

# Self-face recognition in attended and unattended conditions: an event-related brain potential study

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This study investigated whether neural mechanisms of self-face recognition are modulated by attention by recording event-related brain potentials associated with self-face recognition. Participants identified head orientations of self-faces and familiar or unfamiliar other faces presented briefly at the center of the visual field. Event-related brain potentials to self-faces and other faces were recorded when self-faces and familiar or unfamiliar other faces were either task relevant (attended) or irrelevant (unattended) in separate blocks of trials. We found that early face-specific event-related brain potential components such as the N170 and vertex positive potential did not differ between self-faces and other faces. Relative to familiar faces, however, self-faces induced an increased positivity

over the frontocentral area at 220–700 ms. The increased positivity to self-faces relative to familiar faces between 500 and 700 ms was reduced in the attended relative to the unattended conditions, which arose from the fact that the amplitude to familiar faces during this time window was increased in the attended relative to the unattended conditions, whereas the event-related brain potential amplitude to self-faces was not influenced by attention. The event-related brain potential results suggest an automatic process of self-face recognition in human brains that occurs after face structure encoding and is independent of task relevance. *NeuroReport* 17:423–427 © 2006 Lippincott Williams & Wilkins.

**Keywords:** attention, event-related potential, face recognition, self

## Introduction

Human beings are extremely good at recognition of human faces that provide affective and other social information. For example, humans respond faster to self-faces than to other faces, and this self-face advantage has been demonstrated over either familiar or unfamiliar faces and is evident even when face stimuli are presented in unfamiliar views [1,2]. It has been suggested that recognition of self-faces is an indicator of higher-order self-awareness and involves neural substrates beyond those involved in general face recognition and exists only in higher primates [3–6].

While neuropsychological studies suggest that self-face recognition is dominated by the right hemisphere [4,5,7,8], but see [9]), functional magnetic resonance imaging (fMRI) studies have identified neural activities in the right superior frontal gyrus linked to self-face recognition [10,11]. The anterior cingulate, left prefrontal, superior temporal, and inferior parietal cortex also show stronger activation to the morphed version of self-faces than to unknown faces or partners' faces [6,12]. Event-related brain potentials (ERPs) have also been used to examine the neural mechanisms underlying self-face recognition. It has been shown that self-faces elicited a positivity peaking at 400 ms after stimulus onset (P3) relative to unfamiliar faces [13]. As self-faces

appeared less (30%) than unfamiliar faces (60%) in the study by Ninomiya *et al.* [13], the enhanced P3 to self-faces might arise from the difference in stimulus probability. Passively viewing self-faces produced a positivity at 200–300 ms (P2) with smaller amplitude relative to passively viewing a famous face (the president's face) [14]. As familiarity of self-faces and famous faces may not be equally matched (e.g. participants saw themselves in mirrors more frequently than they saw the president in the media), the results of Caharel *et al.* [14] may index the processing of face familiarity rather than self-specific processing.

This study examined the temporal aspects of the neural mechanisms of self-face recognition while controlling the possible flaws of the previous work. We recorded ERPs to self-faces and other faces shown with equal probability. In addition, to match familiarity of self-faces and other faces, we took pictures from the participants in this study and their classmates or roommates, whom the participants saw every day. We also investigated whether the neural mechanisms underlying self-face recognition are modulated by attention by comparing the ERP differences between self-face and other-face recognition in attended and unattended conditions. Previous work required participants to passively view self-faces [13,14] and thus reported the self-face effect

only in an unattended condition. A recent positron emission tomography (PET) study examined attentional effects on neural representation of self-faces by comparing regional cerebral blood flow between the conditions when active or passive self-face recognition was required [15]. The researchers found increased activity in the prefrontal cortex and right anterior cingulate in the active relative to the passive viewing condition. As stimulus familiarity was not matched between self-faces and other faces, it is unclear whether the neural activity observed reflected the enhanced recognition of self-faces or familiar faces *per se*. The PET results also lacked temporal information of self-face recognition because of the long latency of PET signals. It has been proposed that self-face processing demands less attention resources than that of other faces [2]. We assessed this proposal by having participants identify head orientations of self-faces or other faces in separate blocks of trials, and thus self-faces and other faces could be task relevant (attended) or task irrelevant (unattended). Self-specific processing was identified by comparing ERPs to self-faces and familiar faces. The process of face familiarity was examined by comparing ERPs to familiar and unfamiliar other faces.

