

An ERP study on self-relevant object recognition

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Abstract

We performed an event-related potential study to investigate the self-relevance effect in object recognition. Three stimulus categories were prepared: SELF (participant's own objects), FAMILIAR (disposable and public objects, defined as objects with less-self-relevant familiarity), and UNFAMILIAR (others' objects). The participants' task was to watch the stimuli passively. Results showed that left-lateralized N250 activity differentiated SELF and FAMILIAR from UNFAMILIAR, but SELF and FAMILIAR were not differentiated. In the later time-course, SELF was dissociated from FAMILIAR, indicating the self-relevance effect in object recognition at this stage. This activity did not show consistent lateralization, in contrast to previous studies reporting right lateralization in self-relevant face and name recognition. We concluded that in object recognition, self-relevance was processed by higher-order cognitive functions later than 300 ms after stimulus onset.

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1. Introduction

Our own property is unmistakably distinguishable from that of others, just as our own names and faces are. This salience indicates the existence of a top-down bias of processing self-relevant information. This self-relevance effect has been investigated by researchers. Previous event-related potential (ERP) studies have reported that the self-relevance effect is reflected in P300. P300 is known to reflect the engagement of higher-order cognitive functions (Farwell & Donchin, 1991; Johnston, Miller, & Burselson, 1986; Johnston & Wang, 1991; Nasman & Rosenfeld, 1990). These higher-order cognitive functions are considered to be involved in self-relevance processing, therefore, self-relevance has been investigated with P300 (Berlad & Pratt, 1995; Fischler, Jin, Boaz, Perry, & Childers, 1987; Folmer & Yingling, 1997; Gray, Ambady, Lowenthal, & Deldin, 2004;

Muller & Kutas, 1996; Ninomiya, Onitsuka, Chen, Sato, & Tashiro, 1998; Perrin, Garcia-Larrea, Mauguiere, & Batsuji, 1999; Perrin et al., 2005). Despite previous efforts, however, the role of self-relevance in object recognition remains unclear. As far as we know, the only psychophysiological research on self-relevant object recognition was Sugiura, Shah, Zilles, and Fink (2005b). However, because they did not dissociate self-relevance from familiarity, their interpretation inevitably remains ambiguous.

In order to measure the self-relevance effect in object recognition, we performed an ERP experiment. In the present study, we attempted to distinguish self-relevance from less-self-relevant familiarity. This approach is in line with recent face recognition studies, in which self-relevance is compared to less-self-relevant familiarity (for familiarity defined as familiar–famous, Caharel et al., 2002; Platek, Keenan, Gallup, & Mohamed, 2004 for familiarity defined as familiar–intimate, Herzmann, Schweinberger, Sommer, & Jentsch, 2004; Kircher et al., 2000, 2001; Platek et al., 2006; Sugiura et al., 2005a; Uddin, Kaplan, Molnar-Szakacs, Zaidel, & Iacoboni, 2005). In our experiment, self-relevant

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objects were compared to less-self-relevant familiar objects, which were defined as pre-experimentally known but not belonging to the participants, to dissociate self-relevance from familiarity.

