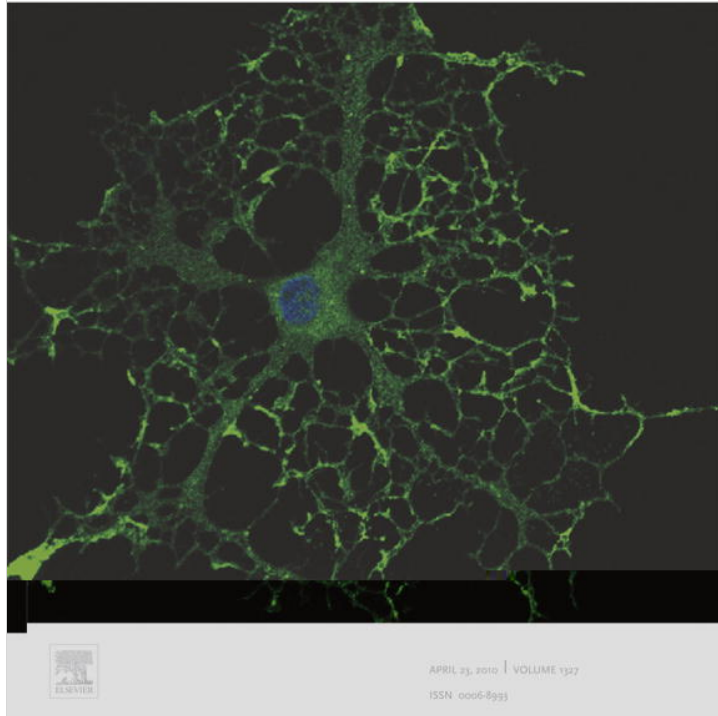


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Research Report

Sex differences in face gender recognition: An event-related potential study

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ABSTRACT

Multiple level neurocognitive processes are involved in face processing in humans. The present study examined whether the early face processing such as structural encoding is modulated by task demands that manipulate attention to perceptual or social features of faces and such an effect, if any, is different between men and women. Event-related brain potentials were recorded from male and female adults while they identified a low-level perceptual feature of faces (i.e., face orientation) and a high-level social feature of faces (i.e., gender). We found that task demands that required the processing of face orientations or face gender resulted in modulations of both the early occipital/temporal negativity (N170) and the late central/parietal positivity (P3). The N170 amplitude was smaller in the gender relative to the orientation identification task whereas the P3 amplitude was larger in the gender identification task relative to the orientation identification task. In addition, these effects were much stronger in women than in men. Our findings suggest that attention to social information in faces such as gender modulates both the early encoding of facial structures and late evaluative process of faces to a greater degree in women than in men.

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1. Introduction

Human faces provide important social information about others such as gender, age, identity, emotion and intention. The information obtained from others' faces is helpful for individuals to adopt appropriate behaviors during social interactions. Previous brain imaging studies have shown evidences that a distributed neural circuit in the human brain is involved in perception of different information in faces (Haxby et al., 2000; Palermo and Rhodes, 2007). For example, functional magnetic resonance imaging (fMRI) studies showed that the lateral fusiform gyrus and the superior temporal sulcus are respectively involved in the perception of unique identity, eye gaze, and facial expressions

(Hoffman and Haxby, 2000). Event-related brain potential (ERP) studies also identified a neural activity in a specific time window that is associated with face perception. A negative ERP component with the maximum amplitude at occipital/temporal electrodes peaking around 170 ms after stimulus delivery (i.e., N170) is enlarged to face stimuli relative to non-face objects or words and the N170 is sensitive to the structural analysis of face components and their configuration (Bentin et al., 1996; Eimer, 2000a; Rossion et al., 1999a). The amplitude of the N170 is increased for inverted compared to upright faces (Eimer, 2000b; Rossion et al., 1999b), reflecting disrupted processing of configural information of faces. Magnetoencephalography (MEG) research showed that an early neural activity peaking at 100 ms after stimulus onset

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(M100) is associated with only categorization of face vs. non-face whereas a late component at about 170 ms (M170) is correlated with both face categorization and face recognition (Liu et al. 2002).

