Biological Psychology 99 (2014) 69–76

Contents lists available at ScienceDirect

Biological Psychology

journal homepage: www.elsevier.com/locate/biopsycho

Maternal face processing in Mosuo preschool children

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ARTICLE INFO

Article history:
Received 21 April 2013
Accepted 2 March 2014
Available online 12 March 2014

Keywords:
Mother–child bond
Face processing
Familiarity
Event-related potentials
Electrical neuroimaging
Love

ABSTRACT

Instinctively responding to maternal face is an evolutionary function of enhancing survival and development. However, because of the confounding nature of familiarity, little is known concerning the neural mechanism involved in maternal face recognition. We had a rare opportunity to examine Mosuo preschool children who were raised in a matrilineal society in which mothers and aunts represent equally familiar faces to the children. The participants were exposed to photographs of their mother's face, aunt's face, and an unfamiliar female's faces during electroencephalography (EEG) recording. The EEG results showed that the mother's face elicited a more negative N1 component, a larger left N170 component, and a larger P300 component; both the mother's and aunt's faces elicited a larger right N170 component. These results suggest that the emotional attachment between mother and child has neural ramifications across three successive face processing stages that are distinguished from the neural effects of facial familiarity.

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1. Introduction

Maternal caretaking plays a quintessential role in the lives of social species and in the evolutionary function of enhancing survival, development and health; the maternal bond established at childbirth typically grows into a more conceptual, abstract and mental representation throughout a child's development (Broad, Curley and Keverne, 2006; Mousseau and Fox, 1998a, 1998b). A mother's face, which constitutes an important source of information for the child (see Bruce and Young, 1986; Vico, Guerra, Robles, Vila and Anllo-Vento, 2010 for review), elicits a preferential response in human newborns who are several hours old (Cecchini et al., 2011), even when olfactory information is strictly controlled (Bushnell et al., 1989).

A growing body of neuroimaging research on pair-bonding and maternal face processing has investigated love in general and maternal love in particular (Bartels and Zeki, 2004; Cacioppo, Bianchi Demicheli, Frum, Pfaus and Lewis, 2012; Guerra, Sánchez-Adam, Anllo-Vento, Ramírez and Vila, 2012; Leibenluft, Gobbini, Harrison and Haxby, 2004; Nitschke et al., 2004; Noriuchi, Kikuchi and Senoo, 2008; Ortigue, Bianchi Demicheli, Patel, Frum and Lewis, 2010; Quirin et al., 2012). To date, the majority of the neuroimaging studies recorded brain activity from mothers as they looked at their babies' faces, although two neuroimaging studies investigated the brain activity of adults as they looked at their mothers' faces. The two neuroimaging studies of adults support the view that a mother's face elicits a broader range of brain areas associated with face processing than the faces of strangers (e.g., bilateral fusiform gyri, inferior frontal gyri and thalamus; right superior temporal gyrus, right lingual gyrus, right angular gyrus, right inferior parietal lobule and right middle frontal gyrus as well as the left cuneus; Arsalidou, Barbeau, Bayless and Taylor, 2010; Guerra et al., 2012). The two regions involved in processing the mother's face are the inferior frontal and the middle temporal gyri, which suggests the existence of a significant overlap between the mother and self-related processing that complements the distributed brain network models for face processing (Gobbini and Haxby, 2007; Ishai, Schmidt and Boesiger, 2005). This work, therefore, has the potential for extending the standard models of face processing (Arsalidou,

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http://dx.doi.org/10.1016/j.biopsycho.2014.03.001
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Barbeau, Bayless and Taylor, 2010; Cacioppo, Bianchi Demicheli, Hatfield and Rapson, 2012).

The chronoarchitecture of processing familiar faces of loved ones has also been investigated (Başar, Schmiedt-Fehr, Öniz and Başar-Eroğlu, 2008; Bobes, Quinonez, Perez, Leon and Valdes-Sosa, 2007; Grasso, Moser, Dozier and Simons, 2009; Herzmann, Schweinberger, Sommer and Jentzsch, 2004; Langeslag, Jansma, Franken and Van Strien, 2007; Vico et al., 2010). Research on face perception has focused on two early electrophysiological potentials, the N1 and N170, and a later component, the P300 or LPP. Studies of the N1 component suggest that this component reflects early attentional allocation during face processing (Antal, Kéri, Kovács, Janka and Benedek, 2000; Hopf, Vogel, Woodman, Heinze and Luck, 2002; Vogel and Luck, 2000), whereas studies of the N170 component, which is predominantly distributed over the right occipito-temporal region, varies as a function of facial familiarity (Caharel et al., 2002 Caharel, Courtay, Bernard, Lalonde and Rebaī, 2005; Caharel, d'Arripe, Ramon, Jacques, & Rossion, 2009; Rossion & Jacques, 2008). This right lateralized N170 has been interpreted to reflect encoding of structural information from the face, as proposed by Bruce and Young, 1986. A left lateralized N170 component has also been reported when face processing emphasizes specific features of the face rather than the holistic configuration (Hillger and Koenig, 1991; Posamentier and Abdi, 2003; Rossion et al., 2000). Finally, the P300 component, with a centroparietal distribution, is modulated by task relevance, emotional relevance, explicit memory, and evaluative distinctiveness in various versions of the oddball paradigm (Cacioppo, Crites Jr, Berntson and Coles, 1993; Ito and Cacioppo, 2000; Langeslag, Franken and Van Strien, 2008; Picton, 1992; Schlaghecken, StÜrmer and Eimer, 2000; Schupp et al., 2004; Voss and Paller, 2006, 2007). For instance, the study of female college students by Vico et al., 2010 showed that pictures of loved ones (romantic partners, parents, and siblings) elicited a larger P300 component compared with pictures of unfamiliar persons.