In terms of the methodology, we adopted the visual recognition processing model proposed by Bruce and Young (1986). In their model, several visual processing stages are assumed, and these stages were later studied by ERP researchers to identify corresponding ERP components. Although the model originally concerns face recognition, we believe it also provides a model of visual information processing and an established methodology to measure the activity of each processing stage with ERP components. The first component is P100, which is sensitive to the perceptual aspects of stimuli such as brightness, contrast, size, and visual acuity (Allison, Puce, Spencer, & McCarthy, 1999; Pfütze & Sommer, 2002). The second component is N170, which reflects the structural encoding process (Eimer, 1998, 2000; Pfütze & Sommer, 2002). N170 shows larger amplitude for faces compared to other objects (Bentin, Allison, Puce, Perez, & McCarthy, 1996; Eimer, 1998; Itier & Taylor, 2004; Rossion, Gauthier, Goffaux, Tarr, & Crommelinck, 2002; Schweinberger, Huddy, & Burton, 2004). Some researchers reported that N170 did not reflect familiarity (Pfütze & Sommer, 2002; Schweinberger, Pickering, Jentsch, Burton, & Kaufmann, 2002; see also Rossion et al., 1999), while other researchers reported it did (Caharel et al., 2002; Caharel, Courta, Bernard, Lalonde, & Rebaï, 2005; Campanella et al., 2000). Therefore, N170's sensitivity to familiarity remains ambiguous. The third component is N250, which reflects the process of matching input information to stored representations (Pfütze & Sommer, 2002; Schweinberger et al., 2002; Schweinberger et al., 2004). Importantly, N250 is reported to be sensitive to familiarity in repetitive (up to 100 times) stimulus presentation paradigms (Caharel et al., 2002) as well as in immediate priming paradigms (familiarity as familiar–famous, Begleiter, Porjesz, & Wang, 1995; Pfütze & Sommer, 2002; Pickering & Schweinberger, 2003; Schweinberger, Pfütze, & Sommer, 1995; Schweinberger et al., 2002 the dissociation of familiar–famous from familiar–intimate in N250 was reported Herzmann et al., 2004). Therefore, N250 was expected to serve as the index of familiarity. In the last stage, N400 reflects access to the person identity node and semantic processing. N400 is not only sensitive to perceptive priming but also to semantic priming (Pfütze & Sommer, 2002; Pickering & Schweinberger, 2003; Schweinberger et al., 2002), reflecting wide range of cognitive activities. Both N400 and P300 are commonly characterized as slow (i.e. low-frequency) waveforms, they show modulation in late time-course (typically after 300 ms poststimulus), and reflect higher-order cognitive processes including self-relevance. We defined these types of ERP components as the late slow wave (LSW).

According to the above mentioned studies, we adopted four ERP components as indices: P100 as the index of perceptual features; N170 as the index of the structural encoding process; N250 as the index of familiarity, reflecting the

process of matching input information to stored representations; the late slow wave (LSW) which captures ERP activities after 300 ms poststimulus as the index of higher-order cognitive functions. Our interest was to identify and examine a self-relevance effect that is dissociated from less-self-relevant familiarity in object recognition. We adopted a passive viewing task to exclude task-relevant effects. For the same purpose, stimulus categories were separated by blocks and all stimuli were presented with equal probability.

2. Materials and methods

2.1. Participants

Eighteen right-handed healthy undergraduate students of Nagoya University participated in the experiment (mean age of 20.0 and aged between 19 and 24 years, 13 women). Informed consent was obtained from all the participants. All participants reported normal or corrected-to-normal vision.

2.2. Stimuli

Four kinds of objects served as stimuli: an umbrella, shoes, a cup, and a bag. Three versions of each object kind were presented, corresponding to three levels of FAMILIARITY: personally familiar objects belonging to participants (SELF); unowned objects of frequently encountered types, instances of which participants had seen and used before (FAMILIAR); and previously unseen objects belonging to someone else (UNFAMILIAR). For preparation of SELF stimuli, participants were asked to bring their own umbrella, shoes, cup, and bag. Those who did not possess all of these four items were initially excluded from the study. For FAMILIAR stimuli, a disposable umbrella, slippers, a paper cup, and a paper bag were chosen, all of commonly encountered varieties. UNFAMILIAR stimuli were chosen from objects belonging to other participants of the same sex, unless the objects were considered to be popular (e.g. products of famous brands). All items were photographed with a digital camera, and the photos were processed on a PC with Adobe Illustrator 8.0J. The backgrounds of all the photos were removed, and the clipped-out objects were pasted in the center of a gray background (see Fig. 1). All the stimuli were presented in natural color on a PC monitor. The visual angle of the stimuli was $9 \times 12^\circ$. In order to confirm the participants' familiarity with the stimuli, after the experiment, participants were asked to complete questionnaires about how long and how many times they had used or seen the objects. A mean period of using objects presented as SELF was 2.6 ± 2.8 (mean \pm SD) years. Of FAMILIAR objects, 44 out of 68 (for 17 participants, four objects each) answers indicated having seen the object more than 10 times a year, and the mean of the rest was 5.9 times a year. About the previous experience of using them, 21 out of 68 answers indicated more than 10 times a year, and the mean of the rest was 4.8 times a year.