Although the neural mechanisms underlying face recognition have been studied extensively, it remains unclear whether differential neural mechanisms are involved in face recognition in men and women. Prior behavior studies suggest that women outperform men on a face-recognition task. Lewin et al. (2001) and Herlitz and Yonker (2002) first showed men and women a number of faces. At the second stage of the study, participants were presented with original faces together with distractor faces and had to judge whether they had seen each face at the first stage of the study. Lewin et al. (2001) found that women performed better than men on the face recognition task. Lewin and Herlitz (2002) showed that women particularly performed at a higher level than men in the recognition of female faces irrespective of the faces being presented as full faces with hair and ears or as features of eyes, nose and mouth only. The sex differences in memory performances of faces imply that the perceptual processing of faces may be different between men and women. Cellerino et al. (2004) tested this hypothesis using a psychophysical method (i.e., masking by spatial filtration) that masked pictures of male and female faces and disturbed either shape or color information in the pictures. They found that spatial filtration affected recognition of female faces more than recognition of male faces. More interestingly, they showed that participants were more efficient in categorizing same-sex faces.

The present research investigated potential sex differences in the neural activities underlying face processing by recording ERPs from men and women. Specifically, we examined whether early face processing such as structural encoding (Bruce and Young, 1986) is modulated by task demands that manipulate attention to perceptual or social features of faces and such an effect would be different between men and women. We presented participants with male and female faces that oriented to the left or to the right as illustrated in Fig. 1 and asked them to judge either face orientations (a low-

level perceptual feature) or face gender (a high-level social feature). Although a passive viewing task was used in the previous research (Lewin et al., 2001; Lewin and Herlitz, 2002), the observation that women outperform men on face recognition suggest that neural mechanisms underlying encoding of facial configuration and categorization of faces may be different between the two sexes and thus cause better performances in memory retrieval in women.

Table 1 – Mean RTs and response accuracy (standard deviation) in each stimulus condition.

	Gender identification	Orientation identification
RTs (ms)		
Men		
Male faces	523 (83)	431 (75)
Female faces	527 (73)	428 (73)
Women		
Male faces	499 (36)	398 (49)
Female faces	505 (38)	407 (51)
Accuracy (%)		
Men		
Male faces	78.2 (14.3)	93.8 (8.2)
Female faces	85.7 (5.2)	93.2 (7.3)
Women		
Male faces	79.9 (10.8)	94.9 (3.6)
Female faces	81.3 (11.9)	95.5 (2.4)

Note: The mean RTs and response accuracy were significantly different between the gender and orientation identification tasks at $p < 0.001$.

2.2. E c c a d a

Grand-averaged ERPs to face stimuli in both gender and orientation identification tasks recorded from women and men are illustrated in Figs. 2 and 3. Face stimuli in both tasks 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. Face stimuli also induced an early negative wave between 80 and 140 ms over the frontal/central electrode (anterior N1), which was followed by a positivity at 160–200 ms (vertex positive potential, VPP), a negative wave between 280 and 380 ms (N310), and a positive wave between 330 and 730 ms (P3) with the maximum amplitude over the central/parietal region. In the following session, we first presented the ERP results separately for female and male participants to examine the effects of task demand and its interaction with face gender. We then reported the results of ANOVAs that confirmed apparent sex differences in modulations of specific ERP components by task demands.

2.2.1. ERPs recorded from women

The ANOVA of ERPs recorded from women showed a significant effect of Task as early as 140–200 ms at the occipital/temporal electrodes ($F(1,13) = 14.35, p < 0.005$), indicating that the N170 was of smaller amplitude in the gender relative to orientation identification tasks. Similarly, the VPP amplitude between 160 and 200 ms decreased in the gender identification task compared to the orientation identification task ($F(1,13) = 9.585, p < 0.05$). The ANOVA of the ERP amplitudes at 280–380 ms showed a significant main effect of task at frontal/central electrodes ($F(1,13) = 21.73, p < 0.005$) due to that the gender identification task induced a negative wave (N310) whereas the orientation identification task did not.