The vast majority of neuroimaging studies of maternal face processing has focused on adults rather than children. A serious limitation in most of these studies is that the faces of mothers are more familiar than are the faces of the control stimuli (Grasso & Simons, 2010; Guerra et al., 2011; Langeslag et al., 2007; Kringelbach, 2008). Familiarity was characterized by the length of time spent with someone or the information collected concerning someone (Guerra et al., 2011; Kringelbach et al., 2008; Langeslag et al., 2007; Vico et al., 2010). Two studies that addressed this confounding effect used more familiar faces, such as the faces of fathers; however, including paternal faces introduced differences in the gender of the faces (Arsalidou et al., 2010; Guerra et al., 2012). In the present study, we had a rare opportunity to investigate the spatio-temporal brain dynamics of maternal face processing in Mosuo preschool children who were raised in a matrilineal society of Yunnan Province in China. Contrary to typical families, Mosuo children live with their mother, maternal aunt, uncle and grandmother from birth. Mosuo mothers and aunts are both regarded as "Ami" and they raise their children together. The mother and aunt, therefore, represent equally familiar faces to the Mosuo children (Dashi, 2006; see also http://en.wikipedia.org/wiki/Mosuo). This matriarchal population represented a rare opportunity to study maternal face processing using a control stimulus that was matched for gender, age, and familiarity. Considering the extensive processing of maternal faces found in previous studies (Arsalidou et al., 2010; Guerra et al., 2012), as well as its profound role and evolutionary function for social species (Broad, Curley and Keverne, 2006; Mousseau and Fox, 1998a, 1998b), the maternal face would expectedly trigger greater responses at various processing stages marked by the electrophysiological potentials.

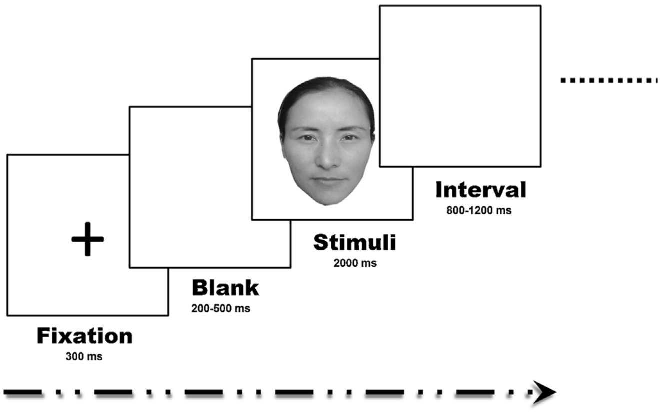

Fig. 1. Overview of the recording procedure and the sample of facial stimuli. The females whose photographs are presented here have provided written informed consent, permitting us to publish, reuse and reprint their photographs.

2. Methods

2.1. Participants

The final sample included 13 Mosuo children (7 females and 6 males; mean age, 5.8 years) who were recruited through flyers and verbal appeals to groups by local guides and experimenters. The EEGs from six additional participants were not analyzed because of excessive eye blinks and movement artifacts, and the EEG data from two additional participants were lost due to technical problems during data collection. All of the participants were right handed, had normal vision and no psychiatric disorders, received no medications, and reported that they had lived with their mothers and aunts since birth. Moreover, neither these children's mothers nor their aunts reported that they had ever worked outside of the village for a period of time (i.e., there was uninterrupted exposure to or bonding with their children). The participants were tested using the *Chinese-Binet Scale* before the experiment to ensure that they had normal cognitive abilities (Score: $M = 95.38$, $SD = 5.65$). The participants' guardians signed the informed consent before the experiment, and the participants received gifts after their participation.

2.2. Stimuli

Color photographs were taken from the neck up of the mother, aunt, and an unfamiliar female of similar age and ethnicity against a light gray background. All of the women assumed a neutral expression for the photograph and wore the same gray scarf to obscure the neckline and clothing; earrings and other jewelry were removed. To avoid the perceptual information generated by skin color that could affect the participants' behavioral and neurophysiological responses, the photographs were presented on-screen in grayscale (Fig. 1). Adobe Photoshop CS Version 5.0 was used to control the size, color and luminance (50.5 cd/m^2) of the facial stimuli.