## Materials and methods

### Study participants

Eighteen healthy participants (eight men, 10 women, aged between 20 and 29 years; mean  $24.7 \pm 2.46$  years) took part in this study as paid volunteers. All participants had normal or corrected-to-normal vision and were right handed. Three participants were excluded from data analysis because of excessive artifacts during electroencephalogram (EEG) recording. Informed consent was obtained from all participants before the study. This study was approved by a local ethics committee.

### Stimuli and procedure

Each participant was presented with images of self-face, one familiar other face, and one unfamiliar other face matched for sex and age. Thus, stimulus probability of self-face, familiar, and unfamiliar faces was identical. The familiar face stimuli were taken from the classmates or roommates of the participants, whom the participants had known for at least 3 years. Ten face pictures of each participant, with a neutral facial expression, were taken using a digital camera. Participants' heads were oriented to the left (from  $45^\circ$ – $90^\circ$ ) in five pictures and to the right in the others. All images were calibrated in luminance and contrast and were converted into jpg format. Each face stimulus was presented in color and subtended a visual angle of  $3.0^\circ \times 3.0^\circ$  at a viewing distance of 120 cm.

The stimuli were presented on a black background of a 21-inch color monitor. Each trial began with the presentation of a fixation cross for 900 ms, which was followed by a blank screen for 100 ms. A face image was then displayed for 300 ms, overlapping the fixation and followed by a blank screen for 700 ms. Twelve blocks of 40 trials were included. In four blocks of trials, participants identified head orientations of self-faces, familiar faces, or unfamiliar faces by pressing the left or right buttons using the left and right index fingers while ignoring other faces. The order of the tasks was counterbalanced across participants. Instructions emphasized both accuracy and response speed.

## Electrophysiological data recording and analysis

The EEG was recorded from electrodes placed at 10–20 standard positions and five other pairs of nonstandard sites. Recordings were made with respect to the left and right mastoid references. The electrode impedance was kept below  $5\text{ k}\Omega$ . The EEG was amplified by using a bandpass of 0.1–75 Hz (1/2 amplitude cutoffs), digitized at 250 Hz/channel. The vertical electrooculogram was monitored from two electrodes placed above and below the right eye. The horizontal electrooculogram was recorded from electrodes placed about 1.5 cm lateral to the left and right external canthi. ERPs were averaged offline using a computer program that extracted epochs of EEG beginning 200 ms before stimulus onset and continuing for 1000 ms. Trials containing eye blinks, eye movement deflections exceeding  $\pm 50\ \mu\text{V}$  at any electrode, or incorrect behavioral responses were excluded from the ERP averages. The baseline for ERP measurements was the mean voltage of a 200-ms prestimulus interval and the latency was measured relative to the stimulus onset.

Reaction times and response accuracy to different faces were compared using a paired *t*-test. The mean ERP amplitudes were submitted to repeated-measures analyses of variance with face owner (self, familiar, unfamiliar faces), attention (task relevant vs. irrelevant), and hemisphere (electrodes over the left vs. right hemispheres) as independent variables.