The P3 amplitude was larger in the gender identification task relative to the orientation identification task at 460–700 ms over the frontal/central/parietal electrodes ($F(1,13) =$

19.38, $p < 0.001$). Moreover, the rising phase of the P3 occurred earlier in the orientation identification task compared to the gender identification task, resulting in a longer P3 peak latency in the gender identification task than in the orientation identification task (460 vs. 372 ms, $F(1,13) = 26.74, p < 0.001$).

ANOVAs of the ERPs also showed a significant main effect of Face Gender at 80–120 ms ($F(1,13) = 9.187, p < 0.05$) over the frontal/central electrodes, suggesting that the anterior N1 was of larger amplitude to female than male faces.

2.2.2. ERPs recorded from men

The ERPs recorded from men did not differentiate between the gender and orientation identification tasks in the early time window at occipital/temporal electrodes. There was a significant main effect of Task at 300–380 ms over the central/parietal electrodes ($F(1,13) = 9.305, p < 0.05$) as the gender identification task elicited the N310 whereas the orientation identification task did not.

Similar to that observed in female subjects, the rising phase of the P3 occurred earlier and showed enlarge amplitudes in the orientation than gender identification tasks whereas the descending phase of the P3 was of larger amplitudes in the gender identification task, resulting in a significant main effect of task at 300–380 ms at the frontal/central electrodes ($F(1,13) = 9.897, p < 0.05$) and at 400–660 ms over the frontal/central/parietal electrodes ($F(1,13) = 19.11, p < 0.01$). The ANOVA of the P3 peak latency confirmed that the P3 peak delayed in the gender than orientation identification tasks (418 vs. 374 ms, $F(1,13) = 14.23, p = 0.002$).

The ascending phase of the anterior N1 at 140–160 ms at the frontal/central electrodes was of larger amplitude to the female face than to the male faces ($F(1,13) = 6.77, p < 0.05$).

2.2.3. Sex differences in modulations of ERPs by task demands

To further confirm the sex differences in the modulations of ERPs by task demands, we conducted ANOVAs with Face Gender and Task as within-subject independent variables and Sex as a between-subjects variable. We found a reliable interaction of Task \times Sex between 160 and 220 ms at occipital/temporal electrodes ($F(1,26) = 7.104, p < 0.05$). This confirmed that the N170 was of smaller amplitude to the gender relative to orientation identification tasks for women, whereas the N170 amplitudes did not differ between the two tasks for men (Table 2).

There was also a significant interaction of Task \times Sex at 500–740 ms over the central/frontal area ($F(1,26) = 8.471, p < 0.05$), indicating that the modulations of the P3 amplitudes in this time window by task demands were stronger for women than for men (Table 2).

3. Discussion

Previous studies investigated sex differences in face gender recognition by measuring behavior performances and found that women outperformed men on recognition of faces that had been studied in a prior stage (e.g., Lewin and Herlitz, 2002). While the behavioral measurement suggests a sex difference in face encoding at the study phase, the underlying neural mechanisms remain unknown. The current work extended the previous research by examining sex differences in the