The Mosuo children tested in the present study came from several villages; thus, the faces of several mothers and aunts were used as unfamiliar faces for other children. All of the faces were matched for age, and all of the participants were asked to ensure whether they had any knowledge of the unfamiliar female before beginning the experiment.

2.3. Procedure

A modified oddball paradigm was used in the present study because the oddball paradigm is well studied, and the potentials elicited in this paradigm are known to reflect specific aspects of attention, expectancy violation, face perception, and motivational relevance (Halgren & Marinkovic, 1995; Li, Yuan and Lin, 2008; Mejias et al., 2005). In the paradigm of the present study, the photographs of the mother and aunt served as targets, whereas the photographs of the unfamiliar female served as non-targets. In a counterbalanced order, the participants were instructed to press the F key (placed under their left index finger) when a photograph of the mother (aunt) appeared, press the J key (placed under their right index finger) when a photograph of their aunt (mother) appeared, and not respond when a photograph of an unfamiliar person appeared.

The participants sat in front of a table approximately 75 cm from a 15.6-in. (38.5 cm × 25.5 cm) Hewlett-Packard video monitor that delivered the stimulus, with a vertical visual angle of 5.3° and a horizontal visual angle of 3.6°. The experiment consisted of 420 trials that were separated into 5 blocks of 84 trials each. The stimulus order was randomized in each block; the photographs of the mother and the aunt were presented 12 times each (14.29%) within each block; and the photographs of the unfamiliar female's face was presented 60 times (71.43%) per block; each of the photographs of the five unfamiliar females appeared 12 times per block. The photographs of five unfamiliar females were used to avoid neural adaptation to a specific picture due to exposure frequency and to maintain the participant's attention during the task. The trial sequence was a black fixation (luminance: 87 cd/m^2; tested by a luminance meter) cross-presented for 300 ms on a white background (luminance: 55.2 cd/m^2) that varied randomly between 200 and 500 ms; a facial stimulus (luminance: 50.5 cd/m^2) was presented for 2000 ms or until a response was produced, with an inter-stimulus interval (ISI) that randomly varied between 800 and 1200 ms (Fig. 1). The participants practiced the procedure while electrodes were attached, and they were proficient when the experiment commenced.

After the EEG recording, all of the children completed a questionnaire with the help of their teacher. The participants were required to rank on a scale ranging from 1 (most inconsistent) to 5 (most consistent) whether "I spent a lot of time with my mother/aunt." The analysis of this questionnaire revealed that the children rated their exposure to their mother and aunt as being comparable (4.64 ± 0.49 versus 4.45 ± 0.51, $p > .05$).

2.4. *Electroencephalogram recording and analysis*

An appropriately sized, 128-channel Geodesic sensor net (Electrical Geodesics, Inc., Eugene, OR) that corresponded to the extended international 10–20 electrode sites was placed on the child's head. Impedance levels were maintained below 40 kΩ, and the vertex (Cz) served as the online reference electrode. Four additional electrodes were manually placed around the participant's eyes for electrooculographic (EOG) measures of eye movements and blinks. The amplification was set at 1000, and filtering was performed using a 0.1–100-Hz band-pass filter with a 50-Hz notch filter. The conditioned signal was multiplexed and digitized at 500 samples per second.

After the recording, the EEG data were re-referenced offline to an average reference. The signals were sampled at 500 Hz, and the EEG data were filtered offline using a 0.1–30 Hz band-pass filter. Bad channels were automatically replaced, and trials with eye blink or movement artifacts in which the signal amplitude exceeded ±80 μV were excluded from averaging. The ERP waveforms were time-locked to the onset of the facial stimulus, and the epoch in which the EEG activity averaged was 1200 ms, including a 200-ms pre-stimulus baseline. The grand average ERP waveforms (Fig. 2) and the topographical distribution (Fig. 3) displayed a prominent fronto-central N1 component, a bilateral occipito-temporal N170 component, and a centro-parietal P300 component, which were the focus of this study. Thus, Fz, Fcz, and Cz electrodes were selected for statistical analysis of the N1 component (peak values of 100–200 ms range); PO7 and PO8 sites were selected for statistical analysis of the N170 component (peak values of 180–280 ms range); and Cz, CPz, and Pz were selected for statistical analysis of the P300 component (mean values of 380–850 ms range) (Fig. 4). A two-way repeated-measures analysis of variance (ANOVA) on the amplitude and latency of each component was conducted using

