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Time Course Analysis of Hemispheric Asymmetry in Self-Face Recognition: A Magnetoencepharography Study

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1. Introduction

Self-face recognition is considered a highly complex neurocognitive function. In fact, the ability to understand a face in a mirror as one's own is not observed in non-primates, other than adult great apes [1,2]. This ability is also typically not observed in human infants under 18 months of age [3,4]. Recent cognitive neuroscientific studies have identified brain regions that selectively respond to a subject's own face [5]. Many studies have demonstrated that right prefrontal cortex is associated with self-face recognition, using functional magnetic resonance imaging (fMRI) [6-9], positron emission tomography (PET) [10], and transcranial magnetic stimulation (TMS) techniques [11,12]. Other observations have demonstrated that activation of the left fusiform gyrus is enhanced by self-faces relative to other familiar faces [9,10,13,14]. However, it is still unknown when these brain regions are activated over the time course of self-face recognition.

The temporal aspects of self-face recognition have principally been investigated by event-related potential (ERP) experiments [15,16]. Facial stimuli are known to elicit a negative component relative to nonfacial objects at approximately 170 ms post-stimulus (N170) in the occipito-temporal region [17,18]. Sui et al. [15] reported that N170 amplitude did not differ between self- and other-faces. Instead, self-faces enhanced long-latency positivity (220-700 ms) over the frontocentral area relative to other familiar faces. Moreover, Ninomiya et al [16] found that self-faces elicited larger P3 components than other-faces. Although these observations are interesting, the poor spatial resolution of ERPs makes it difficult to clearly associate the temporal aspects of ERP findings with the spatial aspects of fMRI observations.

The aim of this study was to examine the time course of differences in neural response between self and other-face recognition using magnetoencephalography (MEG). MEG not only has excellent temporal resolution relative to fMRI, but also has excellent spatial resolution compared with ERP. It is thus suitable for specifying the time course of activation of self-specific brain regions. We recorded magnetic field responses using a whole-head 160 channel MEG system while subjects were passively viewing self- and other-faces (of close friends) with various expressions and head positions. We examined the time course of MEG waveforms in the fronto-temporal (anterior) region and occipito-temporal (posterior) region in both hemispheres.

2. Methods

2.1. Subjects

Subjects were 10 right-handed healthy male volunteers aged 27.50 ± 5.23 years (mean ± SD) (range, 23-41 years). All subjects had normal or corrected-to-normal vision. Handedness was assessed by the Edinburgh Handedness Inventory [19]. The study was conducted in accordance with the principles of the Declaration of Helsinki, and the protocol was approved by the Ethics Committee of Keio University. All subjects provided written informed consent prior to participation.

2.2. Materials and Procedures

Prior to MEG measurements, 10 color pictures, with various expressions or head positions, were taken of each subject. Six of these facial views were frontal views with happy, angry, or neutral expressions, and with closed eyes, left-averted eyes, or right-averted eyes. The remaining 4 were left-profile, right-profile, left-three-quarter, and right-three-quarter faces. We also prepared photographs of 10 different clocks as targets in a dummy task. All images were full-color photographs with gray backgrounds. Each image was prepared as a bitmap file with 256×256 pixels.

During the experiment, subjects lay in a dimly lit, magnetically shielded room while images were projected on to a half-mirror by a slide projector outside the room. The viewing distance was 110 cm from subjects to the half-mirror. The stimulus size was 10 cm×10 cm. Each trial began with a fixation cross for 500 ms, which was followed by a stimulus image for 800 ms. The intertrial interval (ITI) was randomly set between 1800 ms and 2200 ms.

A total of 50 images were presented for each subject: 10 self-faces, 30 other-faces (10×3 persons), and 10 clocks. We used faces of close friends (colleagues in the same laboratory) as the other-faces. Each image was presented five times throughout the experiment. We therefore averaged 50 trials for the self-face and 150 trials for other-faces. Although a dummy task of counting the appearance of clocks was given to the subjects, our principal interest was in the MEG responses to self- and other-faces. Therefore, we do not report the MEG results for clock stimuli here.