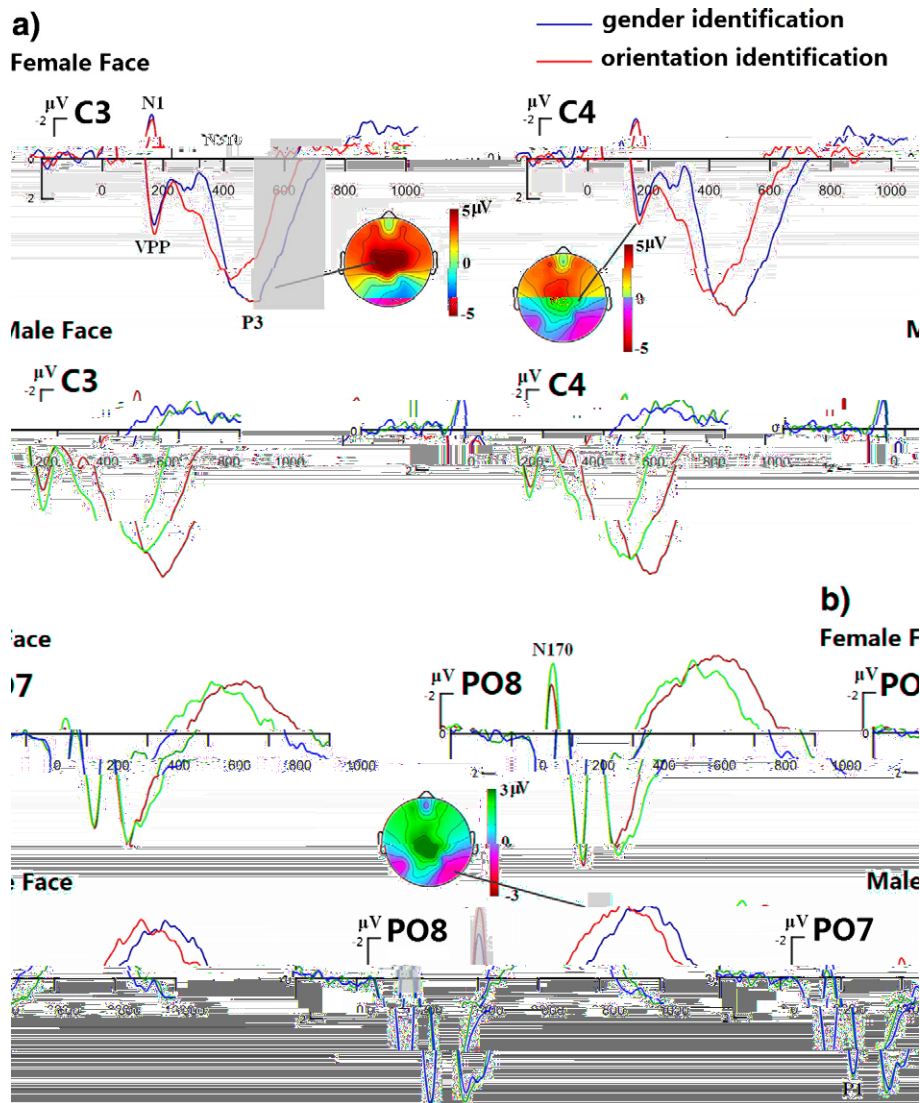


Fig. 2 – Illustration of ERPs to face stimuli during the gender identification and orientation identification tasks recorded from female subjects. (a) ERPs recorded at a central electrode to female and male faces. (b). ERPs recorded at an occipital electrode to female and male faces. The voltage topographies show the distribution of the maximum amplitude of each ERP component elicited by face stimuli in the gender identification task. The grey bars show the time window in which the mean amplitudes showed significant sex differences in modulations by the task demands.

neural processes of faces by recording ERPs from male and female adults. The ERP data with high-time resolution help to clarify whether neural activities associated with different stages of face processing, such as early structure encoding indexed by the N170 and late evaluation processes indexed by the P3, are modulated by the task demands that emphasize either perceptual or social features of faces.

Behavior performances recorded from both male and female subjects showed longer RTs and lower response accuracies during the gender identification task than during the orientation identification task. In parallel with the behavioral performances, we observed delay P3 peak latencies and larger P3 amplitudes at the descending phase in the gender identification task than in the orientation identification task. Both the behavioral performances and the P3 results suggest that enhanced evaluative processes are involved in the processing

of social features (e.g., gender) compared to perceptual features (e.g., face orientation) of faces in both sexes.