## Results

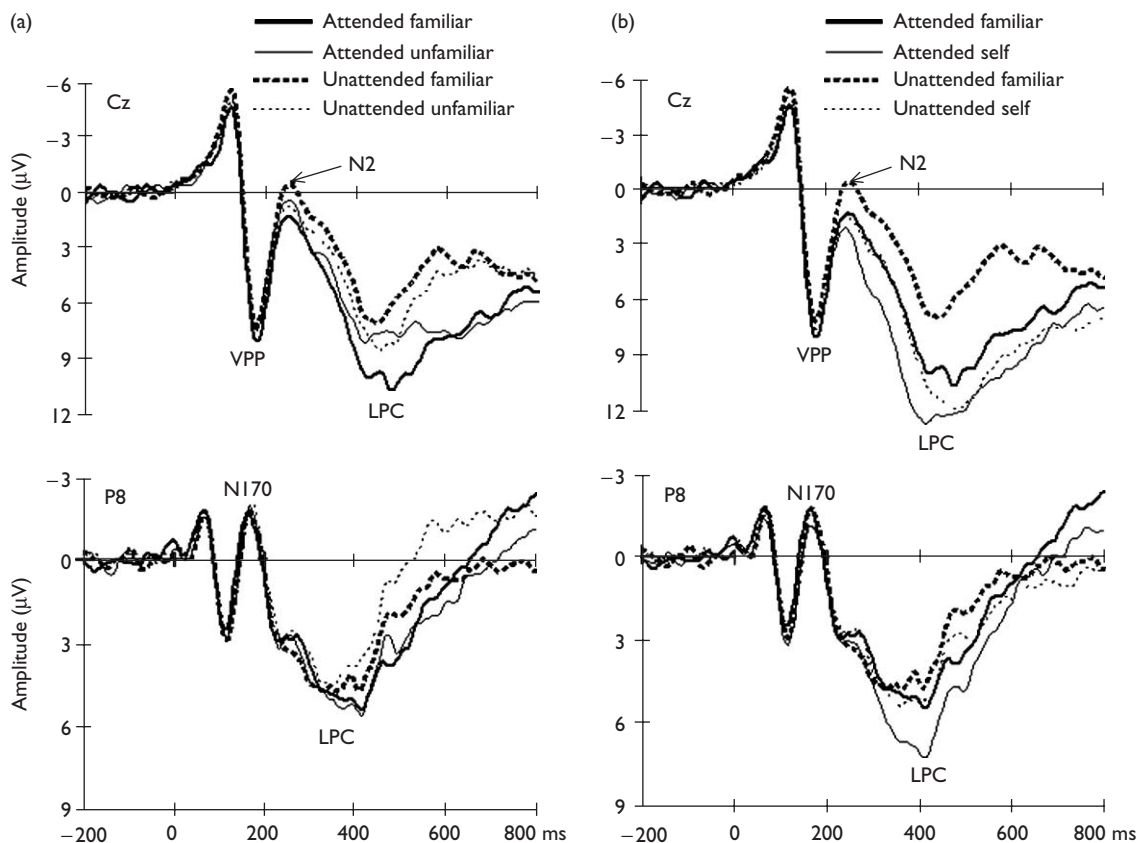
### Behavioral data

A main effect of face owner on reaction times [ $F(2,28)=5.44$ ,  $P<0.05$ ] was observed. Responses to self-faces (551 ms) were faster than those to familiar faces (596 ms) [ $t(14)=4.340$ ,  $P<0.001$ ] and unfamiliar faces (588 ms) [ $t(14)=2.283$ ,  $P<0.05$ ]. Reaction times, however, did not differ between the familiar and unfamiliar faces [ $t(14)=0.469$ ,  $P>0.05$ ]. The response accuracy did not differ among the three conditions [99%, 96%, and 98%, to self-faces, familiar faces, and unfamiliar faces, respectively,  $F(2, 28)=3.59$ ,  $P>0.05$ ].

