerebral data from the two participants [16]. However, as fMRI requires a large-scale device, it is considered difficult to use in a real environment, though necessity of measuring empathy in interactive setting was pointed out [21].

Electroencephalography (EEG) is a representative method for measuring brain activity and has the advantage of being usable in a real environment. A previous research measured the inter-brain synchronization during observation of others in pain by EEG hyperscanning [8]. Although a facial expression play crucial role in social interaction [7], there is no EEG hyperscanning study that investigates affective sharing in response to emotional faces. In this study, we measure affective sharing in response to emotional faces by EEG hyperscanning.

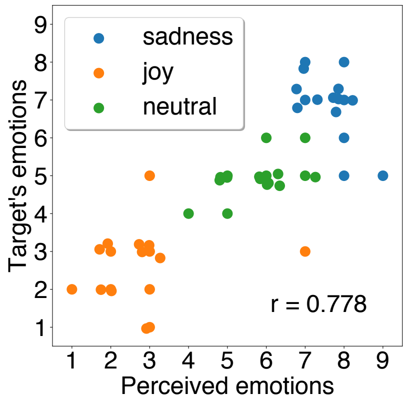

Figure 3: SAM values of target's emotions and perceived emotions. The number on the lower right side is the polychoric correlation. Colors of plots indicate the kind of emotions instructed to targets. In the scatter plot, random noise was added to scores to avoid overlap of dots.

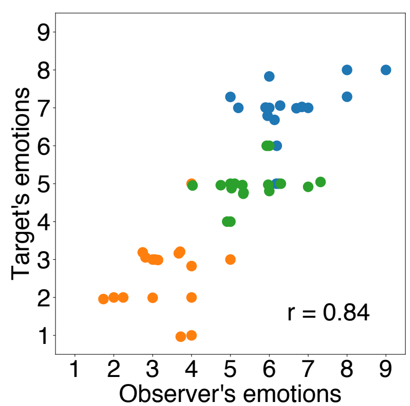

Figure 4: SAM values of target's emotions and observer's emotions.

METHODS

Experimental design

The participants were six females (three pairs). The individuals in each pair were friends. As females are typically considered more empathic than males [4], we only recruited female participants. The average age of participants was 24.5 years and the standard deviation was 1.8. The experiment was approved by the ethics committee of the Nara Institute of Science Technology, and written informed consent was obtained from all participants.

Our experiment was designed in the same manner as the previous fMRI study [1]. A photograph of our experimental setting is shown in Figure 1. The outline of the experiment is shown in Figure 2. We assigned one of the participant the role of "target" and the other of "observer". The participant given the role of "target" was instructed using a monitor during the experiment. When the word "rest" was displayed on the target's monitor, the target was relaxed. When "joy" or "sadness" was displayed, the target indulged herself in emotional situations and expressed her emotion with her facial expression. When "neutral" was displayed, the target tried to be as emotionless as possible. At the end of each trial, the target reported the valence of the emotion that she had expressed in nine levels using the Self-Assessment Manikin (SAM) [2]. We call this score "target's emotion". A higher SAM value means a more negative emotion and a lower value means a more positive one.

For the participant given the role of "observer," the facial expression of the target was presented in real time. The observer watched the target's facial expression and tried to feel with her. At the end of each trial, the observer reported the valence of two kinds of emotions using SAM. The first one, "perceived emotion," was the emotion that the observer perceived from the target's facial expression. The second one, "observer's emotion," was the emotion of the observer that was elicited by looking at the target's facial expression. Six trials were conducted in one experiment. To obtain enough data, the experiment was repeated three times on different days. We used two 30-channel EEG caps (Quick-30 manufactured by Cognionics) to record EEG signals. To investigate muscular artifacts, we recorded electromyographic (EMG) signals from corrugator supercilii and zygomaticus muscle.