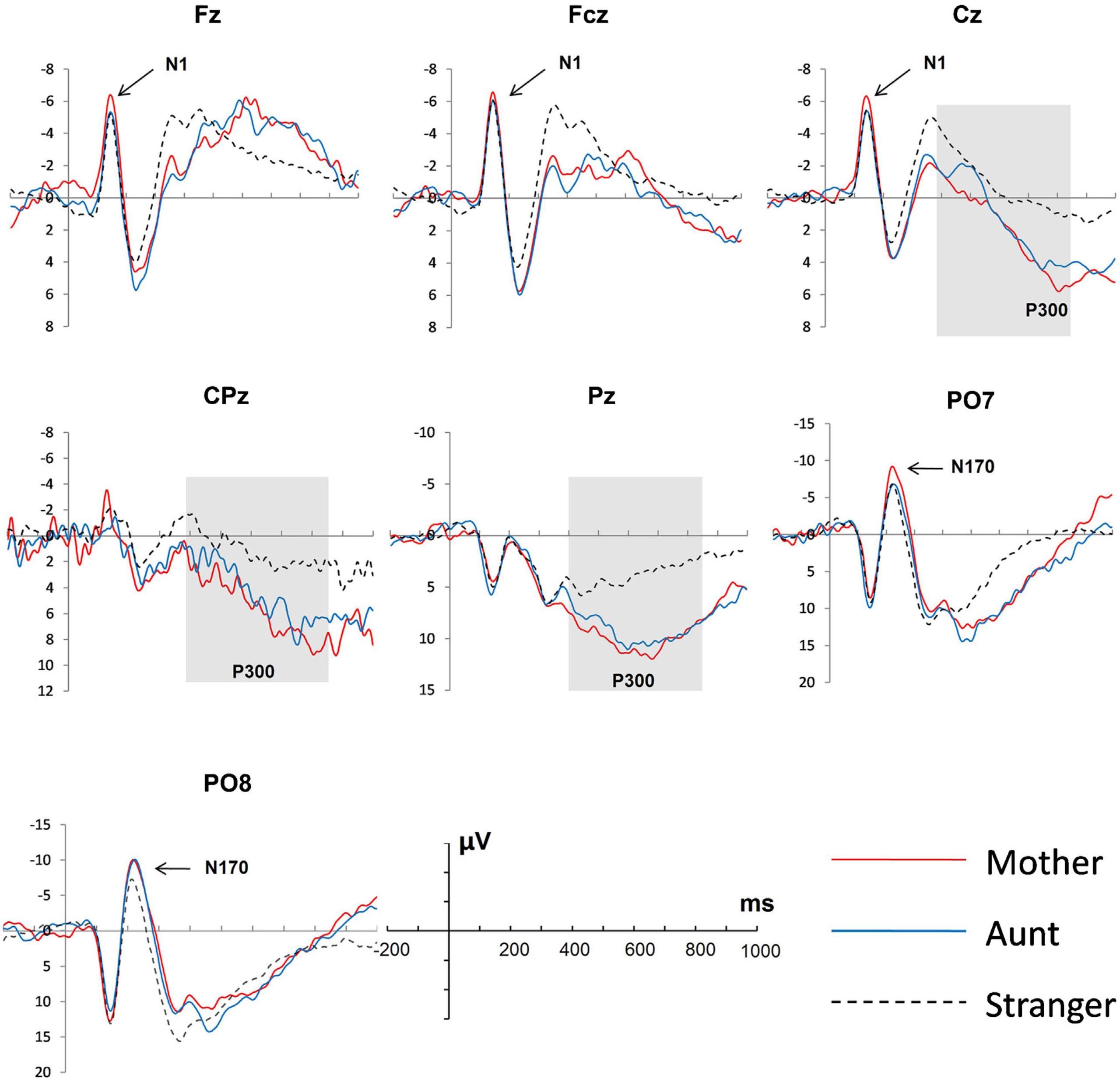

Fig. 2. The grand average ERPs for the faces of the mother, aunt, and strangers at the frontal–central–parietal midlines (Fz, Fcz, Cz, CPz, and Pz) and bilateral occipito-temporal electrode sites (PO7 and PO8). The gray shaded areas indicate the 400–800 ms analysis window in which the P300 component was quantified.