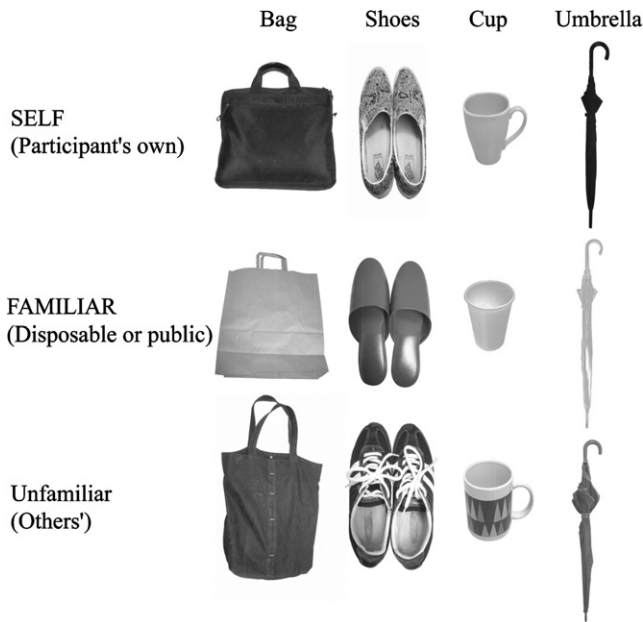


Fig. 1. Examples of stimuli presented in one experiment.

All participants answered that they had seen or used any object in the familiar category. It was also confirmed that none of the participants was familiar with the UNFAMILIAR objects.

2.3. Task design

In one block, two stimuli of the same FAMILIARITY were presented in randomized order, and each of them was presented 40 times. Therefore, one block was composed of 80 trials. Two blocks were assigned for each FAMILIARITY. Therefore, each participant underwent a total of six blocks, and the total trial number was 480. The orders of the blocks and the sorts of objects were randomized.

2.4. Procedure

In an electrically shielded and sound-attenuated dark chamber, a participant was comfortably seated at a distance of 90 cm from the CRT monitor. During the task, a white fixation cross was presented for 1500 ms at the center of the display. It was replaced by a red fixation cross that was presented for 1500 ms, during which eye blink was prohibited. Then, the visual stimulus was presented for 800 ms. The flow of a trial is illustrated in Fig. 2. Between blocks, several minutes of rest were taken appropriately. The participants' task was to observe the stimuli carefully and to answer questions about presented stimuli by describing them in detail during the rest period. All the participants described the stimuli correctly.

2.5. Electroencephalogram (EEG) recording and processing

On the basis of the International 10–20 system, EEG was recorded with BIOPAC (Goleta, CA) MP100 16 EEG

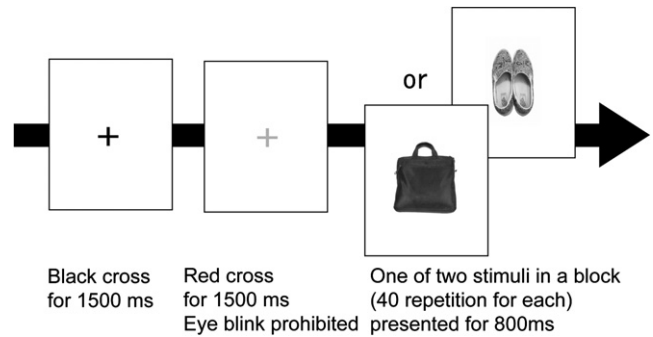


Fig. 2. The flow of a trial. The participant's task was to observe the stimuli carefully so that during the rest period they could describe the stimuli.

recording units from 15 sites by using Ag/AgCl electrodes: the sites were Fz, F3, F4, F7, F8, Cz, C3, C4, T7, T8, Pz, P3, P4, P7, and P8. Reference electrodes were initially placed on the earlobes, and later an average reference method was applied. Electrooculogram (EOG) activity was monitored at the electrodes on the canthus and lower orbital ridge of the left eye. Impedance was kept below 10 k Ω , typically below 5 k Ω . Signals were recorded with a 0.1 Hz high-pass filter (6 dB/Oct) and 100 Hz low-pass filter (18 dB/Oct). The sampling rate was 500 Hz with a 16-bit A/D conversion.