EEG signal analysis

The pre-processing consisted of the following seven steps. All steps were performed with EEGLAB. (1) The sampling frequency was downsampled to 200 Hz. (2) EEG signals were band-pass filtered in the range of 0.3 to 45 Hz. (3) Onsets were set as the points where the emotional word was displayed on the target's monitor. Then, EEG signals were segmented from 2 seconds to 20 seconds. Data from the first 2 seconds were excluded from analysis because of artifacts. (4) Bad epochs were rejected by visual inspection. (5) Independent component analysis (ICA) was performed. (6) To deal with EMG artifacts, we rejected ICA components that had a cross correlation with EMG signals of more than 0.1. Next,

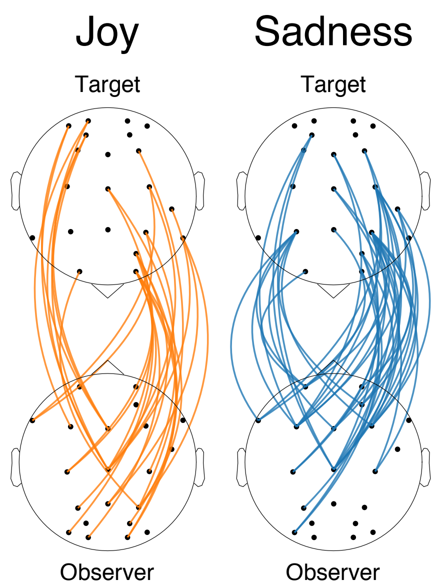

Figure 5: The significant ($p < 0.05$, non-parametric permutation test, corrected for multiple comparisons) connectivities in the alpha-mu band. AF3 and FC5 were used for recording EMG signals and some electrodes were rejected due artifacts. So, they are not shown in the figure.

ICA components were automatically rejected by ADJUST [15] and by additional visual inspection. (7) Six electrodes T7, T8, CP5, CP6, P7, and P8 were rejected due to muscular artifacts.

In previous studies, inter-brain connectivity has been measured by correlation of EEG powers [12][13] or phase synchronization of EEG signals [10][8]. We calculated the former because both presentation of emotional faces and emotion elicitation are known to affect EEG powers [9].

The EEG powers were calculated by discrete Hilbert methods for specific frequency bands: theta (4-7Hz), alpha-mu (8-12Hz), beta (13-30Hz), and gamma (31-40Hz). Then the EEG data were segmented into 1 second windows. The pearson correlation coefficient was calculated for each window over every possible combination of target's and observer's electrodes. Next, we compared the correlations of the high affective sharing condition (joy or sadness) and low affective sharing condition (neutral) by a nonparametric permutation test. This statistical testing was performed in the same manner as a previous research [10].

RESULTS

Figure 3 and Figure 4 show the results of analysis on SAM. As indicated in the scatter plots, the SAM scores reported by the targets and observers were highly correlated. Therefore, we consider target's emotions were successfully perceived by observers and successfully induced affective sharing.

Figure 5 shows the result of connectivity estimation. The correlations that were significantly higher in the high affective sharing condition were found in the alpha-mu band. Regarding the connectivity patterns, the target's parietal and central regions were connected with the observer's frontal and central regions in both joy and sadness conditions. We consider this result is reasonable because the alpha-mu band is associated with the mirror neuron system that underlies empathy [18][22] and with empathic response for emotional faces [17].

CONCLUSION

In this study, we measured affective sharing in response to emotional faces by EEG hyperscanning. The results showed that correlations of EEG powers were significantly higher under the high affective sharing condition compared to the low affective sharing condition. These results demonstrate the possibility of measuring affective sharing in response to emotional faces by EEG hyperscanning.

In the future work, we would like to conduct the experiment on more participants including unfamiliar participant pairs to generalize the results. Furthermore, the result of connectivity patterns needs further discussion because different patterns were found between sadness and joy condition. This difference might be caused by the activation of visual cortex in the occipital region [7].

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