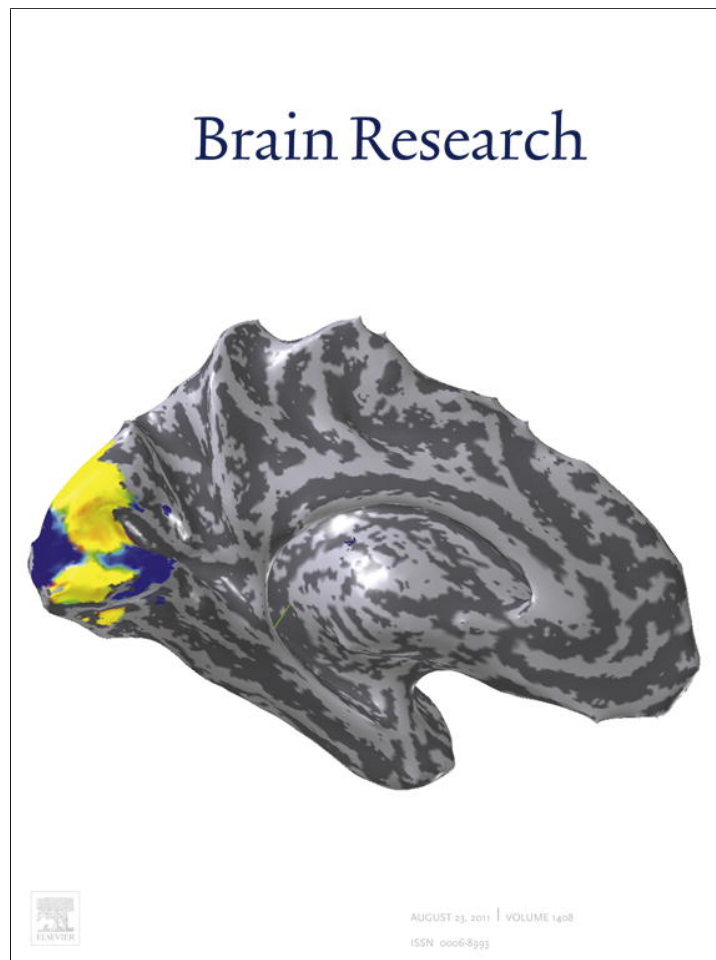


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RESEARCH

## Research Report

# Sex difference in the processing of task-relevant and task-irrelevant social information: An event-related potential study of familiar face recognition

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## ABSTRACT

Behavioral studies suggest that men are more likely to develop independent self-construals whereas women are more likely to develop interdependent self-construals. The gender difference in self-construals leads to two predictions. First, independent self-construals may result in a bias of attentional processing of self-related information that is stronger in men than in women. Second, interdependent self-construals may induce greater sensitivity to contextual information from the environment in women than in men. The present study tested these hypotheses by recording event-related potentials (ERPs) to familiar faces (self-, mother-, and father-faces) and unfamiliar faces (gender/age matched strangers' faces) from 14 male and 14 female adults. Using an odd ball paradigm, in separate blocks of trials, familiar faces were designated as either targets that required behavioral responses or as non-targets that did not require a behavioral response. We found that a long latency positivity at 420–620 ms over the parietal area (the attention sensitive target P3) showed a larger amplitude to self-face than to mother-/father-faces that were designated as targets in men but not in women. In contrast, a long latency positivity at 430–530 ms over the central area (the context sensitive novelty P3) was enlarged to familiar compared to strangers' faces that were designated as non-targets and this effect was greater in women than in men. Our results showed ERP evidence for sex differences in the processing of task-relevant and task-irrelevant social information.

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## 1. Introduction

Mental representations of the self and others are critical for guiding appropriate behaviors during social interactions. However, how people think about themselves and others is

strongly influenced by sociocultural contexts and life experiences. For example, most individuals in a Western cultural context view the self as an autonomous entity separate from others and attribute their behaviors to his/her own personal traits (the independent self) whereas most people in an East Asian

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cultural context conceptualize the self by emphasizing their interconnectedness with others and social contexts (the interdependent self) (Markus and Kitayama, 1991).

Interestingly, social psychological research has shown that, besides the difference in self-construals between Western and East Asian cultures, discrepant social roles and living contexts/experiences also give rise to different self-construals between men and women. For example, women are more likely to describe themselves in terms of connectedness to others, whereas men are more likely to describe themselves in terms of separateness from others (Lyons, 1983; see also Mackie, 1983; Pratt et al., 1990; Stern, 1990). Women are more likely than men to include relationships in their descriptions of their ideal self and their undesired self (Boggiano and Barrett, 1991; Bybee et al., 1990; Ogilvie and Clark, 1992). These observations suggest that women are more likely to develop an interdependent self-construal whereas men are more likely to develop an independent self-construal (Cross and Madson, 1997; Guimond et al., 2007).

Does the difference in self-construals between the two sexes influence the processing of social information in men and women? The present study investigated this issue by examining the neurocognitive processing of familiar faces (self-face and mother/father-faces) in men and women. The gender differences in self-construals lead to two predictions relevant to the cognitive processing of social information. First, as independent self-construals result in a bias of attentional processing of self-related information (Markus and Kitayama, 1991, 2003), men may be more sensitive than women to self-related information in targets that require attentional processing and behavioral responses. Second, as interdependent self-construals induce increased sensitivity to contextual information from the environment (Ji et al., 2000; Kitayama et al., 2003; Morris and Peng, 1994), women may be more sensitive than men to task-irrelevant information that provides a context for the processing of targets.

Recent brain imaging studies have shown that differences in self-construals may generate neural consequences. For example, neural activity in the medial prefrontal cortex was increased to trait judgments about close others (e.g., mother) in Chinese people with interdependent self-construals but not in English-speaking Westerners with independent self-construals (Zhu et al., 2007). The medial prefrontal activity associated with self-representation correlated with participants' cultural values (Chiao et al., 2009a, 2009b). A recent event-related potential (ERP) study showed that self-face processing induced a larger negative activity at 280–340 ms over the frontal-central area (N2) relative to that of a familiar face in British people with independent self-construals, whereas Chinese people with interdependent self-construals showed larger N2 amplitudes to the processing of familiar face compared to self-face (Sui et al., 2009). In addition, relative to interdependent self-construal priming, independent self-construal priming induced greater activity to self-face compared to a familiar face over the right frontal cortex (Sui and Han, 2007). These brain imaging findings suggest that differential neurocognitive processing of the self and others is influenced by self-construals. Given the gender difference in self-construals, one may expect that men and women may recruit distinct neurocognitive mechanisms during the processing of the self and others.