EEG data analysis was performed using EEGLAB 5.02 (Delorme & Makeig, 2004; <http://www.sccn.ucsd.edu/eeglab>) running under Matlab 7.1 (The Mathworks). EEG of correctly responded trials was segmented to obtain epochs starting from 300 ms before the stimulus onset until 1000 ms after stimulus (baseline – 300 to – 50 ms). All trials were inspected visually, and only artifact-free trials were retained. Epochs containing unique, non-stereotyped artifacts such as eye blinks and heart beats were corrected using ICA. The mean percentage of rejected epochs was 25.4% (range: 0–37.5%). Next, individual concatenated single-trial data-sets were decomposed with Infomax ICA. Sixteen components were derived from each subject's data. Components representing artifacts were identified and rejected from further analysis by visual inspection of individual component properties. A mean of three independent components (range: 1–6) were identified and rejected by analyzing the component map (the inverse weight matrix for the component), the component ERP (time-domain average of the activity time course), the component power spectrum (frequency-domain average of the component activity), and the component ERP-image. Then, artifact-free EEG data were obtained by back-projecting the remaining non-artifactual ICA components by multiplying the selected component activities with the reduced component mixing matrix. The EEG was low-pass filtered at 20 Hz with a finite impulse response (FIR) filter. The EEG was recalculated to an average reference excluding the EOG channel. ERPs were calculated independently for each channel and condition. Average amplitudes of P100, N170, N250, and LSW were measured. The peak latencies of P100 and N170 at P7 and P8 served as the center of the time window. As a result, the time window of P100 was defined as that between poststimulus periods of 80 and 120 ms, and the time

window of N170 was defined as that between poststimulus periods of 140 and 180ms. The time window of N250 was defined as that between poststimulus periods of 200 and 300ms from previous studies. The time window of LSW was defined based on post hoc visual inspection of our ERP data to capture the time range of wave modulation, and defined as from 300 to 700ms poststimulus.

2.6. Statistical analysis

Mean amplitudes of P100, N170, N250, and LSW were submitted to 3 (FAMILIARITY: SELF, FAMILIAR, UNFAMILIAR) \times 15 (ELECTRODE: Fz, F3, F4, F7, F8, Cz, C3, C4, T7, T8, Pz, P3, P4, P7, and P8) two-way repeated measures ANOVAs. For the purpose of confirmation, N170 lateralization at P7 and P8 were tested by three (FAMILIARITY: SELF, FAMILIAR, and UNFAMILIAR) \times 2 (LATERALITY: P7, P8) two-way repeated measures ANOVAs. The Greenhouse–Geisser correction was applied wherever necessary. For post hoc multiple comparisons, the Bonferroni correction was used with a significance level of .05.

3. Results

Fig. 3 shows the grand mean ERP for all the scalp electrodes in all the conditions. Fig. 4 shows the results of multiple comparisons with scalp electrode locations.

3.1. P100

The results of the ANOVAs showed a significant interaction FAMILIARITY \times ELECTRODE, $F(28, 504) = 2.63$, $p < .05$. The result indicates the different perceptual features across stimuli.

3.2. N170

The results of the ANOVAs did not show a significant interaction FAMILIARITY \times ELECTRODE, $F(28, 504) < 1$. For confirmation, post hoc multiple comparisons were performed, but no significant difference was found in any electrodes across any combination of FAMILIARITY. Thus, the familiarity effect on N170 was not observed. The two-way ANOVAs FAMILIARITY \times ELECTRODE (P7 and P8) did