2.3. MEG recordings and data analysis

MEG signals were measured with a whole-head 160-channel superconducting quantum interference device (SQUID) system based on a coaxial type gradiometer (PQ1160C, Yokogawa Electronic Corporation, Japan). The MEG was continuously sampled at a digitization rate of 500 Hz. We filtered the MEG waveforms through a DC band-pass filter to 100 Hz. A 50-Hz notch filter was also used. Each MEG was averaged at the time of stimulus onset. The baselines were mean amplitudes during 200-ms pre-stimulus periods for each condition.

Prior to the experiment, five head coils were attached to the subject's face in order to detect movement. One of these was placed on the right and left pre-auricular points. A central coil was placed 5 cm above the nasion,

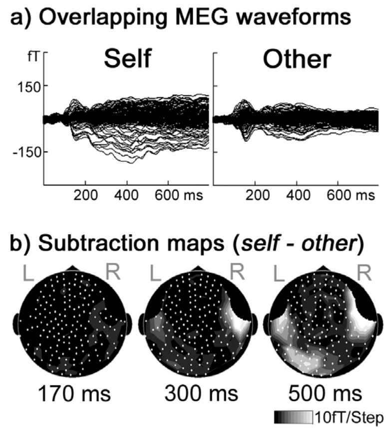

Fig. 1 (a) Overlapping MEG waveforms of the whole-head 160 channels for self- and other-faces. (b) Subtraction maps of RMS (root-mean square) values of magnetic field response for self-minus other-faces at 170 ms, 300 ms, and 500 ms post-stimulus. The lighter areas in the maps represent regions with larger difference between self- and other-faces.

and the other two frontal coils were placed 5 cm lateral to the center marker. No subjects moved more than 3 mm in any plane during the recording. MEG was recorded and analyzed in the MEG Laboratory, at the Center for Integrated Medical Research, Keio University, in Tokyo, Japan.

3. Results

We summarize overlapping MEG waveforms of 160 ch for self- and other-faces in the upper part of Fig 1. Self-faces elicit stronger magnetic response relative to other-faces after 200 ms post-stimulus. The lower part of Figure 1 represents subtraction maps (self – other) of root mean square (RMS) values of magnetic-field response at 170 ms, 300 ms, and 500 ms post-stimulus. There was no difference of magnetic field response between self- and other- faces at 170 ms. On the other hands, the self-faces enhanced activation relative to other-faces particularly in the right fronto-temporal region at 300 ms. Furthermore, the self-face dominance was extended into the occipito-temporal region in the left hemisphere at 500 ms.

For statistical analysis, we estimated RMS waveforms using 7 channels at the fronto-temporal sites (Fig 2) and occipito-temporal sites (Fig 3). The mean amplitudes were calculated during 3 epochs: 0 - 200 ms, 200 - 400

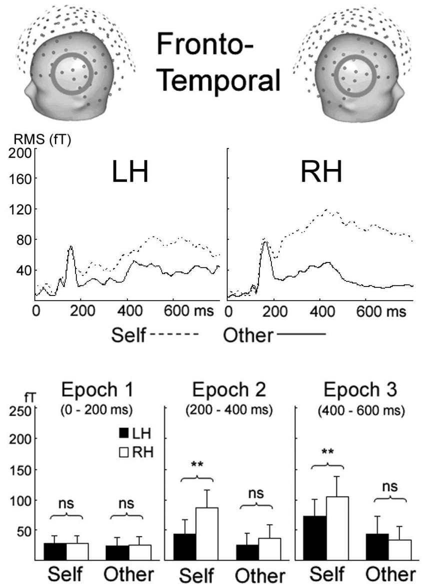

Fig. 2 RMS waveforms for self- and other-faces at left (LH) and right hemisphere (RH) fronto-temporal sites. The lower bar graphs summarize mean RMS amplitudes in phase 1 (0-200 ms), phase 2 (200-400 ms), and phase 3 (400-600 ms)(** $p<0.01$).

ms, and 400 - 600 ms. We statistically tested mean RMS amplitudes in each recording site by 3-way analysis of variance (ANOVA) with within-subject factors of Hemisphere (right hemisphere [RH], left hemisphere [LH]), Image (self-face, other-face), and Epoch (epoch 1, epoch 2, and epoch 3).