To test the hypothesis that men are more sensitive to self-related information in targets whereas women are more

sensitive to task-irrelevant contextual information, the current work adopted an oddball paradigm in which subjects were presented with infrequent target stimuli (i.e., oddball) that require attentional processing and behavioral responses, and standard/high-probability stimuli that do not require behavioral responses. Previous ERP studies have shown that target stimuli in the oddball paradigm elicit a positive component over the parietal area that peaks around 300–400 ms after sensory stimulation (i.e., target P3, Hillyard and Picton, 1987; Polich, 2007). The target P3 is supposed to reflect the function of the orienting attentional system for detecting rare, meaningful events (Herrmann and Knight, 2001). Another type of oddball paradigm consists of three classes of stimuli, i.e., infrequent target stimuli, standard (frequent non-target) stimuli, and infrequent non-target 'novel' stimuli (Debener et al., 2005; Friedman et al., 2001). Novel stimuli are usually more complex than both target and standard stimuli, and are unique in terms of low probability, unexpectedness, task irrelevance, and contextual salience. The novelty P3 reflects the brain's orienting responses to task-irrelevant unfamiliar stimuli. It has been shown that, relative to frequent non-target stimuli, novel infrequent non-target stimuli also elicited a positive wave between 250 and 400 ms with the maximum amplitude over the fronto-central area (i.e., novelty P3, Friedman et al., 2001; Polich, 2007). The amplitude of the novelty P3 is sensitive to perceptual discrepancy between events in the contextual environment (Friedman et al., 2001). A recent ERP study showed evidence for cultural influences on the target P3 and novelty P3 during an oddball task that required the detection of target numbers while ignoring non-target numbers and words (Lewis et al., 2008). The authors found that European Americans showed greater target P3 amplitudes whereas East Asian Americans displayed greater novelty P3 amplitudes, supporting the idea that American and East Asian cultures emphasize object-dependent attentional processing and field-dependent contextual processing, respectively.

We used a similar oddball paradigm to assess sex differences in sensitivity to self-related information in targets or in contexts. To generate stimuli with information relevant to the self and close others, subjects were asked to provide pictures of their own face and their mother's and father's faces. To assess the attentional processing of self-, mother-, and father-faces, in three blocks of trials, these stimuli (8% of self-, mother-, or father-faces in each block of trials and thus 24% familiar faces in total) were designated as infrequent targets and presented in a random order with frequent age/gender matched strangers' faces (76%). Subjects were asked to make a button press only when they identified self-, mother-, or father-faces. The target P3 to self-, mother-, and father-faces was recorded from male and female adults, respectively. We predicted that participants would show greater target P3 amplitudes to self- than to mother-/father-faces and this effect would be larger in men than in women because men with independent self-construals are more sensitive to self-related information at the focus of attention.

We also employed a modified novelty oddball paradigm to measure the novelty P3. In six blocks of trials, familiar faces (4% of self-, mother-, or father-faces in each block of trials and thus 12% familiar faces in total) were presented with frequent age/gender matched strangers' faces (76%) and infrequent

scrambled faces (12%). Subjects were asked to respond only to scrambled faces while ignore familiar and unfamiliar faces. In our study, the ‘novel’ stimuli (i.e., self/mother/father-faces) were presented with low probability and were task irrelevant but, in contrast to the previous novelty oddball paradigm, were familiar and expected. Thus the novel stimuli in our work were similar to the previously defined ‘novel stimuli’ in terms of task relevance and probability but were different in terms of familiarity and expectedness. However, the P3 elicited by novel stimuli in our work would also be associated with the processing of task-irrelevant contextual information and thus was similarly named as ‘novelty P3’. We predicted that the novelty P3 to infrequent non-target familiar faces would be greater in women than in men as women with interdependent self-construals are more sensitive to context information.

## 2. Result

### 2.1. Questionnaire measurements

As can be seen in Table 1, men showed higher scores than women on each subscale of the self-construal scale and the individualism/collectivism attitude scale. However, two sample t-tests only confirmed that men scored significantly higher than women on the individualism subscale ( $t(27)=13.712, p<0.001$ ) and on the independent self-construal subscale ( $t(27)=8.289, p<0.001$ ).

### 2.2. Behavioral performances

Table 2 shows the mean RTs and response accuracies to target faces. ANOVAs of mean RTs with Face (self-, mother-, and father-faces) as a within-subjects variable and Sex (male and female subjects) as a between-subjects variable showed a significant main effect of Face ( $F(2,25)=28.179, p<0.001, \eta^2=0.693$ ) and a significant Face $\times$ Sex interaction ( $F(2,25)=6.271, p=0.006, \eta^2=0.334$ ). One-way ANOVAs showed a significant main effect of Face in men ( $F(2,12)=42.283, p<0.001, \eta^2=0.876$ ) but not in women ( $F(2,12)=3.102, p=0.220, \eta^2=0.341$ ). Post-hoc t-tests confirmed that men responded significantly slower to self-face compared to mother-face ( $p=0.002$ ) and father-face ( $p<0.001$ ), whereas RTs did not differ between mother-face and father-face ( $p=0.200$ ). The effect of Sex was not significant ( $F(1,26)=0.025, p=0.875, \eta^2=0.001$ ). ANOVAs of mean accuracies did not show any significant effect ( $ps>0.05$ ).

Participants responded to scrambled faces with high accuracy. Neither response accuracy (Females:  $96.7\pm 2.19\%$ ; Males:  $96.2\pm$

**Table 2 – Mean RTs (ms) and response accuracy (%) (SD) to target familiar faces.**

	Self	Mother	Father
RT (ms)			
Female	424 (31.7)	418 (26.2)	414 (27.2)
Male	432 (26.0)	414 (26.0)	405 (19.6)
Accuracy (%)			
Female	92.5 (6.13)	93.8 (5.60)	94.4 (5.02)
Male	92.3 (4.83)	94.8 (5.06)	93.9 (3.51)

2.97%) nor RTs (Females:  $371\pm 20.6$  ms; Males:  $379\pm 38.6$  ms) differed significantly between men and women ( $t(26)=0.688$  and  $0.537, ps>0.4$ ).