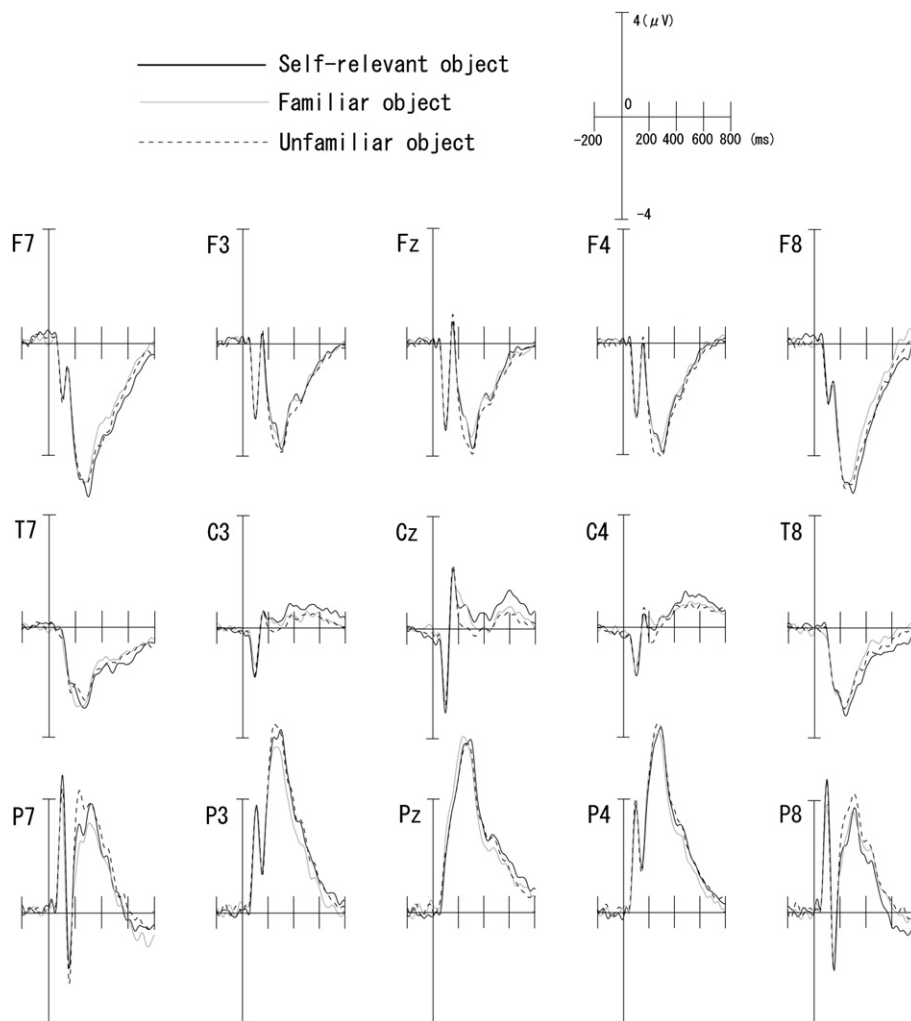


Fig. 3. Grand mean ERPs for SELF, FAMILIAR, and UNFAMILIAR object recognition.

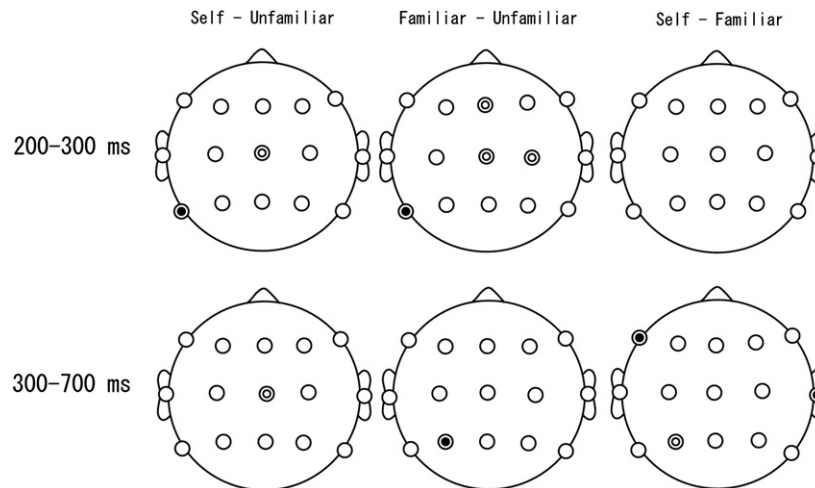


Fig. 4. The results of multiple comparisons on N250 (200–300 ms, top row) and LSW (300–700 ms, bottom row) across FAMILIARITY (columns). Single circles show non-significant results of multiple comparisons, concentric double circles show significantly positive difference, and single circles with concentric solid black circle show significantly negative difference.

not reveal significant main effect of ELECTRODE, $F(1,18) < 1$; FAMILIARITY, $F(2,36) < 1$; or the interaction, $F(2,36) < 1$. Thus, the lateralization was not observed in N170.