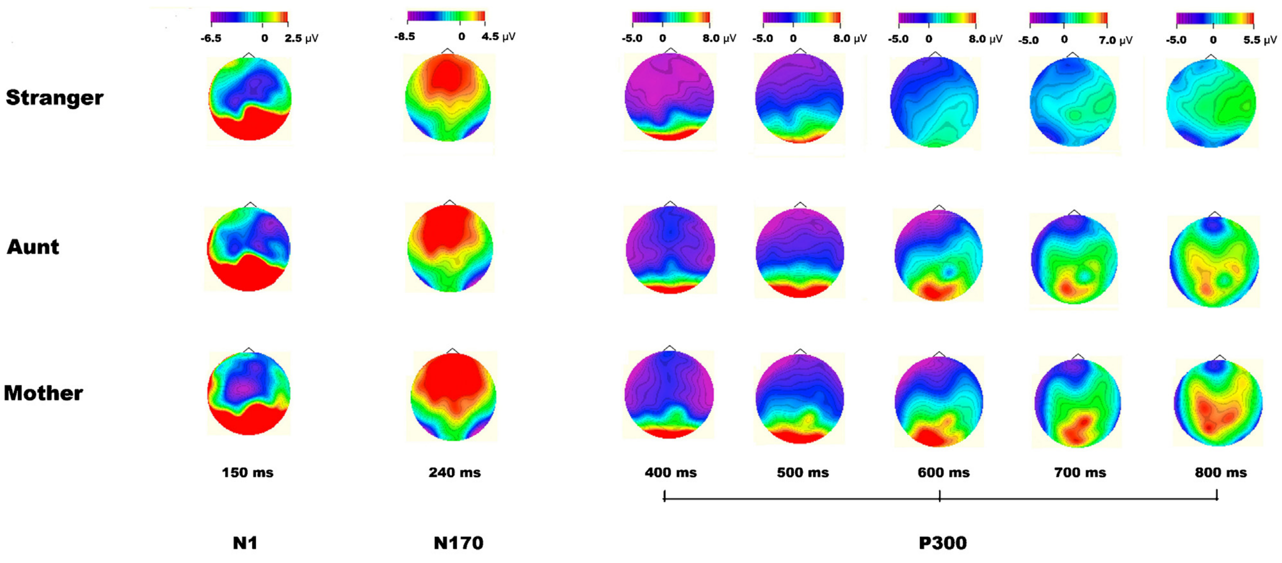

Fig. 3. Scalp topography of ERPs generated by the faces of the mother, aunt, and strangers at different processing stages, as indicated by different time windows.

the face category (three levels: mother, aunt, and unfamiliar female), and electrode sites were employed as within-subject factors. A Greenhouse–Geisser correction was applied when sphericity could not be assumed.

2.5. Dipole source analysis

As outlined below, the maternal face showed a pronounced N170 component in the left occipito-temporal region. The larger left lateralized N170 component that we observed was further examined using the Brain Electrical Source Analyses program (BESA, version 5.3.7 software, MEGIS Software GmbH, Munich, Bavaria, Germany). To perform the dipole source analysis, a four-shell ellipsoidal head model was used. To focus on the scalp's electrical activity related to the processing of the maternal face, the averaged ERPs evoked by the aunt's face were subtracted from the ERPs evoked by the maternal face, which produced a waveform difference. The principal component analysis (PCA) was employed in the 180–280 ms interval for the N170 component in the left occipito-temporal region to estimate the number of dipoles that are necessary to explain the difference wave. When the number of dipoles was determined with PCA, the algorithm implemented in the BESA software used to calculate the best-fit sphere and to determine their spherical coordinates (Pollatos et al., 2005), without symmetry and orientation constraints. This algorithm would shift the position of dipoles until it found a maximum fit position (Dien et al., 2003). A different dipole-fitting strategy that included symmetry and orientation constraints was also applied (Martinez et al., 1999), which yielded a similar dipole location in our analysis. The relevant residual variance criteria were used to evaluate whether this model best explained the data and accounted for the majority of the variance (Li, Yuan and Lin, 2008; Luo, Feng, He, Wang and Luo, 2010). Finally, the spherical coordinates of the dipole were converted to Talairach coordinates.

3. Results

3.1. Behavioral performance

The participants were instructed to press a button when a photograph of either the mother or the aunt was presented. The paired sample *t*-tests revealed that reaction times were longer when the participants identified a mother's ($M = 1079$ ms, $SD = 154$) than an aunt's face [$M = 975$ ms, $SD = 124$, $t(12) = 2.78$, $p < .05$], whereas the ACC was comparable for the mother ($M = 83.8\%$, $SD = 11.8$) and aunt [$M = 81.2\%$, $SD = 9.6$, $t(12) = 1.08$].

3.2. ERP results

3.2.1. N1 component

The face category (three levels: mother, aunt, and unknown female) × electrode sites (three levels: Fz, Fcz, and Cz) repeated-measures ANOVA on the N1 peak amplitude revealed a significant primary effect for the face category, $F(1.54, 18.45) = 6.58$, $p < .05$, $\eta_p^2 = .354$. Bonferroni-adjusted pairwise comparisons indicated that the mother's face ($M = -6.48$ μV, $SD = 2.91$) elicited a more negative N1 component than the aunt's face ($M = -4.93$ μV, $SD = 2.87$, $p < .05$) or the face of the unknown female ($M = -5.08$ μV, $SD = 2.78$) and that the faces of the aunt and unknown female did not differ. No other test for N1 amplitude or latency was statistically significant.

3.2.2. N170 component

Face category (three levels: mother, aunt, and unknown female) × electrode sites (two levels: PO7 and PO8) repeated-measures ANOVA on N170 peak amplitude revealed a significant primary effect for the face category [$F(1.90, 22.84) = 5.49$, $p < .05$, $\eta_p^2 = .314$] and an interaction effect [$F(1.60, 19.21) = 3.94$, $p < .05$, $\eta_p^2 = .295$]. Simple primary effect tests showed that at the PO7 electrode site (i.e., left occipito-temporal area), the mother's face ($M = -11.88$ μV, $SD = 8.40$) elicited a larger N170 component than the aunt's face ($M = -8.27$ μV, $SD = 7.19$, $p < .05$) and the unknown female's face ($M = -7.72$ μV, $SD = 6.29$, $p < .05$), whereas at the PO8 site (i.e., right occipito-temporal area), the mother's face ($M = -11.72$ μV, $SD = 9.01$) elicited a comparable N170 component to the aunt's face ($M = -11.75$ μV, $SD = 9.09$), and each elicited a larger N170 component than the unknown female's face ($M = -8.27$ μV, $SD = 8.91$, $p < .05$). No effects were found for N170 latency.