### 2.3. ERP data

Grand-averaged ERPs to target and non-target stimuli in both men and women are illustrated in Figs. 1 and 3, respectively. Face stimuli induced an early negative wave between 80 and 140 ms over the frontal/central electrode (N1), which was followed by a positivity at 160–200 ms (vertex positive potential, VPP). Target and non-target faces also elicited a positive wave between 350 and 650 ms with the maximum amplitude over the central/parietal region (target P3) and between 400 and 600 ms with the maximum amplitude over the central region (novelty P3). Face stimuli also evoked a positive wave between 80 and 140 ms over bilateral occipital electrodes (P1), which was followed by a negative component at 150–190 ms (N170) over bilateral occipital/temporal electrodes. There were no significant effects shown in either 3 (self-, mother-, father-faces) $\times$ 2-way (female vs. male subjects) ANOVAs of the P1/N170 amplitudes to target faces or in 2 (Face: familiar vs. unfamiliar) $\times$ 2-way (Sex: male vs. female subjects) ANOVAs of the P1/N170 amplitudes to non-target faces. Thus the ERP data analysis below focused on target and non-target P3 components. Epochs and sites were chosen based on both previous literature (Friedman et al., 2001; Polich, 2007) and visual inspection of the grand ERPs/voltage topographies in the current study.

#### 2.3.1. Target P3

Fig. 1 illustrates the grand-average ERPs to target faces (self-face, mother-face, and father-faces) and non-target faces (strangers’ faces) and the mean amplitudes of the target P3 to self-face, mother-face, and father-face. ANOVAs of the target P3 amplitudes showed a significant main effect of Face at 420–620 ms at frontal, central, and parietal electrodes (Fz,  $F(2,25)=12.172, p<0.001, \eta^2=0.493$ ; F3–F4,  $F(2,25)=8.437, p=0.002, \eta^2=0.403$ ; Cz,  $F(2,25)=11.926, p<0.001, \eta^2=0.488$ ; C3–C4,  $F(2,25)=12.731, p<0.001, \eta^2=0.505$ ; Pz,  $F(2,25)=10.532, p<0.001, \eta^2=0.457$ ; P3–P4,  $F(2,25)=10.026, p=0.001, \eta^2=0.445$ ). The main effect of sex was not significant ( $ps>0.2$ ). However, there was a significant Face $\times$ Sex interaction (Fz,  $F(2,25)=4.165, p=0.027, \eta^2=0.250$ ; Cz,  $F(2,25)=4.425, p=0.023, \eta^2=0.261$ ; C3–C4,  $F(2,25)=4.890, p=0.016, \eta^2=0.281$ ; Pz,  $F(2,25)=6.025, p=0.007, \eta^2=0.325$ ; P3–P4,  $F(2,25)=5.324, p=0.012, \eta^2=0.299$ ).

To further examine the sex difference in target P3 amplitudes to familiar faces, we conducted one-way ANOVAs of the P3 amplitudes in men and women, respectively. A significant main

**Table 1 – Mean scores (SD) on the individualism/collectivism attitude scale and the self-construal scale (SCS).**

	HVIC-IND	HVIC-COL	SCS-IN	SCS-INTER
Female	4.73 (0.26)	2.67 (0.67)	4.30 (0.73)	2.80 (0.64)
Male	4.80 (0.63)	2.73 (0.52)	4.55 (0.77)	2.87 (0.58)

HVIC-IND = individualism attitude scale; HVIC-COL = collectivism attitude scale; SCS-IN = independent self-construal scale; SCS-INTER = interdependent self-construal scale.



effect of Face was found in men (Fz,  $F(2,12)=8.670$ ,  $p=0.005$ ,  $\eta^2=0.591$ ; F3–F4,  $F(2,12)=5.757$ ,  $p=0.018$ ,  $\eta^2=0.490$ ; Cz,  $F(2,12)=10.185$ ,  $p=0.003$ ,  $\eta^2=0.629$ ; C3–C4,  $F(2,12)=13.024$ ,  $p=0.001$ ,  $\eta^2=0.685$ ; Pz,  $F(2,12)=13.342$ ,  $p=0.001$ ,  $\eta^2=0.690$ ; P3–P4,  $F(2,12)=18.235$ ,  $p<0.001$ ,  $\eta^2=0.752$ ) but not in women ( $ps>0.05$ ). Post-hoc *t*-tests showed that the target P3 was of larger amplitude to self-face than to mother-face ( $ps<0.001$ ) or to father-face ( $ps<0.005$ ) in men. However, the mean amplitudes of the target P3 did not differ between mother-face and father-face ( $ps>0.1$ ). ANOVAs of the target P3 latency showed a significant main effect of Face (Pz,  $F(2,25)=4.463$ ,  $p=0.022$ ,  $\eta^2=0.263$ ) in men, as the self-face P3 peaked later compared to mother-face or father-face P3. Neither the main effect of Hemisphere nor its interaction with Face and Sex was significant ( $ps>0.05$ ). Similar analyses of ERPs elicited by strangers' faces did not show any significant effects ( $ps>0.05$ ).

### 2.3.2. Novelty P3

The analyses of the novelty P3 first examined if, relative to men, women were more sensitive to the difference between familiar and unfamiliar faces when both were presented as contextual events (i.e., non-target stimuli). As can be seen in Fig. 2, ERPs elicited by non-target familiar faces (averaged from self-, mother-, and father-faces) resulted in a positive deflection at 400–600 ms whereas strangers' faces did not. 2 (Face: familiar vs. unfamiliar)  $\times$  2-way (Sex: male vs. female subjects) ANOVAs showed a significant main effect of Face at 430–530 ms at frontal, central, and parietal electrodes (Fz,  $F(1,26)=35.672$ ,  $p<0.001$ ,  $\eta^2=0.578$ ; F3–F4,  $F(1,26)=38.131$ ,  $p<0.001$ ,  $\eta^2=0.595$ ; Cz,  $F(1,26)=49.399$ ,  $p<0.001$ ,  $\eta^2=0.655$ ; C3–C4,  $F(1,26)=18.463$ ,  $p<0.001$ ,  $\eta^2=0.415$ ; Pz,  $F(1,26)=47.649$ ,  $p<0.001$ ,  $\eta^2=0.647$ ; P3–P4,  $F(1,26)=35.156$ ,  $p<0.001$ ,  $\eta^2=0.575$ ), suggesting that the novelty P3 was enlarged to familiar faces compared to strangers' faces. There was a significant Face  $\times$  Sex interaction (Fz,  $F(1,26)=7.056$ ,  $p=0.013$ ,  $\eta^2=0.213$ ; F3–F4,  $F(1,26)=12.853$ ,  $p=0.001$ ,  $\eta^2=0.331$ ; Cz,  $F(1,26)=4.898$ ,  $p=0.036$ ,  $\eta^2=0.159$ ; P3–P4,  $F(1,26)=5.507$ ,  $p=0.027$ ,  $\eta^2=0.175$ ), reflecting the fact that the novelty P3 differentiated between familiar and unfamiliar faces to a greater degree in women than in men.

