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15 How Does Interoception Relate to Feeling Emotion?

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I. Introduction

Understanding how we feel emotion subjectively is one of the most fascinating topics in psychology over the years. William James (1884) proposed that the experience of emotion results from the perception of specific and unique patterns of somatovisceral response and the theory provoked discussions (Schachter & Singer, 1962; Rainville, Bechara, Naqvi, & Damasio, 2006). Though it is still unresolved whether the response essentially affects our emotional experiences, results from recent psychological and brain imaging studies indicate that perception of bodily signal mediates emotional experience (Werner et al., 2009).

In this research, we examined the neural mechanism underlying evaluation of emotional and bodily state, and identified the common and uniquely concern areas for these processing. Previous researches have examined those neural substrates separately, but there is no research to address those commonality and uniquity in a single study. Since we aimed to identify the neural substrate for feeling emotional state itself, we didn't recruit any emotion eliciting procedures not alike previous researches. It helped us to specify the relating brain area without contamination from brain activation for regulating emotional responses. If referring bodily state is an intrinsic property of emotion experience, the referring process would be existed

whenever we aware our emotional state, even though salient bodily state change does not exist. Also, for the purpose of identifying the neural substrates which represent the subjective feeling of body and emotion in the immediate present (now), we prepared temporal constraint conditions, as now and usual.

II . Method

2.1 Participants

18 undergraduate and graduate students (5 male and 13 female) participated our study (mean 22.9 years ± 2.11 *s.d.*). All participants were right-handed, and without any history of neurological or psychiatric diseases. The experiment was performed with local Ethics Committee approval from the Keio University Research Ethics Committee (No. 09006).

2.2. fMRI Data Acquisition and Analysis

A Siemens Trio on 3T was used to acquire high-resolution T1-weighted anatomical images and single-shot gradient-echo EPIs with BOLD contrast of 44 axial slices. A voxel size was 3.5×3.5×2 (mm), and the gap was 1mm. TR 2.35s, TE 30ms and FA 90 degrees. The data were analyzed by SPM5(http://www.fil.ion.ucl.ac.uk/spm/software/spm5/).

2.3 Procedure and materials

Participants were required to answer three types of question about emotional awareness, bodily awareness and possessions. After presenting a fixation point for 4-6 seconds on a monitor placed in fMRI scanner, we presented a cue (“now” or “usual”) which is followed by a statement as “I’m happy (for emotional awareness)”, “I have a fast pulse (for bodily awareness)” and “I have money (for possessions)”. The cue was presented for 3 seconds and the sentence was presented for 10 seconds. In the now condition, they evaluated appropriateness of the statement as a description for their current state. In the usual condition, they evaluated the appropriateness as a description for their usual disposition. Therefore, there were six types of condition; those were such as “body-now”, “body-usual”, “emotion-now”, “emotion-usual”, “possession-now” and “possession-usual”. Their evalua-

tions about the appropriateness of statement were chosen from 4 options, such as “not at all, somewhat, very and definitely”. Stimuli were presented by a control computer located outside the MR room, using Cogent 2000 (http://www.vislab.ucl.ac.uk/cogent_2000.php) which was implemented in MATLAB (The MathWorks Inc.). Participants’ responses were given by using a four-buttons MRI compatible keypad connected to the control computer which recorded reaction time.

Sentences for the emotional awareness conditions were selected from PANAS (Positive and Negative Affect Scale, Watson, Clark, & Carey, 1988) and translated into Japanese. For bodily awareness condition, sentences were selected from Body perception questionnaire (Porges, 1993). We prepared 16 sentences for each condition, thus there were 96 trials in total (2 cues, 3 conditions, 16 sentences). Those trials were divided into three blocks, and the order of blocks and trials were randomized and counterbalanced across participants.

III. Results

3.1 Functional MRI data

For the first step, we analyzed the fMRI data in a mixed effects group analysis (n=18). To identify the regions where subserve evaluation about participants’ own emotion or body, we compared the activated areas for emotion or body condition versus possession condition. The contrast of body-now > possession-now revealed greater BOLD responses in lingual gyrus, inferior / middle frontal cortex, insular cortex, middle cingulate cortex and cerebellum. The contrast of emotion-now > possession-now revealed greater BOLD responses in lingual gyrus, temporal pole, inferior frontal cortex, middle temporal cortex, superior temporal cortex, middle frontal cortex and insular cortex. We also analyzed the fMRI data for usual conditions. The contrast of body-usual > possession-usual revealed greater BOLD responses in cuneus, middle occipital gyrus, supramarginal gyrus, post centaral gyrus, superior temporal cortex, insular cortex, cerebellum and lingual cortex. The contrast of emotional-usual > possession-usual revealed greater BOLD responses in precentral gyrus, precuneus, lingual gyrus, supramarginal gyrus, fusiform gyrus, cuneus, post central gyrus, inferior frontal cortex, superior

temporal cortex, inferior parietal cortex, temporal pole, middle cingulate cortex and middle temporal gyrus.