3.3. N250

The results of the ANOVAs showed a significant interaction FAMILIARITY \times ELECTRODE, $F(28, 504) = 2.9$, $p < .05$. In order to test the interaction, post hoc multiple comparisons were performed. The results are shown in Fig. 4. Significant differences between SELF and UNFAMILIAR were found at electrodes Cz and P7 (both $p < .05$), and between FAMILIAR and UNFAMILIAR at Fz ($p < .05$), Cz ($p < .001$), C4 ($p < .005$), P7 ($p < .05$). A significant difference was not found, however, between SELF and FAMILIAR at any electrode. Therefore, SELF and FAMILIAR were both dissociated from UNFAMILIAR, but SELF was not dissociated from FAMILIAR.

3.4. LSW

The results of ANOVAs showed significant interaction FAMILIARITY \times ELECTRODE, $F(28, 504) = 2.4$, $p < .05$. Post hoc multiple comparisons revealed significant differences between SELF and UNFAMILIAR at Cz ($p < .05$); between FAMILIAR and UNFAMILIAR at P3 ($p < .05$); and importantly, between SELF and FAMILIAR at F7 ($p < .05$), T8 ($p < .005$) and P3 ($p < .05$). These results are shown in Fig. 4. The results indicate that self-relevance was dissociated from less-self-relevant familiarity from 300 ms poststimulus.

4. Discussion

The purpose of this study was to examine the self-relevance effect dissociated from non-self-relevant familiarity in object recognition with ERP. Results are discussed below.

In P100, the interaction FAMILIARITY \times ELECTRODE was significant. The result indicates different visual features across stimuli (Allison et al., 1999; Pfütze & Sommer, 2002), which was interpreted to be due to variation in the shape and appearance of the objects.

N170 did not reveal any significant main effect or interaction, suggesting that familiarity with objects did not affect their structural encoding processes. Our finding supports that of previous studies in which familiarity did not affect N170 (Pfütze & Sommer, 2002; Schweinberger et al., 2002). In terms of N170 lateralization, although previous face recognition studies have commonly reported a larger N170 over the right hemisphere (Bentin et al., 1996; Eimer, 1998; Itier & Taylor, 2004; Rossion et al., 2002; Schweinberger et al., 2004), this was not observed in our results. Thus, object recognition process in N170 is not specialized to either laterality, suggesting the difference from face recognition process.

N250 showed a larger potential for both self-relevant and less-self-relevant familiar objects than for unfamiliar objects. Between self-relevant objects and less-self-relevant familiar objects, however, a significant difference was not found. Thus, familiarity was distinguished from unfamiliarity irrespective of the degree of self-relevance, presumably due to already existing stored representations of familiar objects (Pfütze & Sommer, 2002; Schweinberger et al., 2002; Schweinberger et al., 2004). Our results are in contrast with previous findings in face recognition ERP studies in which N250 dissociated self-relevance from familiar-famous (Caharel et al., 2002; Herzmann et al., 2004). This might suggest a difference between faces and objects in familiarity processing, and our results indicate that self-relevance does not affect this process in object recognition.

This N250 activity was found at the left occipitotemporal electrode but not at the right one, suggesting the left lateralization of this process. Our result is consistent with the finding of the previous ERP study conducted by

Nessler, Mecklinger, and Penney (2005) in which N250 differentiated familiar–famous faces from unfamiliar faces at left occipitotemporal, left frontal, and central electrodes, while it was not found over right hemisphere. Evidence of a left-lateralized familiarity process was also provided by brain imaging studies. Gorno-Tempini et al. (1998) reported brain activity related to domain-general familiarity, which was familiar–famous across faces and names, in the region from left anterior temporal to left temporoparietal. Later, Gorno-Tempini and Price (2001) also found left-lateralized brain activity related to another domain-general familiarity (familiar–famous) across faces and buildings in the left middle temporal gyrus. Evidence of familiarity-related processes was also found in left fusiform gyrus in familiar–famous face recognition (Eger, Schweinberger, Dolan, & Henson, 2005; Pourtois, Schwartz, Seghier, Lazeyras, & Vuilleumier, 2005) as well as the left medial temporal region in familiar–intimate face recognition (Sugiura et al., 2001). Considering the fact that N250 was estimated to be originated within fusiform gyri (Schweinberger et al., 2002), our results suggest that the left fusiform gyrus might be involved in object familiarity processing within the time-course of 200–300 ms after stimulus onset.