Next we assessed if the novelty P3 was more sensitive to the difference between self-face and mother-/father-face in women than in men when these faces were non-targets. Fig. 3 illustrates ERPs to self-, mother-, and father-faces, respectively. 3 (self-, mother-, father-faces)  $\times$  2-way (female vs. male subjects) ANOVAs of the novelty P3 amplitudes at 430–530 ms showed a significant main effect of Face at frontal, central, and parietal electrodes (Fz,  $F(2,25)=5.970$ ,  $p=0.008$ ,  $\eta^2=0.323$ ; F3–F4,  $F(2,25)=4.631$ ,  $p=0.019$ ,  $\eta^2=0.270$ ; Cz,  $F(2,25)=5.928$ ,  $p=0.008$ ,  $\eta^2=0.322$ ; C3–C4,  $F(2,25)=4.441$ ,  $p=0.022$ ,  $\eta^2=0.262$ ; Pz,  $F(2,25)=7.983$ ,  $p=0.002$ ,  $\eta^2=0.390$ ; P3–P4,  $F(2,25)=5.245$ ,  $p=0.013$ ,  $\eta^2=0.296$ ), this effect resulted from a larger novelty P3 to self-face than to mother-/father-faces. However, the Face  $\times$  Sex interaction was not significant ( $ps>0.1$ ),

suggesting that the effect of Face did not differ significantly between women and men.

The ANOVAs of the novelty P3 amplitudes showed a main effect of Hemisphere at frontal electrodes (F3–F4,  $F(1,26)=6.275$ ,  $p=0.019$ ,  $\eta^2=0.194$ ). There was also a significant Hemisphere  $\times$  Sex interaction ( $F(1,26)=6.196$ ,  $p=0.020$ ,  $\eta^2=0.192$ ), suggesting that the pattern of larger novelty P3 amplitudes over the left compared to the right hemisphere was more salient in men than in women. However, the interaction of Sex  $\times$  Face  $\times$  Hemisphere was not significant ( $ps>0.05$ ), suggesting a similar pattern of sex differences in hemispheric asymmetry for the novelty P3 amplitudes elicited by self-, mother-, and father-faces. Similar analyses of the novelty P3 latencies did not show any significant effects ( $ps>0.05$ ). We also conducted independent sample *t*-tests to examine potential sex differences in the P3 amplitudes to target scrambled faces. However, there was no significant sex difference in P3 amplitudes to scrambled faces at any electrode ( $ps>0.05$ ).

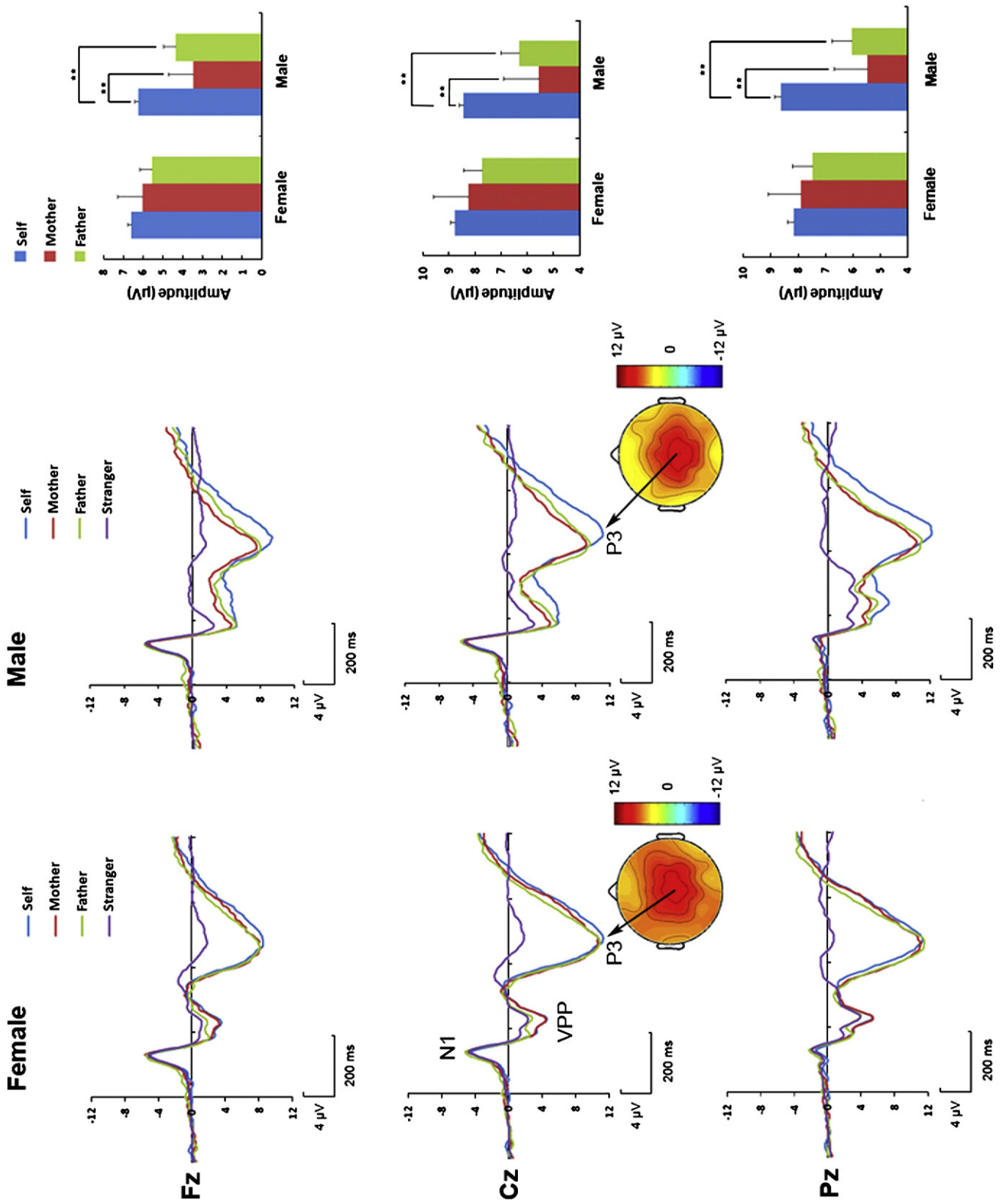
### 2.3.3. Different attentional effects between women and men