3.2.3. P300 component

Face category (three levels: mother, aunt, and unknown female) × electrode sites (three levels: Cz, CPz, and Pz) repeated-measures ANOVA on P300 amplitude revealed significant primary effects of face category [$F(1.60, 19.25) = 25.30$, $p < .001$, $\eta_p^2 = .678$] and electrode sites [$F(1.61, 19.34) = 17.14$, $p < .001$, $\eta_p^2 = .588$]. The Bonferroni-adjusted pairwise comparisons indicated that the mother's face ($M = 5.92$ μV, $SD = 4.61$) elicited a larger P300 component than the aunt's face ($M = 4.61$ μV, $SD = 3.24$, $p < .05$), and both the mother's face and the aunt's face elicited a larger P300 component than the faces of the unknown females ($M = 0.67$ μV, $SD = 4.23$, $p < .001$). The post hoc analysis of electrode sites showed that the P300 amplitude was larger over Pz ($M = 11.07$ μV, $SD = 5.58$) than CPz ($M = 4.45$ μV, $SD = 4.14$, $p < .01$) and Cz ($M = 0.28$ μV, $SD = 3.43$, $p < .001$).

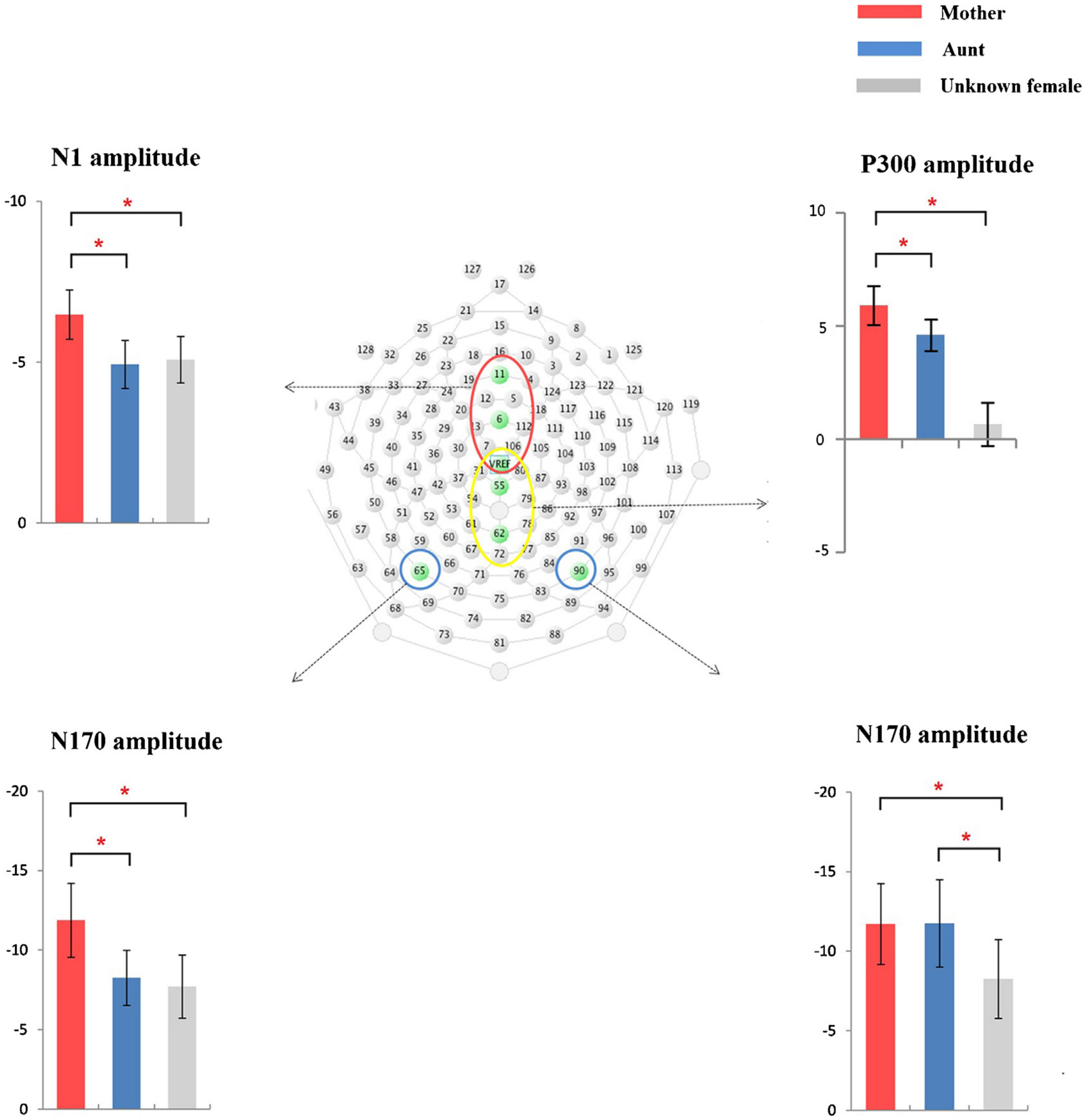

Fig. 4. Recording electrode arrangement. The fronto-central electrode sites were indicated for analyzing the peak amplitude in the N1 time window, and the centro-parietal electrode sites were indicated for analyzing the average amplitude in the P300 time window. Additionally, PO7 and PO8 were indicated for analyzing the N170 component. The histograms symbolize the mean voltage amplitude (with standard error bars) of the above potentials; the red asterisks indicate the significance.

3.3. *Source localization*

PCA indicated that a single principal component could explain 92.6% of the differences between the face of the mother and the aunt within the time window of N170. Therefore, only one dipole was fitted with no restriction as to the direction or location of the dipole. The results indicated that the dipole was located approximately in the region of the left fusiform gyrus [termed FFA (fusiform face area) (Kanwisher et al., 1997) (Fig. 5), Talairach coordinates: $x = -18.8$, $y = -84.7$, $z = -11.0$] and that the