LSW dissociated self-relevance from less-self-relevant familiarity. This late component is considered to indicate involvement of higher-order cognitive functions as ERP modulation in this latency observed in P300 and N400 has been related to them (for P300 studies, Farwell & Donchin, 1991; Johnston et al., 1986; Johnston & Wang, 1991; Nassman & Rosenfeld, 1990 for N400 studies, Pfützte & Sommer, 2002; Pickering & Schweinberger, 2003; Schweinberger et al., 2002), therefore, it indicates involvement of higher-order cognitive functions in distinguishing self-relevance from less-self-relevant familiarity (Berlad & Pratt, 1995; Fischler et al., 1987; Folmer & Yingling, 1997; Gray et al., 2004; Muller & Kutas, 1996; Ninomiya et al., 1998; Perrin et al., 1999, 2005). Thus, our results suggest that self-relevance and less-self-relevant familiarity in object recognition are dissociated by higher-order cognitive functions after 300 ms poststimulus.

In terms of lateralization of LSW, previous studies reported the association of self-relevance with right-lateralized brain activities (Keenan et al., 1999, Keenan, Freund, Hamilton, Ganis, & Pascual-Leone, 2000a, Keenan, Nelson, O'Connor, & Pascual-Leone, 2001; Platak et al., 2004; Sugiura et al., 2005a; Uddin et al., 2005; for review, Keenan, Wheeler, Gallup, & Pascual-Leone, 2000b; Van Lancker, 1991). Nonetheless, our LSW results did not show consistent right lateralization. The absence of right-lateralized brain activity was also reported by Sugiura et al. (2005a, 2005b), in which self-relevant object recognition was compared to unfamiliar object recognition by fMRI. This absence of right-lateralization might suggest that self-relevance in object recognition is not as prominent as that in face or name recognition. This assumption is supported by evidence from a previous object recognition study on global aphasia. Van Lancker and Nicklay (1992) reported

that globally aphasic patients recognized names of familiar–famous and familiar–intimate persons and landmarks better than non-personal words, while no advantage was found for names of personal belongings. This result might be related to the absence of clear right-lateralization in self-relevant object recognition, indicating less represented self-relevance in object recognition than in face and name recognition.

Another finding of our study is that P300 peak amplitude modulation was not clearly present although P300 was present. This could be explained by the fact that the self-relevant recognition task with active response engages not only response-related brain regions but also self-relevant processing regions (Sugiura et al., 2000). Therefore, the absence of P300 amplitude modulation might be due to the passive task, which does not engage active discrimination processes and, therefore, does not modulate P300 peak amplitude. It is notable that the self-relevance effect was present and dissociated from familiarity differently from P300 peak amplitude modulation, indicating that the time-course of the non-task-relevant self-relevant process does not necessarily overlap with the P300 peak.

A limitation of the present study is that self-relevance was defined as the increased engagement of higher-order cognitive functions, which remains only a sufficient condition of self-relevance. Although self-relevance was dissociated from familiarity later than 300 ms after stimulus onset, self-relevance was still not differentiated from other higher-order cognitive functions. Further research on this point is awaited.

In sum, we performed an ERP study to clarify the role of self-relevance in object recognition. We found that both self-relevance and less-self-relevant familiarity were dissociated from unfamiliarity in the left occipitotemporal area between 200 and 300 ms after stimulus onset. These differences were interpreted to reflect the availability of stored representations for familiar objects. Subsequently, self-relevance was differentiated from less-self-relevant familiarity later than 300 ms poststimulus, indicating that self-relevance was discriminated by higher-order cognitive processes, but clear right lateralization was not observed. We concluded that in object recognition, self-relevance was processed by higher-order cognitive functions later than 300 ms after stimulus onset.

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