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13 Motor Activity and Imagery Modulate The Body-selective Region in The Occipital-temporal Area

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Introduction

The Extrastriate Body Area (EBA) lies within the occipital-temporal cortex in humans and has been described as a "body-selective" region that responds higher to human bodies (see Peelen & Downing, 2007 for a review). This hypothetical function of EBA has been challenged by several studies recently. These studies suggest that the EBA's function is not simply confined to visual perception but also extends into distinguishing between self and other (Saxe et al., 2006), movement and motor imagery (Astafiev et al., 2004). Astafiev et al. (2004) reported that the EBA is strongly modulated when moving limbs to a visual target even with eyes shut. What is more, mentally imagining these goal directed movements also activates the EBA. This indicates that the EBA is not simply involved in perceptual but also in motor related processes.

Near-infrared spectroscopy (NIRS) is a particularly non-invasive and highly flexible neuroimaging method that it does not preclude the use of metal equipment or require the subject to remain still, as other methods do. Therefore it provides greater flexibility for the experimental methodology in the study of the EBA.

In this study, experiment 1 was designed to establish whether NIRS can capture activity within the EBA when visual images of the human body are

presented to the subject. Experiment 2 was designed to confirm whether carrying out movement by the subject elicits activity in this same area and experiment 3 aimed to measure whether this area also responds when the subject imagines their own body moving as previous studies have suggested.

Methods

Subjects

Nine healthy volunteers (M/F, 4/5; mean age, 24.3, all right-handed) participated in this study. This study was approved by the Ethics Committee of Keio University. Written informed consent was obtained before the experiments.

Materials and procedure

Experiment 1 (EBA localizer experiment): Grey scale pictures of clothed male and female bodies (heads not visible) and chairs were used as the stimuli. A block design was used as the experimental paradigm, consisting of 13 blocks (7 control and 6 test blocks; control, test, control, test,.. ..control). Within each block, each image lasted 300 ms with an inter stimulus interval of 500 ms (16 s in total).

Experiment 2 (Motor execution experiment): In experiment 2, subjects were asked to move their hand to the goal point with the right index finger along a L shaped slit (width 1.5 cm, length 40 cm), carved on a cork board. Subjects were asked to perform back and forth once between the goal and starting point taking 15 seconds to do it. During the task and the practice session, subjects had their eyes closed, so did not get any visual feedback. An event-related design was used as the experimental paradigm, consisting of 13 events (7 control and 6 test events). In the control condition event, subjects were asked to keep their hands relaxed without making any movements.

Experiment 3 (Motor imagery experiment): In experiment 3, subjects were instructed to imagine moving their hands on the board, in exactly the

same way they really did move their hands in the motor execution experiment, taking the same 15 seconds, but keeping their hands still and relaxed. During the task, subjects had their eyes closed. An event-related design was used as the experimental paradigm, consisting of 13 events (7 control and 6 test events). During theses three experiments, any changes in oxy-hemoglobin (oxy-Hb) and deoxy-hemoglobin (deoxy-Hb) were recorded using an ETG-7000.

Placement of channels and analysis

The changes in Hb concentration and its oxygenation level in the bilateral occipital-temporal areas were measured with a multichannel NIRS system (ETG-7000, Hitachi Medical Corporation, Tokyo, Japan). In the present study, a pair of probe holders (22 channels in each) covered a portion of the occipital-temporal lobe bilaterally. The international 10-20 system was used as a reference for placing the channels (Okamoto et al., 2004). The left (right) holder was placed in such a way that the middle of the bottom tip was adjusted to T5 (T6) so that the five central channels (channels 2, 3, 7, 11, and 12) covered the location of the EBA. Fig. 1 shows the position of channels over the left occipital temporal area. Any activation of the EBA could be measured by this placement.