maximal strength of the dipole occurred at approximately 220 ms. This model best explained the data with a residual variance (RV) of 12.67% at the peak activity of this dipole. The display of the residual maps in the time window showed no further dipolar activity, and no other dipoles could be fitted in this time window when the solution was compared with other plausible alternatives (e.g., bilaterally symmetric dipoles; Li, Yuan and Lin, 2008; Luo, Feng, He, Wang and Luo, 2010).

4. Discussion

The present study is the first to examine the neural mechanism underlying a child's response to the mother's face and simultaneously controlling for the confounding effect of familiarity. Specifically, ERPs were recorded in Mosuo preschool children to investigate their response to photographs of the mother, an equally familiar aunt, and an unfamiliar female. The behavioral results showed that the children were equally accurate in their task performance and took longer to identify the mother's than the aunt's face. Similar behavioral differences have been found in prior studies of facial appeal or beauty (Aharon et al., 2001; Sui and Liu, 2009) and may reflect the child's greater affection for his or her mother than the aunt. Interestingly, the ERP data analysis revealed differentiable neural responses at several distinct stages of facial information processing of the mother's face.

Specifically, the mother's face elicited a larger N1 component in the early face processing stages than the faces of the aunt or the

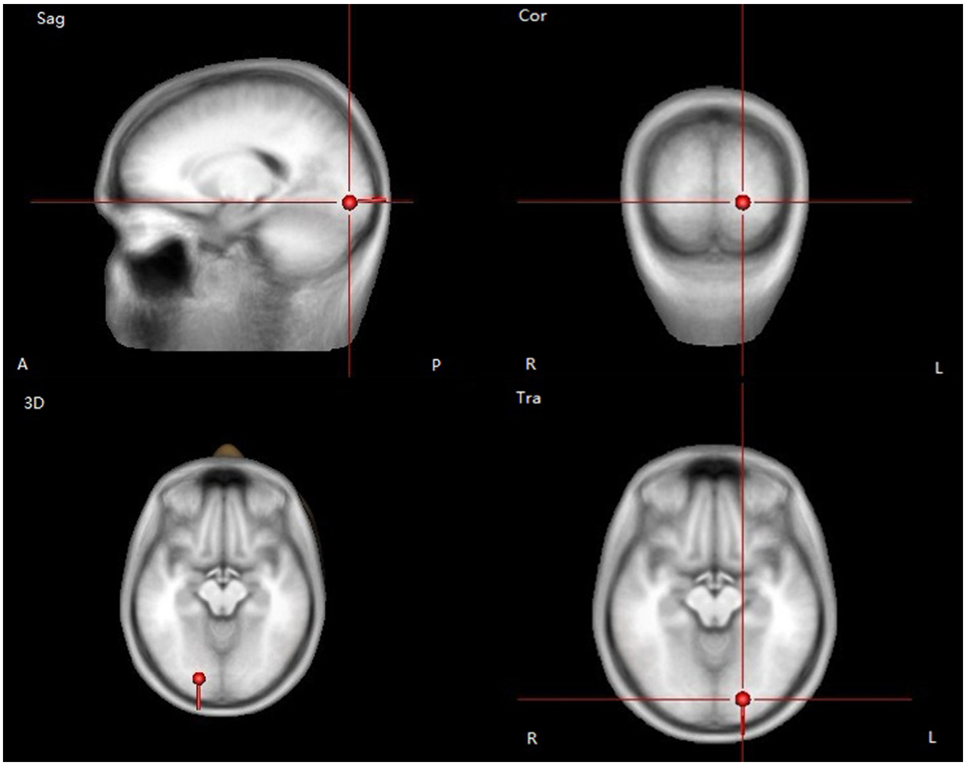

Fig. 5. Dipole source localization images of the waveform difference of the maternal face versus the aunt's face for the N170 component. The panels show data for the fitted dipole 180–280 ms after the stimulus presentation window demonstrated in the sagittal, coronal, and transverse planes and a three-dimensional (3D) image. The dipole is located in the region of the left fusiform gyrus (Talairach coordinates: $x = -18.8$, $y = -84.7$, $z = -11.0$).