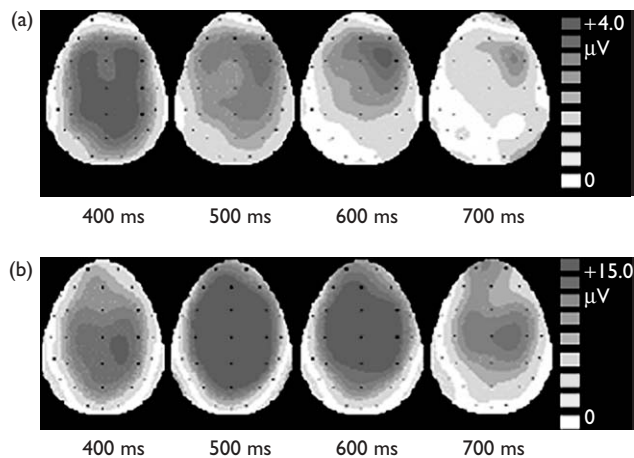
### Electrophysiological data

Figure 1 illustrates the grand-average ERPs to familiar and unfamiliar faces, and self-faces. ERPs to both self-faces and other faces were characterized by a negativity peaking at 148 and 188 ms (N170), which was followed by a negative-going wave at 220 and 300 ms (posterior N2). A positivity at 148–188 ms [vertex positive potential (VPP)] at middle, central, and frontal sites and a negative-going component at 220–300 ms (anterior N2) were observed. A long-latency positive component at 300–700 ms was evident over the frontal, central, and parietal areas.

The analyses of variance of the mean ERP amplitudes did not show any significant effects before 300 ms. To examine the ERP effects of face familiarity, we compared ERPs elicited by familiar and unfamiliar faces. A main effect of attention at 300–700 ms at FCz, Cz, CPz, Pz, FC3–FC4, C3–C4, CP3–CP4, and P3–P4 [ $F(1,14)=5.96$ – $37.26$ , all  $P<0.05$ ] was observed; familiar and unfamiliar other faces elicited a long-latency positivity with larger amplitudes in the attended than in the unattended conditions. Neither the main effect of face owner (familiar vs. unfamiliar faces) nor the interaction between attention and face owner was significant ( $P>0.05$ ).



**Fig. 1** (a) Grand-average ERPs elicited by familiar and unfamiliar faces recorded at Cz and P8. (b) Grand-average ERPs elicited by self-faces and familiar other faces recorded at Cz and P8. ERP, event-related potentials; VPP, vertex positive potential; LPC, long-latency positive component.



**Fig. 2** Voltage topographies of the difference wave obtained by subtracting event-related potentials to self-faces from those to familiar other faces. (a) Self-faces minus familiar faces in the attended condition. (b) Self-faces minus familiar faces in the unattended condition; the difference waves in both attended and unattended conditions showed a frontocentral scalp distribution.

To examine the self-specific ERP effects, ERPs to self-faces were compared with those to familiar faces. A significant main effect of face owner at 220–700 ms at FCz, Cz, CPz, Pz, FC3–FC4, C3–C4, CP3–CP4, and P3–P4 [ $F(1,14)=6.65-54.49$ , all  $P < 0.05$ ] was found, indicating that the long-latency

positivity was of larger amplitudes to self-faces than to familiar faces. A reliable main effect of attention at 220–700 ms at FCz, Cz, CPz, Pz, FC3–FC4, C3–C4, CP3–CP4, and P3–P4 [ $F(1,14)=5.46-31.14$ , all  $P < 0.05$ ] was observed, suggesting that the long-latency positivity was of larger amplitudes in the attended than in the unattended conditions. A reliable interaction was also noted between face owner and attention at 500–700 ms at Cz, CPz, Pz, and CP3–CP4 [ $F(2,28)=4.27-7.62$ , all  $P < 0.05$ ]; the self-face ERP effect during this time window was reduced in the attended relative to the unattended condition. This interaction stemmed from the fact that the mean amplitude to familiar faces was increased in the attended relative to the unattended conditions at Cz, CPz, Pz, and CP3–CP4 [ $F(1,14)=9.75-20.55$ , all  $P < 0.005$ ], whereas attention did not influence the amplitude to self-faces ( $P > 0.05$ ). The voltage topographies of the difference waves obtained by subtracting ERPs to familiar faces from those to self-faces showed that the enhanced positivity in association with self-face recognition had a focus over the frontocentral scalp sites in both attended and unattended conditions (Fig. 2).