3.1. Fronto-temporal region

We summarize RMS waveforms for self- and other-faces at the fronto-temporal site as shown in Fig. 2. The lower bar graphs summarize the mean RMS amplitudes in epoch 1 (0-200 ms), epoch 2 (200-400 ms), and epoch 3 (400-600 ms). Figure 2 shows that although self-face advantage was found in both hemispheres, the advantage was larger in RH than in LH. Moreover, RH advantage was found for self-faces but not for other-faces. These effects were observed 200 ms post-stimulus.

In fact, 3-way ANOVA revealed significant second-order interaction of

Hemisphere × Image × Epoch, $F(2, 18) = 16.64$, $p < 0.01$. Separate 2-way ANOVA in each epoch revealed significant Hemisphere × Image interactions in Epoch 2, $F(1, 54) = 47.60$, $p < 0.01$, and Epoch 3, $F(1, 54) = 28.86$, $p < 0.01$. These interactions indicate that self-face advantage was larger in RH than in LH, while the advantage was significant in both hemispheres, $p < 0.01$. They also indicate that RH superiority was significant only for self-faces in epoch 2, $F(1, 54) = 47.60$, $p < 0.01$, and epoch 3, $F(1, 54) = 28.86$, $p < 0.01$, while no significant hemispheric superiority was observed for other-faces in epoch 2, $F(1, 54) = 2.51$, $p = 0.12$, and epoch3, $F(1, 54) = 2.55$, $p = 0.12$. In contrast to the later epochs, no significant Hemisphere × Image interaction was found in epoch 1, $F(1, 27) = 0.05$, $p = 0.83$.

3.2. Occipito-temporal region

Figure 3 summarizes RMS waveforms for self- and other-faces at the occipito-temporal sites. The lower bar graphs summarize the mean RMS amplitudes in epoch 1 (0-200 ms), epoch 2 (200-400 ms), and epoch 3 (400-600 ms). Unlike the fronto-temporal site, self-face advantage was found in LH after 400 ms. In addition, LH advantage was found for self-faces but not other-faces.

In fact, 3-way ANOVA revealed significant second-order Hemisphere × Image × Epoch interaction, $F(2, 18) = 4.33$, $p < 0.05$. Separate 2-way ANOVA showed that Hemisphere × Image interaction was significant in epoch 3, $F(1, 27) = 18.39$, $p < 0.01$, suggesting that self-face advantage was found in LH, $F(1, 54) = 37.66$, $p < 0.01$, but not in RH, $F(1, 54) = 0.99$, $p = 0.32$. This interaction also indicates that LH superiority was significant for self-faces, $F(1, 54) = 10.66$, $p < 0.01$, but not for other-faces, $F(1, 54) = 1.96$, $p = 0.17$. In contrast, the interactions were significant in neither epoch 1, $F(1, 27) = 0.03$, $p = 0.87$, nor Epoch 2, $F(1, 27) = 2.21$, $p = 0.15$.

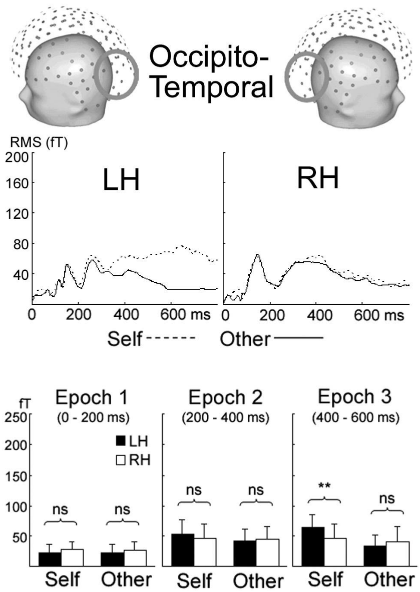

Fig. 3 RMS waveforms for self- and other-faces at left (LH) and right hemisphere (RH) occipito-temporal sites. The lower bar graphs summarize mean RMS amplitudes in epoch 1 (0-200 ms), epoch 2 (200-400 ms), and epoch 3 (400-600 ms)(** p<0.01).