The intersection of contrast images for body-now (body-now > possession-now) and emotion now (emotion-now > possession-now) identified the common activated regions. The right anterior insular cortex (BA 13), the left ventromedial prefrontal cortex (VMPFC, BA11) and the bilateral lingual gyrus (BA17) were identified as common activated regions (Figure 1).

To disentangle the relationship between emotional and interoceptive processing, we focused on the uniquity of neural substrates for these two processes. Uniquely activated regions for emotion-now or body-now condition were identified with the contrast images of emotion-now and body-now. As the uniquely activated regions for emotion-now condition, the left superior temporal gyrus (BA22/38), the bilateral posterior cingulate gyrus (BA31), the bilateral anterior cingulate gyrus (BA24/32), the right superior medial frontal gyrus (BA9/10), the bilateral inferior frontal gyrus (BA45, 47), the left supramarginal gyrus and the superior frontal gyrus (BA8) were identified. In contrast, the left supplementary motor area (BA6) and the inferior parietal gyrus were the only more activated regions in body- than emotion-now trials.

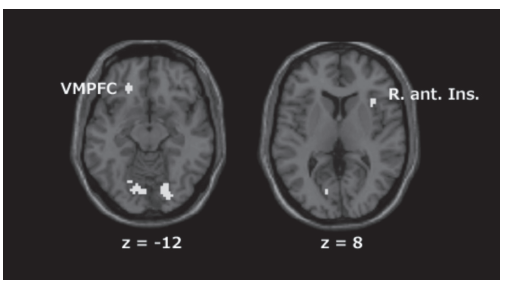

Figure 1. Common activated areas for emotion-now and body-now conditions. VMPFC, ventromedial prefrontal cortex; R. ant. Ins, right anterior insular cortex.

IV. Discussion

In this research, we aimed to disentangle the relationship between interoception and feeling emotion and understand how interoception shapes emotion,

by examining the neural mechanisms underlying evaluation of emotional and bodily awareness. We identified the common activated regions for emotional and bodily awareness, and some uniquely activated regions for emotional or bodily awareness.

The present study revealed that the right anterior insular cortex, the VMPFC and the bilateral lingual gyrus activated prominently in both emotion-now and body-now trials. The insular cortex is classically known as a viscerosensory region and neuropsychogical studies provide evidence that the insula is a crucial region for recognizing visceral sensation(Penfield & Faulk, 1955). On the other hand, recent neuroimaging studies reveal that the insular, especially its anterior part, is taking important role in emotional processing and social interactions (e.g. Damasio et al., 2000). Also, the right anterior part of the insula relates not only subjective emotion but interoceptive awareness (Critchley, Wiens, Rotshtein, Ohman, & Dolan, 2004). Activation in this region is reported when participants aware some changes in their bodily state (homeostasis), and try to attend their internal bodily states. Also, the VMPFC is found to activate while we are focusing on ourselves, like monitoring moment-to-moment experience in response to the presented adjectives (Farb et al., 2007).

It is remarkable point that the activation in insular and VMPFC were identified, even though any emotion eliciting procedures were recruited in this research. The activation in these brain areas suggests that interoceptive process is essential for evaluating emotional state. In some review articles on neural substrates of emotion identify these areas as critical regions for regulation of internally oriented attention (Menon & Uddin, 2009), and suggest that evaluation of one's own emotion may include evaluation of bodily experience (Lee & Siegel, 2009). Our results provide direct evidence to the implication about the interoceptive process on the emotional evaluation. The findings imply that we refer bodily states implicitly when we evaluate our own emotional state, even if dynamic emotional bodily response is absent. Several regions are identified as uniquely activated areas for emotion-now condition. Almost all of these areas were identified as related areas for feeling and understanding one's own or others mental state. Contrary to emotion-now condition, a few areas were found as uniquely activated areas for body-now condition. This result indicates that neural substrates for evaluating bodily state are mostly included in those for evaluating emotional state,

and attending bodily state is fundamental process for awareness of the one's own emotional state.

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