Differences of Functional Connectivity Brain Network in Emotional Judgment

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Abstract: Using combined emotional stimuli, combining photos of faces and recording of voices, we investigated the neural dynamics of emotional judgment using scalp EEG recordings. Stimuli could be either combioned in a congruent, or a non-congruent way.. As many evidences show the major role of alpha in emotional processing, the alpha band was subjected to be analyzed. Analysis was performed by computing the synchronization of the EEGs and the conditions congruent vs. non-congruent were compared using statistical tools. The obtained results demonstrate that scalp EEG ccould be used as a tool to investigate the neural dynamics of emotional valence and discriminate various emotions (angry, happy and neutral stimuli).

1 INTRODUCTION

Neural synchrony of neural assemblies is thought to be correlated with cognitive functions and mental representation. Despite years of investigations, much further work is required to explore the various functions of oscillations and neural synchrony (Uhlhaas, et al., 2009). This is especially the case for affective cognition, which is a recent topic of interest in neuroscience (see Duncan and Barrett for a review). Judgment is important for decision making, and involves both cognitive and infra-cognitive processes. In social cognition, judging the emotion of another human being is important to interpret communications. For instance, patients with emotional judgment disorders, such as patients suffering from major depression (Griamm et al., 2006), can have serious social impairments. Our purpose in this manuscript is to investigate the neural synchrony of human emotional judgments.

A huge literature emphasizes the role of sub-cortical areas in emotion processing. However, these areas do not work independently one from another, and consequently emotion processing necessarily involves large-scale networks of neural assemblies (see e.g. Tsuchiya, and Adolfs, 2007).

What would happen if subjects were exposed to contradictory visual and auditory stimuli? Such contradiction is termed as a “McGurk effect” (McGurk and MacDonald, 1976) – the visual and auditory stimuli do not carry the same message. Subjects confronted to these emotional stimuli, and asked to provide feedbacks on their internal perceptions while their neural activities are recorded, are confronted to the difficulty of binding contradictory emotional features.

The purpose of our study was to induce a controlled perturbation in the emotional system of the brain by multi-modal stimuli, and to control if such stimuli could induce reproducible changes in EEG signal. We use a combination of photos and voices with congruent or non-congruent emotional valence. As the synchronization and functional connectivity plays a major role in flowing information among brain regions and then for information processing, we analyze the EEG data using the functional connectivity, with the goal of finding the differences of brain dynamics during judgment in the congruent and non-congruent emotional conditions.

2 METHOD

2.1 Participants

The data were recorded in RIKEN Brain Science Institute (RIKEN BSI), Tokyo, Japan. 12 young healthy adults (10 females) were recruited with ages ranged from 21 to 24 with mean of 21.9 years. The participants had no history of any neurological/psychiatric disorders.

As assessed through the Edinburgh handedness test, all participants were right handed. The Positive and Negative Affect Schedule (PANAS, Watson et al. 1988) was collected for each subject before and after the experiment, and no subject displayed unusual PANAS scores (which would have been indicative of mood disorders).

All participants signed an informed consent form, and the experiment complied with the Riken BSI's ethic review board guidelines.

2.2 Emotional Task

We exposed these subjects to combined audio-visual stimuli. Stimuli were presented for 2 sec, the subjects was asked to answer afterwards within a 3 sec window, and then had 5 sec of rest (one trial = 10 sec). The audio-visual stimuli (see Fig. 1) were composed using simultaneous combinations of auditory and visual stimuli with three emotional valences (Angry - A, Happy – H, Neutral - N), either congruent (e.g. H x H) or non-congruent (e.g. H x A). Audio stimuli consisted of voice recordings of the Japanese word 'arigato' (thank you) pronounced with the three different intonations (A, H, and N). Visual stimuli consisted of faces of women expressing the same emotional valences, taken from the JACfee and JACNeuf Japanese-Caucasian photo databases (Biehl et al. 1997).

The emotional task included 180 stimuli presenting in a pre-decided random order, so that two consecutive emotions were always different, and so that the same number of trials occurred for all possible pairs of stimuli. For all trials, the task was to judge if the percept was angry or happy – by pressing a button.

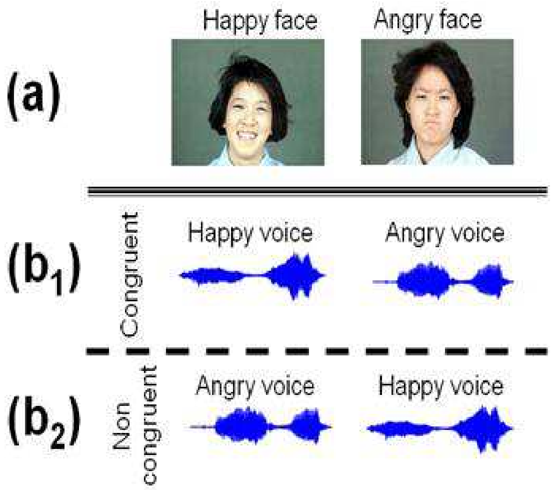

Figure 1: McGurk effect. Visual stimuli (a) are combined with audio stimuli (b). Subjects will expect congruent stimuli (b1), where visual and auditory clues are concordant (e.g. happy face and happy voice). Non-congruent stimuli (b2), where visual and auditory clues are discordant (e.g. happy face and angry voice), will induce distortions in either the visual or auditory perception (this distortion is termed as a "McGurk effect").