Previous studies have shown that the N170 is engaged in structural analyses of face components and their configurations (Bentin et al., 1996; Eimer, 2000a; Rossion et al., 1999a). The N170 amplitude increased to inverted compared to upright faces (Eimer, 2000b; Rossion et al., 1999b), suggesting disrupted processing of configural information. In addition, attention to centrally presented faces also increased the N170 amplitude relative to attention to peripherally presented faces (Eimer, 2000c), suggesting that the encoding of facial structural information associated with the N170 receives top-down modulations by high-level attention systems. The modulation of the N170 by task demands observed in our work cannot be simply explained by the variation of visual attention because the early visual activity such as the occipital P1 was not

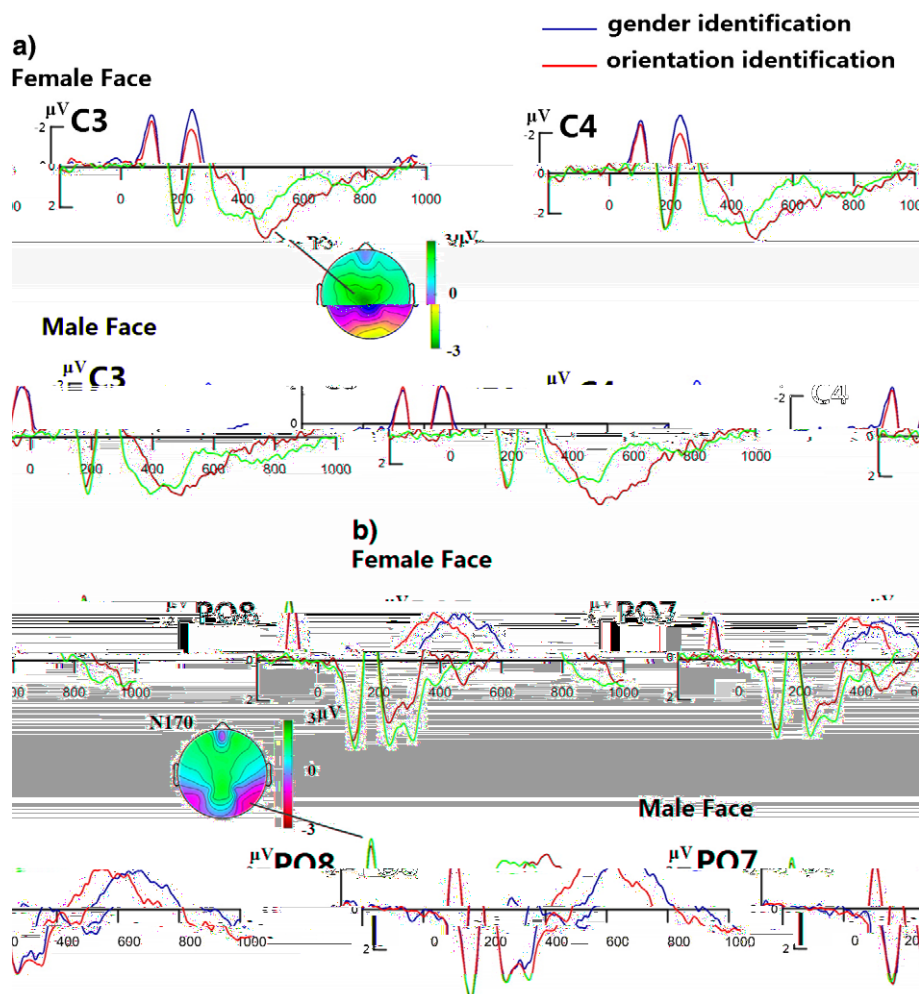


Fig. 3 – Illustration of ERPs to face stimuli during the gender identification and orientation identification tasks recorded from male subjects. (a) ERPs recorded at a central electrode to female and male faces. (b). ERPs recorded at an occipital electrode to female and male faces. The voltage topographies show the distribution of the maximum amplitude of each ERP component elicited by face stimuli in the gender identification task.

modulated by the gender and orientation identification tasks. Enhanced attention might be involved in the gender identification task than in the face orientation identification task as the latter task required processing of perceptual features whereas the former task required processing of complicated social features of faces. Thus according to Eimer's (2000c) finding, one would expect that the gender identification task increased the N170 amplitude relative to the orientation identification task. However, our results showed a reverse pattern. Our results supplement previous findings by showing that the face processing at the stage of facial structural encoding indexed by the N170 endured modulations by task demands that emphasized facial social features.