As can be seen in Figs. 1 and 3, attention to target faces increased the target P3 amplitudes to self-face to a greater degree than to mother-/father-face in men. However, attention to target faces increased the target P3 amplitudes to mother-/father-face to a greater degree relative to self-face in women. To confirm this differential effect of attentional modulation of the P3 amplitudes, we conducted a 2 (Attention: target vs. novelty P3)  $\times$  3 (Face: self-, mother-, father-face)  $\times$  2-way (Sex: female vs. male subjects) ANOVA of the difference waves obtained by subtracting ERPs to unfamiliar faces from ERPs to self-, mother- and father-faces. There were significant main effects of Attention (Fz,  $F(1,26)=27.198$ ,  $p<0.001$ ,  $\eta^2=0.511$ ; Cz,  $F(1,26)=55.160$ ,  $p<0.001$ ,  $\eta^2=0.680$ ; Pz,  $F(1,26)=115.979$ ,  $p<0.001$ ,  $\eta^2=0.817$ ) and Face (Fz,  $F(2,25)=13.789$ ,  $p<0.001$ ; Cz,  $F(2,25)=13.571$ ,  $p<0.001$ ; Pz,  $F(2,25)=13.638$ ,  $p<0.001$ ). Moreover, there was a significant Attention  $\times$  Face  $\times$  Sex interaction (Fz,  $F(2,25)=4.695$ ,  $p=0.019$ ,  $\eta^2=0.273$ ; Cz,  $F(2,25)=4.820$ ,  $p=0.017$ ,  $\eta^2=0.278$ ; Pz,  $F(2,25)=7.379$ ,  $p=0.003$ ,  $\eta^2=0.371$ ), suggesting that attention to faces facilitated differentiation between self-face and mother-/father-face to a larger degree in men than in women.

## 3. Discussion

The current work investigated sex differences in the processing of self-face and faces of close others by recording ERPs to self-, mother-, and father-face which were designated as infrequent targets or infrequent non-targets in separate blocks of trials. The target P3 reflected the attentional processing of self-face and mother-/father-face, whereas the novelty P3 reflected the processing of task-irrelevant self-face and mother-/father-faces in the context of the detection of scrambled faces.

**Fig. 1** – Illustration of the target P3 at the electrodes along the midline of the scalp to familiar faces. The left column shows grand-average ERPs elicited by self-/mother-/father-faces (targets) and strangers' faces (non-targets) recorded from female subjects. The middle column shows grand-average ERPs elicited by self-/mother-/father-faces (targets) and strangers' faces (non-targets) recorded from male subjects. The right column shows the mean target P3 amplitudes at 420–620 ms elicited by self-/mother-/father-faces. Error bars indicate standard errors. \*\* =  $p<0.01$ .



The questionnaire measurements showed that, relative to women, men scored higher in the individualism and independent self-construal subscales. Thus the subjective reports are consistent with the idea that men are biased with independent self-construals to a larger degree than women (Cross and Madson, 1997; Guimond et al., 2007). As independent self-construals bias attentional processing of self-related information (Markus and Kitayama, 1991, 2003), one would predict that behavioral responses would differentiate between self-face and mother-/father-faces to a greater extent in men than in women. Indeed, we found slower responses to self-face than to mother-/father-face in men but not in women. In line with the behavioral response speeds, we found that the target P3 latency was longer to self-face than to familiar faces in men but not in women. Interestingly, previous behavioral studies found that, in visual discrimination tasks, subjects responded faster to self-face compared to familiar (friend) faces (Keenan et al., 1999; Ma and Han, 2009, 2010). The task used in the current study, i.e., detection of familiar faces including self- and mother-/father-face, was different from that used in the previous research, which required discrimination between self-face and a familiar face. It is likely that detection of self-face is followed by extensive attentional processing relative to that of familiar faces in the context of strangers' faces.