**Discussion**

Consistent with previous observations [1,2], our behavioral data showed that responses were faster to self-faces than to unfamiliar or familiar other faces, suggesting either more salient or earlier representation of self-faces [2]. Our ERP results showed, first, that both self-faces and other faces

elicited a posterior N170 and an anterior VPP. In addition, we found that the amplitudes of the N170 and VPP did not differ between familiar and unfamiliar faces. The results are consistent with previous research [16–18] and indicate that the N170 and VPP mainly reflect the process of structural encoding of face stimuli [19]. We showed further that the N170 and the VPP did not differ between self-faces and other faces, suggesting that self-faces could not be distinguished from other faces at the early stage of face structural encoding.

We found, however, that a long-latency positivity over the frontocentral area was involved in dissociating self-faces from other faces. The long-latency positivity over the frontocentral area at 220–700 ms was of larger amplitude to self-faces than to familiar faces. In addition, these effects were evident when self-faces and other faces were both task relevant and irrelevant. In contrast, the long-latency positivity did not differ between familiar and unfamiliar faces. By controlling well factors such as target probability and face familiarity, our results indicate that the increased long-latency positivity over the frontocentral area reflects enhanced neural activity associated with self-face recognition. In addition, our ERP results indicate that self-faces could be distinguished from other faces as early as 220 ms after sensory stimulation. The self-face ERP effect was obtained in the task of identifying head orientation rather than face owners, which implies that the ERP index of self-face recognition may occur even when participants are not required to perform an explicit face-recognition task.

Prior fMRI studies have shown that the anterior brain structures such as the frontal gyrus and anterior cingulate are engaged in self-face recognition [6,11,12,15]. In agreement with the previous results, the self-face ERP effect observed in the current study was evident mainly over the frontocentral areas. The increased long-latency positivity may reflect the enhanced self-face recognition compared with other-face recognition regardless of whether the other faces were familiar or unfamiliar. Alternatively, as studies of social psychology suggest that perception of individuals may induce the spontaneous activation of traits and attitudes associated with the perceived individuals [20,21], the self-face ERP effect may reflect automatically generated representation of one's personal traits or other episodic information that arose from the perception of self-faces. Consistent with this analysis, prior fMRI studies have shown evidence that the medial prefrontal cortex shows increased activity associated with judgment of self-descriptive traits relative to other-descriptive traits [22,23]. Whatever the case, our ERP results indicate that self-awareness induced by self-faces can occur as early as 220 ms after stimulus onset over the frontocentral area.

More interestingly, we found that the increased positivity at 220–500 ms linked to self-faces relative to familiar faces did not differ when the face stimuli were task relevant and irrelevant. The interaction between face owner and attention at 500–700 ms reflected that the ERP amplitudes to familiar and unfamiliar faces (but not to self-faces) were increased in the attended more than unattended conditions. Taken together, these ERP results suggest that, relative to familiar-face recognition, self-face recognition was less influenced by task relevance. Our ERP findings support the proposal that self-face recognition demands less attentional resources relative to other-face recognition [2]. The differential attentional effects on self-face and other-face recognition further indicate that self-face recognition is

underpinned by unique mechanisms compared with other-face recognition.

Previous ERP studies show evidence that familiar faces can be distinguished from unfamiliar faces as early as 250 [24] or 300 ms [16] after stimulus onset. The current experiment, however, did not find any difference in ERPs between familiar and unfamiliar faces. As previous work used only familiar and unfamiliar faces [16,24] or only self-faces and unfamiliar faces [14], the ERP results of these works mainly reflected the neural activity associated with the process of face familiarity. In the current experiment, self-faces were intermixed with familiar and unfamiliar faces and could not be distinguished from other faces by face familiarity. As a result, mainly the mechanisms of self-face recognition were activated to distinguish self-faces from other faces. It follows that familiar-face recognition was inhibited and thus the familiar and unfamiliar other faces were difficult to distinguish from each other. It appears that the involvement of self-faces with other faces may greatly influence the discrimination of familiar and unfamiliar faces.

### Conclusion

We found that self-face recognition was indexed by a long-latency positivity at 220–700 ms and the ERP correlates of self-face recognition were not influenced by the task relevance of self-faces. The results provided evidence for an automatic process of self-face recognition in human brains that occurs after face structure encoding.

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