According to the influential model of face processing proposed by Bruce and Young (1986), the "structural encoding" module of facial features precedes the "directed visual encoding" module that engages in gender recognition, and these systems act independently of another system which is supposed to process emotional expression of face and person's identity. However, recent studies have shown evidence that facial structural encoding reflected by the N170 is not manda-

tory. For instance, Blau et al. (2007) found that faces with fear expression induced a larger N170 compared to neutral faces, suggesting emotional modulation of facial structural encoding. The modulation of the N170 by race was inconclusive as some studies reported larger N170 to White than Black faces (Ito and Urland, 2005) whereas other research reported larger N170 to Black than White faces (Walker et al., 2008), though ERPs were recorded from White subjects in both work. These findings indicate that the early face processing receives top-down modulation by other modules.

The difference in the N170 amplitude between the two tasks observed in our work cannot be accounted for by emotional expressions because the identical neutral faces were used in both tasks. It has been argued that the differences in the N170 amplitudes between upright and inverted faces represent two different types of processing with the emphasis of configural processing of upright faces and with the emphasis of featural processing of inverted faces (Rossion, 2002). The modulation of the N170 amplitudes in our study might reflect the modulation of two processes. It is possible that gender identification required enhanced

Table 2 – The mean amplitude of the N170 and P3 components (standard deviation) in each stimulus condition.

	Gender identification	Orientation identification
N170 (μV)		
Men		
Male faces	-.79(2.9)	-.87(3.0)
Female faces	.92(3.3)	-.52(3.2)
Women		
Male faces	0.94(4.7)	-.17(4.9) **
Female faces	0.59(4.8)	-.04(4.9) **
P3 (μV)		
Men		
Male faces	2.08(1.4)	.69(1.2)**
Female faces	1.74(1.4)	.85(1.1)**
Women		
Male faces	3.55(3.0)	1.04(1.4) **
Female faces	3.45(2.3)	1.48(2.2) **

Note: The N170 or P3 amplitudes were significantly different between the gender and orientation identification tasks at * $p < 0.05$ or ** $p < 0.01$.

processing of facial features and this was mediated by the increased N170 amplitudes. Alternatively, orientation identification required enhanced processing of facial configuration but not of facial features and thus induced decreased N170 amplitudes. These can be clarified in future research.

More interestingly, our ERP results showed evidence for sex differences in both the early and late stages of face processing. Specifically, we found that the modulation of the N170 by the task demands was more salient in women than in men. This suggests that, relative to men, women are more sensitive to the task that requires the processing of social information of faces. The sex difference in face processing at the stage of the N170 during attention to social information observed here may contribute to women's better performances in the recognition of female faces (Lewin et al., 2001; Lewin and Herlitz, 2002; Herlitz and Yonker, 2002) as females subjects may adopt a strategy that emphasizes social information of faces during the study phase.

Besides the modulation of the N170 by task demands, we also found evidence for sex difference in modulations of the P3 by the task demands. The gender identification task elicited larger P3 amplitudes relative to the orientation identification task. Similarly, the previous research observed larger P3 to target faces when the target face was different from non-target faces in gender (Ito and Urland, 2003). We show further here that the modulation of the P3 by gender identification was stronger in women than in man. As the P300 is sensitive to categorization decisions (Cacioppo et al., 1993; Ito and Cacioppo, 2000), our results suggest that both women and men recruited enhanced evaluative processes to categorize faces according social information (i.e., gender) compared to perceptual feature (i.e., face orientation). In addition, women seemed to conduct the evaluative process for categorization of male vs. female faces to a more extensive degree relative to males. It has well been documented that women and men's roles in social behaviors are different in that that men serve as

a liaison between the family and society whereas women serve to facilitate interpersonal harmony within the family unit (Wood and Eagly, 2002). Our ERP findings, i.e., the face processing at both the early and late stages is more sensitive to the task demands requiring attention to social features of faces in women than men, may provide neural basis for better social skills in women than in men.

Finally, our ERP results showed that the anterior N1 was enlarged by female than male faces in both sexes. The anterior N1 has been shown to be sensitive to race, being enlarged by Black than White faces in White participants (Ito and Urland, 2005). Together, these ERP results suggest that the anterior N1 is sensitive to categorization of faces in terms of social features and such processes do not differ between men and women.