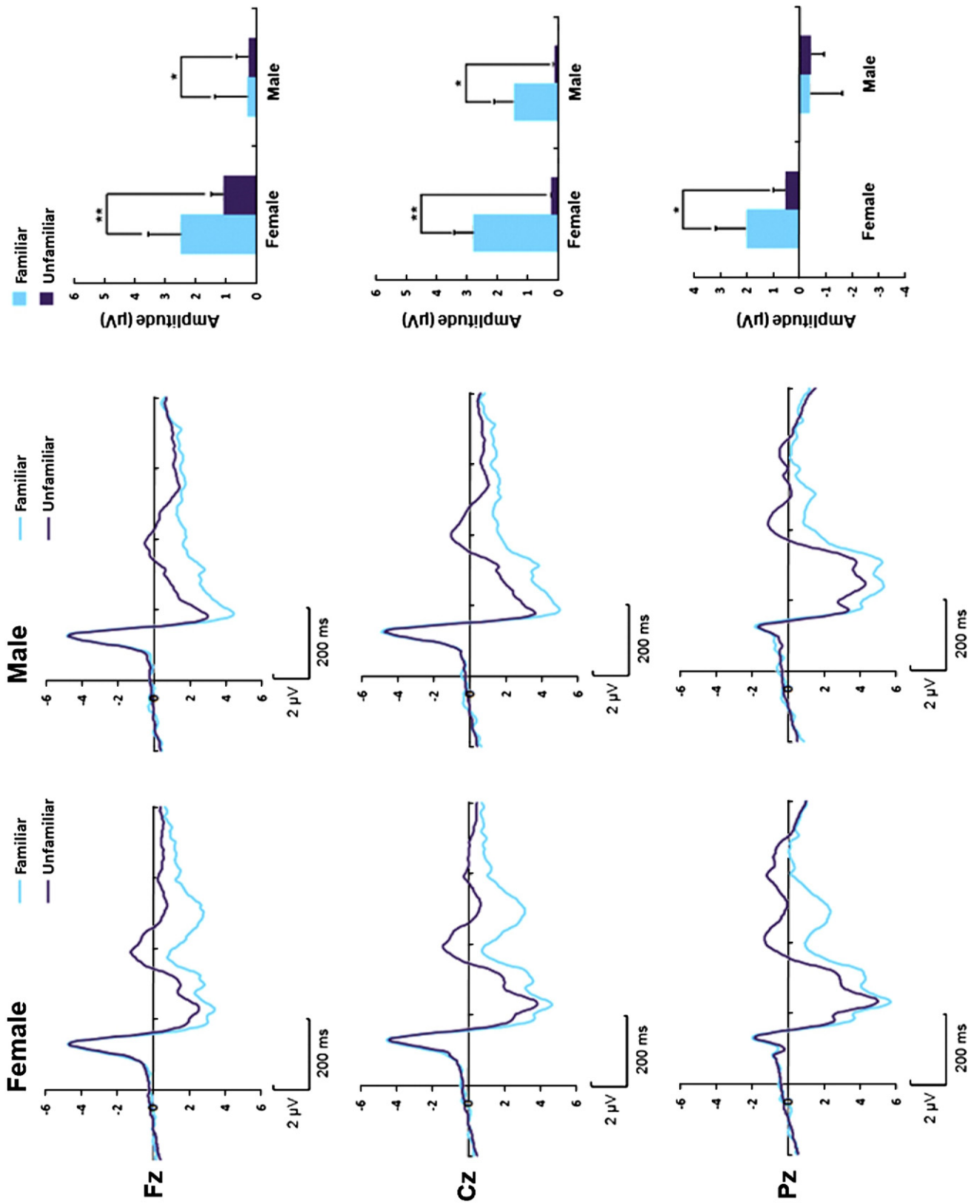
In accordance with our hypothesis that men are more sensitive to self-related information in targets that are required for attentional processing, we found that the target P3 with the maximum amplitudes over the parietal area was enlarged to self-face compared to familiar faces in men but not in women. In contrast, the target P3 did not differentiate between mother-face and father-face in either sex. These findings are consistent with the idea that social experiences and social roles promote independent self-construals in men (Cross and Madson, 1997; Guimond et al., 2007) and induce enhanced attentional processing of self-related information. Lewis et al.'s (2008) findings suggest that independent self-construals in European Americans facilitate attentional processing of targets, however these authors did not present any self-specific information relevant to the participants. Our results indicate that independent self-construals in men may also lead to enhanced attentional processing of self-related information compared to attentional processing of close others. Therefore, independent self-construals appear to influence attentional processing of both low-level perceptual features (Lewis et al., 2008) and high-level social information of target stimuli (the current work). Our previous fMRI study found that the medial prefrontal cortex is involved in neural representation of traits of both the self and mother in Chinese subjects (Zhu et al., 2007). In addition, the medial prefrontal activity did not differ between trait judgments of the self and mother in Chinese subjects (Zhu et al., 2007) or in Westernized bicultural Chinese after Chinese cultural priming (Ng et al., 2010). The brain imaging findings

suggest that the medial prefrontal activity is similarly engaged in conceptual representations of traits of the self and close others. However, the fMRI studies incorporated the results of male and female subjects and thus were unable to uncover the sex difference in attentional processing of personal traits, if any. The target P3 results observed in the current work indicate that enhanced attentional processing of self-face compared to faces of close others occurred to a greater degree in men than in women.

One may notice that the mean amplitudes of target P3 did not significantly differ between men and women. Given that independent self-construals in European Americans facilitate attentional processing of targets relative to East Asian Americans with interdependent self-construals (Lewis et al., 2008), one may expect larger target P3 in men than in women because men are biased with independent self-construals. This would be true if the difference in target P3 amplitude between the two sexes is determined only by self-construals and sex differences exist only in self-construals. However, sex differences have been observed in multiple levels of cognitive processes and their underlying neural substrates (Hamilton, 2008; Sun et al., 2010). A recent study that is more directly related to the current work found that, when responding to infrequently presented squares but ignoring frequently presented circles, women showed larger P3 relative to men, possibly due to efficient working memory, attentional and sequencing processes (Jaušovec and Jaušovec, 2009). Thus sex difference in target P3 amplitude associated with visual shapes is opposite to the pattern predicted by the sex difference in self-construals. Therefore, the sex difference in target P3 amplitudes observed in our work might reflect the sex differences in multiple levels of cognitive processes and self-construals.

The results of the novelty P3 elicited by infrequent non-target familiar faces concur with our second hypothesis that women dominated by interdependent self-construals are more sensitive to contextual information compared to men, who are dominated by independent self-construals. The novelty P3 was of larger amplitude to familiar faces than to unfamiliar faces in both men and women. However, this effect was stronger in women than in men. This result indicates that, relative to men, women were more sensitive to social information in the context of automatic differentiation between familiar and unfamiliar faces. Thus, similar to the previous finding that the difference in self-construals gives rise to a differential sensitivity to contextual information in East Asian and Western cultures (Ji et al., 2000; Kitayama et al., 2003; Morris and Peng, 1994), the current work showed electrophysiological evidence that the difference in self-construals between men and women also results in differential sensitivity to social information in the environment. Together, these findings highlight the important role of social and personal experiences in forming cognitive styles in humans.

**Fig. 2 – Illustration of the novelty P3 at the electrodes along the midline of the scalp to familiar faces. The left column shows ERPs to non-target familiar faces (obtained by grouping ERPs to self-/mother-/father-faces) and strangers' face recorded from female subjects. The middle column shows ERPs to non-target familiar faces (obtained by grouping ERPs to self-/mother-/father-faces) and strangers' face recorded from male subjects. The right column shows the mean novelty P3 amplitudes at 430–530 ms elicited by familiar and unfamiliar faces. Error bars indicate standard errors. \* =  $p < 0.05$ ; \*\* =  $p < 0.01$ .**