4. Discussions

This study examined the time course of hemispheric asymmetry in self-face recognition using MEG. RH dominance was found only for self-faces 200 ms post-stimulus in the fronto-temporal brain region. Self-face advantage was larger in RH than in LH, although significant self-face advantage was found in both hemispheres. Conversely, LH dominance was found only for self-faces after 400 ms in the occipito-temporal site. Self-faces elicited larger response in LH while there was no difference between self- and other-faces in RH. This is, to our knowledge, the first MEG study to explore the time course of hemispheric asymmetry in self-face recognition. We discuss the implications of these observations based on previous fMRI and ERP studies.

There is much evidence that self-faces enhance activation of the anterior brain regions of the right hemisphere, such as the frontal gyrus [6-10] and anterior cingulate cortex [9,13]. This is consistent with our finding that RH dominance was found only for self-faces in the anterior region after 200 ms. RH dominance for self-face recognition has principally been observed by fMRI, with poor temporal resolution. Our MEG findings extend the previous fMRI observations by suggesting that RH dominance for self-face recognition may occur after 200 ms.

The temporal aspects of our findings are also consistent with those of previous ERP studies [15,16]. Sui et al. [15] reported that the N170 amplitude, which was presumed to reflect structural encoding of faces [17,18], did not differ between self- and other-faces. Instead, self-faces enhanced long-latency positivity (220-700 ms) over the frontocentral area relative to other familiar faces, although hemispheric lateralization was not observed. Moreover, Ninomiya et al [18] found that self-faces elicited larger P3 components than other-faces. Although these observations are important, the poor spatial resolution of ERPs makes it difficult to clearly associate the temporal aspects of ERP findings with the spatial aspects of fMRI observations. The present MEG study thus extended the previous ERP findings that the late anterior response is lateralized to the right hemisphere.

In contrast to the anterior brain region, the posterior self-face advantage was lateralized to the left hemisphere. This finding is consistent with those of previous fMRI studies that self-faces enhanced activation in the left fusiform gyrus [9,10, 13,14]. The fusiform gyrus is usually associated with early stages of face perception [20], and is known as a generator of M170 (MEG) or N170 (ERP) components at approximately 170 ms occipito-temporally [21,22]. However, our findings showed that magnetic field differences between self- and other-faces in the left posterior region emerged after 400 ms. This suggests that self-related processing in the left fusiform gyrus may not reflect early stages of visual perception, but may reflect later stages of processing.

In line with this, some studies have reported that the left fusiform gyrus is involved in lexical and semantic processing in general object recognition [23]. Moreover, Kircher et al. [14] reported that left fusiform gyrus activation in self recognition was modality-independent and that this region was also activated by self-related trait adjectives as well as self-faces. These findings suggest that activity in the left fusiform gyrus may reflect abstract processing of self concepts in later stages of processing.

5. Conclusion

This MEG study examined the time course of hemispheric asymmetry in self-face recognition. Self-faces enhanced activity more than other-faces in the RH anterior brain region after 200 ms, suggesting a potential link between previous fMRI and ERP findings. In contrast, self-faces enhanced MEG responses in the posterior LH site after 400 ms. This finding suggests that the left fusiform activity for self-faces may not reflect the early stage of visual perception, and instead reflect the later abstract processing of self-related concepts. To our knowledge, this is the first MEG study to explore the time course of hemispheric asymmetry in self-face recognition. We believe that further MEG investigations with high spatial and temporal resolution will improve understanding of the neural mechanisms of self-face recognition.

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