In summary, the current study provides ERP evidence for sex differences in modulations of multiple level neuro-cognitive processes involved in face processing by task demands that required processing of low-level perceptual features and high-level social information. The early N170 was weakened by task demands requiring the processing of face gender in women but not in men. The late evaluative process reflected in the P3 was, however, enhanced by gender identification to a greater degree in women than in men. Our findings suggest that, relative to men, women may adopt a strategy of paying more attention to social information in faces such as gender.

4. Experimental procedures

4.1. S b e c

Twenty-eight healthy undergraduate and graduate students (18–26 years of age, 14 males, mean = 21.9, SD = 2.13; 14 female, mean = 23.4, SD = 1.55) from Peking University participated in the study as paid volunteers. All were right-handed and had normal or corrected-to-normal vision. Informed consent was obtained prior to the study. This study was approved by a local ethics committee.

4.2. S a d c e d e

Twenty black and white photos of faces with neutral facial expression were taken from 10 female models and 10 male models using a digital camera. Each face was oriented to the left between 45° and 60°. All face images were flipped horizontally to produce 20 right-oriented face stimuli. Each stimulus was 5 cm × 5 cm (width × height), subtending a visual angle of 2.9° × 2.9° at a viewing distance of 100 cm. Face stimuli were calibrated in luminance and contrast and were presented against a black background.

Each subject participated in four blocks of trials. Subjects were asked to identify gender of each face (the gender identification task) in two blocks of trials and to identify face orientation (the orientation identification task) in the other two blocks of trials. Each block consisted of 120 trials and began with the presentation of an instruction that defined the task. On each trial a stimulus display was presented for 200 ms in the center of the screen, which was followed by a fixation cross with a duration that varied randomly between 500 and 1500 ms. Male

and female faces with different orientations were presented in a random order in each block of trials. Subjects responded to each stimulus by a button press using the left or the right index finger. The order of the tasks and the assignment of responding hands to female or male faces were counterbalanced across subjects. In the orientation identification task, subjects responded to the left and right-oriented faces with the left and the right hands, respectively.

4.3. ERP data analysis

The electroencephalogram (EEG) was continuously recorded from 62 scalp electrodes that were mounted on an elastic cap in accordance to the extended 10–20 system, with the addition of two mastoid electrodes. The electrode at the right mastoid was used as reference. The electrode impedance was kept less than 5 k Ω . 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 0.01–100 Hz) and digitized at a sampling rate of 250 Hz. The ERPs in each condition were averaged separately off-line with an epoch beginning 200 ms before the stimulus onset and continuing for 1000 ms. Trials contaminated by eye blinks, eye movements, or muscle potentials exceeding ± 50 V at any electrode were excluded from the average.

ERPs at each electrode were re-referenced to the algebraically computed average of the left and right mastoids before further analysis. 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. Mean voltage of ERPs were obtained (a) at 20-ms intervals starting at 80 ms after stimulus onset and continuing until 380 ms post-stimulus and (b) at 40-ms intervals from 380 to 820 ms post-stimulus. Statistical analysis was conducted at electrodes selected from the frontal (Fz, FCz, F3–F4, FC3–FC4), central (Cz, CPz, C3–C4, CP3–CP4), parietal (Pz, P3–P4), temporal (T7–T8, TP7–TP8, P7–P8), and occipito-temporal (POz, Oz, PO3–PO4, PO7–PO8) regions.

Reaction times (RTs) and response accuracies were subjected to a repeated measure analysis of variance (ANOVA) with Face Gender (female vs. male face), Task (gender identification vs. orientation identification) as within-subjects independent variables, and Sex (female vs. male subjects) as a between-subjects variable. The mean ERP amplitudes recorded from each subject group (female and male subjects) were first subjected to ANOVAs with the factors being Face Gender, Task, Hemisphere (electrodes over the left or right hemisphere) as within-subject independent variables. To further confirm the sex differences in ERPs associated with face gender recognition, we conducted ANOVAs with Face Gender, Task as within-subjects independent variables and Sex as a between-subjects variable.

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