The comparison between target P3 and novelty P3 suggests that enhanced attention to target stimuli facilitated self-face processing to a greater degree in men than in women whereas enhanced attention to target stimuli facilitated the processing of faces of close others to a greater degree in women than in men. These results, when considering the gender difference in self-construals (Cross and Madson, 1997; Guimond et al., 2007), fit well with the suggestion that independent self-construals result in bias of attentional processing of self-related information whereas interdependent self-construals emphasize the fundamental connections between the self and others and result in enhanced attention to others (Markus and Kitayama, 1991, 2003). Previous brain imaging research has shown that attention strongly modulates neural activity involved in face processing. For example, face-specific fusiform activity is reduced when stimuli appear outside the focus of attention (Vuilleumier et al., 2001; Wojciulik et al., 1998). However, it is unknown how the effects of attention on face processing vary as a function of the social information in face stimuli. Our findings raise the possibility that the influence of attention on face processing may depend on both the social significance of stimuli and subjects' self-construals. In addition, as the left and right fusiforms may be respectively engaged in the processing of self-face physical properties and self-face identity (Ma and Han, *in press*), it would be interesting to investigate whether different aspects of self-face processing are facilitated by attention in a similar vein. Another issue related to our ERP results is where the effect of attention on self-face processing arises from in the brain. Previous fMRI studies show evidence that a neural circuit consisting of the fusiform gyrus, anterior and mid-cingulate, lateral and medial frontal gyri, and precuneus is recruited during self-face recognition (see Platek et al., 2008 for a review). Repetitive transcranial magnetic stimulation (TMS) studies found that 1 Hz repetitive TMS to the right inferior parietal lobule selectively disrupted performances during self-other face discrimination (Uddin et al., 2006) and TMS-induced evoked potentials in the right motor cortex were modulated by masked pictures of one's own face (Théoret et al., 2004). The P3 induced by self-face in the current experiment showed the maximum amplitude over the central/parietal regions. Future research may assess if the effect of attentional modulation of self-face recognition has a source in the motor cortex.

Sex differences in face processing have been observed at multiple levels of cognitive processes. For example, Hierlitz and Yonker (2002), Lewin et al. (2001) and Rehnman and Herlitz (2007) found that, after being exposed to a number of faces, women performed better than men when presented with the original faces and distractor faces and being asked to judge whether they had seen each face at the first stage of the study. Sun et al. (2010) recently showed that an early occipito-temporal ERP component, i.e., the N170 that is sensitive to the structural analysis of face components and their configuration

(Bentin et al., 1996; Eimer, 2000; Rossion et al., 1999), was modulated by task demand of gender identification to a larger degree in women than in men. Similarly, stronger task sensitivity was observed in the P3 component in women than in men. Thus it appears men and women may adopt different strategies at multiple levels of face processing. However, it remains unclear whether the sex difference at the early stage of face processing can be associated with the self-construal difference between the two sexes.

To examine whether self-construal or individual/collectivistic cultural values in each subject can predict the P3 effect observed in our study, we calculated the correlation between the P3 amplitudes to self-face and rating scores of questionnaire measurements. However, no significant results were observed. This is possibly due to the small sample size used in the current work. Alternatively, subjective reports of one's attitudes or behaviors may be affected by social desire to a stronger degree relative to measures of neural activity involved in the processing of self-related information. This can be clarified by increasing the sample size in future research.

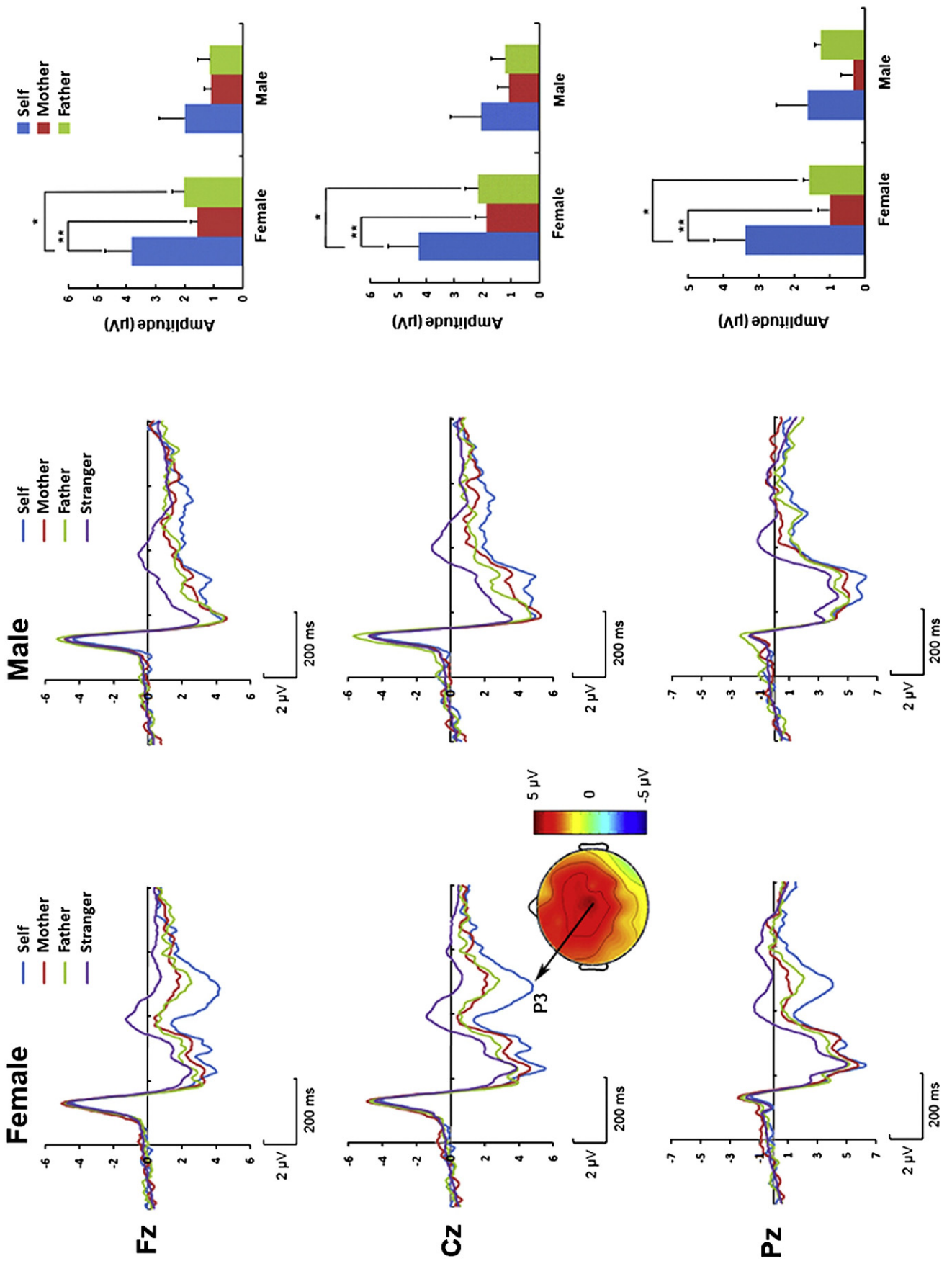
In conclusion, the current work provides evidence for sex differences in the processing of self-face and faces of close others. Greater attentional enhancement of the processing of self-face compared to mother-/father-face, as indexed by the target P3, was observed in men than in women. This lends support to the hypothesis that, relative to women, men are more sensitive to self-related information at the focus of attentional processing. The novelty P3 differentiated familiar from unfamiliar faces to a greater degree in women than in men. This is in agreement with the hypothesis that, relative to men, women are more sensitive to contextual social information. While previous studies have shown that long latency ERP components such as the P3 are involved in the categorization of faces in terms of gender and race (Ito and Urland, 2003), our ERP results suggest that the P3 component is also involved in categorization of faces in terms of familiarity and self-relevance. Our findings are consistent with the proposition that life experiences and social roles tend to induce independent self-construals in men but interdependent self-construals in women. Such sex differences in self-construals in turn result in specific cognitive styles in the processing of self and close others.