We analyzed the changes in the concentration of oxy-hemoglobin (C_{oxyHb}) responses from the five central channels for the left and right holder. We calculated the average changes in C_{oxyHb} in the test and the control conditions for each subject. In experiment 1, the channel that showed maximal peak responses in the C_{oxyHb} among the five central channels was chosen for statistical analysis. We considered that the channel showing a maximal peak reflected the recognition of human bodies. In experiment 2 and 3, the C_{oxyHb} responses from the channels chosen in experiment 1 were used as the representative data for each subject. The averaged C_{oxyHb} were analyzed using repeated measures analyses of variance (ANOVA) with Category (bodies and chairs) and Hemisphere (left and right) for experiment 1, with Motor (execution and rest) and Hemisphere (left and right) for experiment 2, with Imagery (image and rest), Hemisphere (left and right) and Gender (male and female) as an additional factor for Experiment 3. For experiment 3, we added the factor

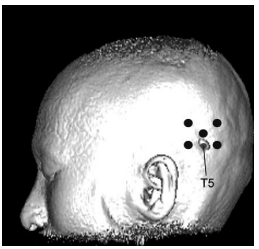

Figure. 1 Position of the central five channels (black dots) and T5. The channels were located over the occipital temporal region.

Gender because there was no significant difference using factors with Imagery and Hemisphere. Post hoc paired *t* tests were systematically adjusted using the Fisher's PLSD for multiple comparisons.

RESULTS

Experiment 1: Activity in the occipital temporal region was defined in all subjects. The channels that showed maximal responses were one of the five central channels of left and right probe holders. We conducted an ANOVA analysis with Category (human bodies and chairs) and Hemisphere (left and right). There was a greater response from the region chosen from the five channels when subjects viewed the images of human bodies compared to chairs (F=15.685, df=1, p=0.0009). There was no significant difference between Hemispheres and any interactions. Fig. 2a provides an example of the changes in C_{oxyHb} for a representative subject.

Experiment 2: The same channels used in experiment 1 were used in experiment 2. An ANOVA analysis was performed using Motor (execution and rest) and Hemisphere (left and right). The main effect for Motor was observed, where the responses measured by the channels were higher when subjects executed the hand movements compared to when resting (F=62.795, df=1, p<0.00001). No significant difference was observed for Hemisphere or any interactions. Fig. 2a provides an example of changes in C_{oxyHb} for a representative subject in Experiment 2.

Experiment 3: Again, the same channels as in experiment 1 were used for statistical analysis in experiment 3. No significant difference for any main

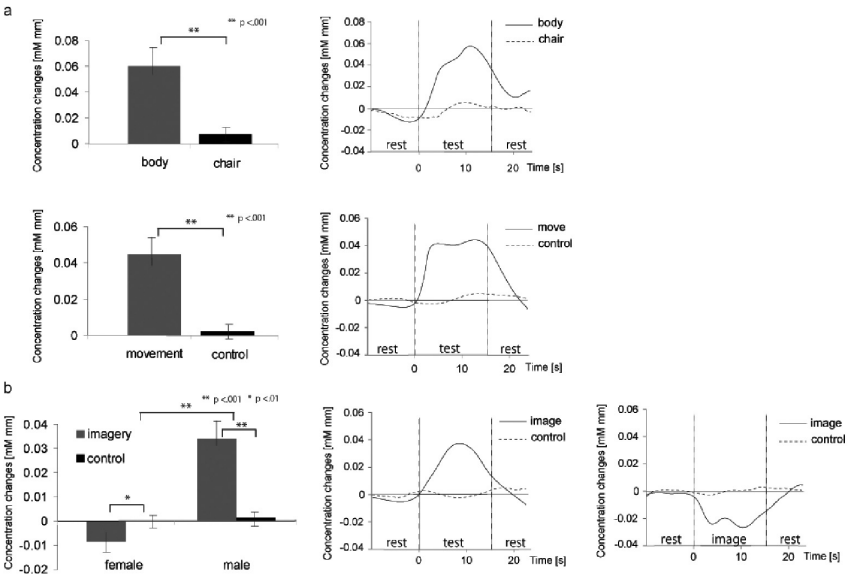

Figure. 2 a: C_{oxyHb} changes in the experiment 1 (upper) and 2 (lower). Bar graphs indicate the results of statistical analysis (double asterisks, p<0.001). Right waveforms represent the time course of changes in C_{oxyHb} in a typical subject in response to viewing images of bodies (solid line) or chairs (dotted line) for experiment 1, and carrying out hand movements (solid line) or resting (dotted line) for experiment 2. b: C_{oxyHb} changes in the experiment 3. Bar graphs indicate the results of statistical analysis for male and female (asterisk, p<0.01; double asterisks, p<0.001). Right waveforms represent the time course of changes in C_{oxyHb} in a typical male subject (left) and female (right) in response to imagining the movement (solid line) or resting (dotted line).