2.3 EEG Recordings

The EEGs were recorded during the emotional tasks. They were collected with a 32-channel Biosemi EEG system with active electrodes in a shielded room. Sampling rate was fixed at 1024 Hz, notch filter at 50 Hz and analog band-pass filter between 0.5 and 100 Hz. Fig. 2 shows positions of the electrodes.

Table 1: p-values of the inter and intra regions in discrimination of congruent and non-congruent conditions

	LA	**RA**	**LP**	**RP**
LA	0.33	0.55	0.31	0.14
RA	0.55	0.02*	0.04*	0.19
LP	0.31	0.04*	0.50	0.18
RP	0.14	0.19	0.18	0.10

*: p-value less than 0.05.

2.4 Data Analysis

Fig. 2 shows the topography used in this study, consisting four regions: Left Anterior (LA), Right Anterior (RA), Left Posterior (LP), and Right Posterior (RP). The alpha frequency (8-12 Hz) EEGs were extracted by applying Butterworth band-pass filter. Then using the conventional cross-correlation function, the functional connectivity between each pair-channel was computed in the alpha band, according to the following formula:

$$S[X,Y]=\left|\frac{\mathrm{cov}[X,Y]}{\sigma_X \sigma_Y}\right| \quad (1)$$

Where X and Y are signals of two channels, $|x|$ indicates absolute value of x, $\mathrm{cov}[x,y]$ is the covariance of x and y, and σ_x is standard deviation of x.

Then by averaging the correlation coefficients over the channels within and between the regions, the intra- and inter- connectivity of the four regions (respectively) were computed in the alpha band. The Mann-Whitney statistical test was used to compare the differences of the obtained synchronization values between the congruent and non-congruent conditions.

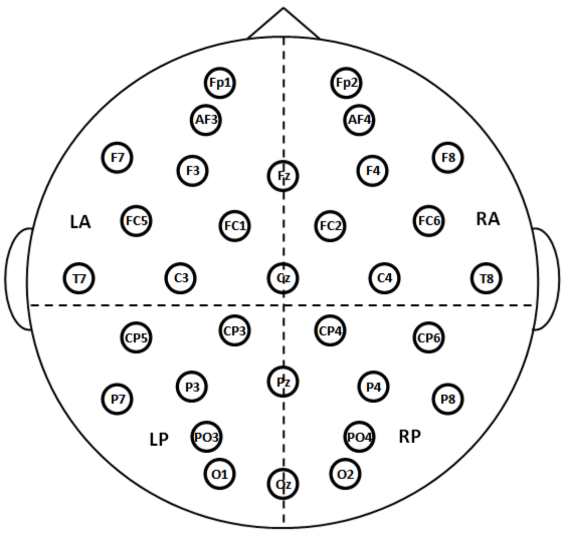

Figure 2: Illustration of the brain topography used in this study, which contains: Left Anterior (LA), Right Anterior (RA), Left Posterior (LP), and Right Posterior (RP).

3 RESULTS

Fig. 3 shows the mean synchronization values of inter- and intra- regions in congruent (red triangles) and non-congruent (blue circles) cognitions. The x-axis shows the pair regions in the studied topography and the y-axis shows synchronization values. It shows all synchronization values in the non-congruent condition are more than those in the congruent condition.

Table I presents the p-values obtained by the Mann-Whitney test for distinguishing the inter- and intra- regional synchronization values between the two conditions. The significant p-values (less than 0.05) are related to the right anterior – right anterior centimeter.

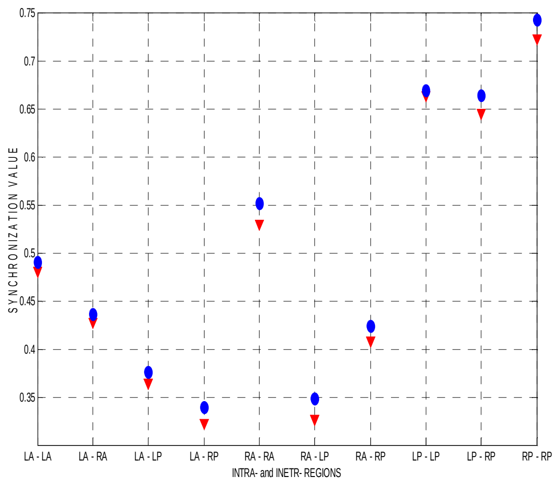

Figure 3: Mean values of inter- and intra- regional synchronizations in congruent (red triangles) and non-congruent (blue circles) emotional judgments. The x-axis shows the pair regions in the studied topography and the y-axis shows synchronization values.

4 CONCLUSIONS

In this study the differences of brain connectivity in emotional judgment between congruent and non-congruent emotional conditions was studied. To the best knowledge of the authors the current paper presented the first study on analysis of functional connectivity in emotional judgment.

It was shown the alpha synchronization in the overall brain in the non-congruent condition is higher than that in the congruent condition. Judgment in the non-congruent condition is more difficult, compared with the congruent condition, and therefore the higher alpha synchronization in the non-congruent condition may be related to the greater demanding and more effort of the brain for judging emotions.

The obtained significant p-values between the conditions in the right anterior – right anterior and right anterior – left posterior connectivity shows the ability of the alpha synchronization (in the associated regions) for discrimination of congruent and non-congruent conditions. Therefore the alpha synchronization may have a good potential for diagnosis of the disorders with deficient emotional judgments and also it may be useful for their treatment using EEG neurofeedback training.

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