## 4. Experimental procedures

### 4.1. Subjects

Twenty-eight Chinese adults (14 males and 14 females, age between 18 and 27, mean = 22.46 ± 2.56 years) participated in this study as paid volunteers. All were right-handed and had normal or corrected-to-normal vision. All reported no history of psychiatric diagnoses. Informed consent was obtained prior

**Fig. 3 – Illustration of the novelty P3 at the electrodes along the midline of the scalp to familiar faces when the scrambled face was the target. The left column shows grand-average ERPs elicited by non-target self-/mother-/father-faces and strangers' face at Cz recorded from female subjects. The middle column shows grand-average ERPs elicited by non-target self-/mother-/father-faces and strangers' face at Cz recorded from male subjects. The right column shows the mean novelty P3 amplitudes at 430–530 ms elicited by non-target self-/mother-/father-faces. Error bars indicate standard errors. \* =  $p < 0.05$ ; \*\* =  $p < 0.01$ .**



to the experiment. This study was approved by a local ethics committee.

#### 4.2. Stimuli and procedure

Each participant was asked to provide photographs of a front view of his/her parents' faces and his/her own face with a neutral expression. Photographs of three age/gender matched faces were also taken from models that were unfamiliar to participants. All photographs were transferred to black and white with the same luminance level using Adobe Photoshop CS4. A profile shaped scrambled face was produced from the photographs. Each face stimulus was 5×7 cm (width×height) and subtended a visual angle of 2.9°×2.9° at a viewing distance of 100 cm.

Each trial consisted of a stimulus with a duration of 200 ms presented in the center of the screen. Each stimulus was followed by a fixation cross with an inter-stimulus interval that varied randomly between 200 and 1000 ms. Three blocks of 300 trials were conducted to obtain the Target P3. Each block consisted of 24 self-faces, 24 mother-faces, 24 father-faces, and 228 strangers faces that were age/gender matched with self-, mother-, and farther-face. Stimuli were presented in a random order. Subjects were instructed to respond only to the familiar faces (i.e., self-, mother-, or father-face) by a button press. Half participants responded with the left index finger and others with the right index finger. Response accuracy was emphasized. Each participant received a block of 35 trials for practice prior to the main experiment. Six blocks of 300 trials were conducted to measure the novelty P3. Each block consisted of 36 scrambled faces, 12 self-faces, 12 mother-faces, 12 father-faces, and 228 strangers faces that were age/gender matched with self-, mother-, and farther-face. Subjects were instructed to respond only to the scrambled face by a button press using the left or right index finger. The order of blocks of trials for target P3 and novelty P3 was counter-balanced across subjects.

The self-construal scale (Singelis, 1994) was used to assess independent/interdependent self-construals. The individualism/collectivism attitude scale (Triandis, 1995) was used to estimate the degree of endorsement of individualistic and collectivistic values. Both questionnaires used a 7-point Likert-type scale with 1 = strongly disagree and 7 = strongly agree.

#### 4.3. EEG data acquisition and analysis

The electroencephalogram (EEG) was continuously recorded from 62 scalp Ag/AgCl electrodes mounted on an elastic cap according to the extended 10–20 system with the addition of two mastoid electrodes. The EEG recording system has a gain of 500 and a resolution of 0.168  $\mu\text{V}/\text{LSB}$ . The mean of the right and left mastoid electrodes was used as reference during online EEG recording. The impedance of each electrode was kept below 5 k $\Omega$ . Eye blinks and vertical eye movements were monitored with electrodes located above and below the left eye. The horizontal electro-oculogram was recorded from electrodes placed 1.5 cm lateral to the left and right external canthi. The EEG was amplified (band pass 0.05–100 Hz) and digitized at a sampling rate of 250 Hz. A band-pass filter of 0.01–40 Hz was applied during offline EEG processing. The

ERPs in each condition were averaged separately off-line with an epoch beginning 200 ms before stimulus onset and continuing for 1200 ms. Trials contaminated by eye blinks, eye movements, or muscle potentials exceeding  $\pm 50 \mu\text{V}$  at any electrode were excluded from the average, leading to exclusion of about 6% trials from data analysis.

ERP data analysis focused on the target P3 and novelty P3 that were defined as the positive deflection peaking at 350–620 ms. The baseline for ERP measurements was the mean voltage of a 200 ms pre-stimulus interval. The mean amplitude was measured for analysis. Data from the midline electrodes (Fz, Cz, and Pz) were subjected to 3×2-way repeated-measures analysis of variance (ANOVAs) with Face (self, father, mother) as a within-subjects variables and Sex (male vs. female subjects) as the between-subjects variable. An additional within-subjects variable, i.e., Hemisphere (electrodes over the left vs. right hemisphere), was used when analyzing ERP data recorded from F3–F4, C3–C4, and P3–P4. To confirm the differential effects of attention on the P3 component in male and female subjects, 2 (Target vs. Novelty)×3 (self-, mother-, father-face)×2-way (male vs. female subjects) ANOVAs were also conducted. Reaction times (RTs) and accuracy to target faces were subjected to 3 (self-, mother-, father-face)×2 (male vs. female subjects) ANOVAs. Incorrect responses were excluded from the overall RT analysis. Mauchly's Test of Sphericity (all  $p>0.05$ ) was conducted before ANOVAs.

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