effect or interactions were found in experiment 3. Upon further analysis, a difference between male and female was found. Thus Gender was added as a third factor and a three-way ANOVA analysis was conducted on the categories Imagery (execution and rest), Hemisphere (left and right) and Gender (male and female). Consequently, significant main effects were observed for Imagery (F=35.976, df=1, p<0.00001) and Gender (F=102.373, df=1, p<0.00001). There was also a significant interaction between Imagery and Gender (F=108.591, df=1, p<0.00001) due to the larger male change in C_{oxyHb} in response to imagery (p<0.00001) compared to female (p<0.01). Fig. 2b provides an example of C_{oxyHb} changes in experiment 3 for a typical male and female subject. The mean C_{oxyHb} responses for the male and female groups are shown in Fig. 2b.

Discussion

In Experiment 1, channels over the occipital temporal cortices were able to measure hemodynamic changes when the subject viewed images of the human body. Therefore, this area may be involved in the perception of human bodies, namely, as expected from the EBA. Many studies employing fMRI, TMS and EEG (Downing et al., 2001; Urgesi et al., 2007; Thierry et al., 2006) have reported that viewing human body images activates the EBA, and the present study confirmed their results using NIRS while demonstrating the usefulness of NIRS in studies of the EBA.

In experiment 2, larger C_{oxyHb} responses were produced during hand movements compared to at rest. These results show that the EBA responds not only during the perception of bodies but also during the execution of hand movements without visual feedback. Therefore, the EBA is involved in two modalities; visual perception and motor activity. These results are consistent with previous fMRI study (Astafiev, 2004), and the current study confirmed this motor-related association of the EBA.

Finally, in experiment 3, larger C_{oxyHb} responses were observed during the imaging of motor activity compared to simply resting, and lager responses were produced in male than in female subjects. This is confirmed by previous studies which have reported that imagining a relevant image can activate the same brain regions normally involved in seeing that image, for example, faces for fusiform face area (O'Craven & Kanwisher, 2000). Similarly with motor function, imagined movements and actual movements also activate similar regions (e.g. Porro et al., 1996, Hanakawa et al., 2003), and Astafiev et al. (2004) which raises the possibility that moving the hand (with eyes shut) and simply imagining moving the hand, both activate the EBA. The current findings are consistent with these studies. Furthermore, it was interesting to find a gender difference in responses to imagining movement. Some behavioral studies using a mental rotation paradigm reported a general superiority in male performance (e.g. Alington et al., 1992) suggesting males have an advantage in spatial mental imagery. Previous neuroimaging studies have also suggested that the brain regions involved in mental imagery were different in men and women (e.g. Seurinck et al., 2004; Amunts et al., 2007). For example, Seurinck et al. (2004) used fMRI to explore gender-

specific cortical activation patterns for the mental rotation of egocentric hands and found that the superior parietal lobe, the dorso-lateral premotor cortex, and the extrastriate occipital areas were used for these tasks in both men and women, but that there were sex differences in the activity of these regions. The current study did not adopt such mental rotation tasks, however, it certainly did require imagery skills, such as imagining the hand itself or the hand moving along a slit. Therefore, it is possible that this gender-specific difference in mental imagery skills influenced the results of the present study. Further research is needed to confirm this possibility.

In summary, the region that we defined as the EBA was clearly activated when viewing human body images, by motor execution and imagery, and demonstrated the usefulness of NIRS as a new brain imaging method in EBA study. Moreover, a difference between male and female response to motor imagery was also found. This result may reflect differences in imaging ability between men and women, however further research is needed to verify this possibility.

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