unknown female. Bruce and Young, 1986 model of face processing includes two successive stages, structural encoding (electrophysiologically marked by the N170 component) and feature processing and personal identification (>300 ms). The N1 effect we obtained precedes either of these stages; however, the N1 effect is consistent with the "early selection" theory of attention, which specifies that sensory inputs can be selectively modulated during sensory perceptual processing before stimulus identification (Hillyard and Anllo-Vento, 1998; Reinitz, 1990). The early modulation of attention observed in our study cannot be attributed to stimulus familiarity because the N1 effect for the aunt and unknown female did not differ. Instead, our results suggested that a mother's face, similar to other biologically important stimuli (Mouchetant Rostaing, Giard, Bentin, Aguera and Pernier, 2008; Mouchetant-Rostaing, Giard, Delpuech, Echallier and Pernier, 2000; Taylor, 2002), elicits additional attentional resources before explicit facial identification.

Prior studies of the N170 component during face processing have found a larger right lateralized N170 component to familiar relative to unfamiliar categories of faces (Caharel et al., 2002; Campanella et al., 2000; Weisman, Feldman and Goldstein, 2011). We replicated this finding in the present study; the N170 component in the right occipito-temporal region was larger for the mother's and the aunt's faces than for the unfamiliar woman's face, and the N170 component for the mother's and aunt's faces did not differ, which may reflect the comparable familiarity of the mother's and aunt's faces. The present study is the first to investigate children's responses to maternal faces controlling for familiarity; however, analyzing the N170 component in the left occipito-temporal region revealed a larger response to the mother's face than to the aunt's or the unfamiliar woman's face, which did not differ from one another. A source localization analysis suggested that the left FFA contributed to the larger N170 component to the mother's face. If the left FFA is particularly involved in processing the elements of a face, whereas the right FFA is more involved in holistic face processing (Hillger and Koenig, 1991; Posamentier and Abdi, 2003; Rossion et al., 2000), then the additional attentional resources elicited by the mother's face may promote the simultaneous processing of local (e.g., lip shape, nose, mouth size or eyes) and global (e.g., shape or outline) features.

In the later processing stage (approximately 380 ms after the stimulus onset), both the mother's and the aunt's faces elicited a classical oddball effect, with a larger-amplitude P300 component relative to the face of the unknown female. Interestingly, the mother's face elicited a larger P300 component than the aunt's face, although these stimuli were matched for familiarity, presentation frequency, task relevance and response requirements. Langeslag et al., 2007 reported a larger P300 component in response to the faces of lovers versus friends, and no difference in the P300 component in response to the faces of friends and unfamiliar individuals. This finding and our own finding suggest that the larger P300 response to the faces of the mother is attributable to the biological importance of the stimulus (Langeslag et al., 2007, 2008). Note that both the mother and aunt are positive stimuli for the participants, and both elicit the P300 response; however, the larger P300 component in response to the mother's versus the aunt's face suggests that the motivational relevance is greater for the maternal face.

One limitation in the present study is the small sample size. The Mosuo represent a minority population that is distributed in various regions in China; the number of available participants was small because the mother and aunt had to be matched for age and working condition. The replication of these findings is warranted. A second limitation stems from the oddball paradigm in which pictures of unfamiliar women were presented five times more frequently than were pictures of the mother or the aunt. To avoid confounding the exposure frequency of the pictures, the participants were exposed to pictures of five unfamiliar women;

the pictures of the five unfamiliar women were presented the same number of times as the pictures of the mother or aunt. An alternative approach worth investigating is the use of pictures of unfamiliar women as targets rather than non-targets; however, this approach might result in other conditions, making the task difficult to complete or resulting in a longer recording time for the children. Another limitation is that although both the N1 and N170 components are insusceptible to task relevance, the P300 component might be influenced by the task relevance to some degree (Meijer et al., 2007). Thus, the enhanced P300 amplitudes of the mother's face and the aunt's face compared to the face of an unknown female might have been partially derived from the task requirement, although the difference in the P300 components between targets (the mother's and aunt's faces in the present study) and non-targets (the unknown female's face in the present study) is generally tremendous (Weisman et al., 2011). To maintain pure neural processing, this issue merits exploration in future studies.

In summary, the mother typically maintains the greatest responsibility for the survival, care and welfare of her offspring (Geary, 2000). Prior research has shown that newborns are more responsive to a mother's face than to an unfamiliar face (Bushnell et al., 1989; Cecchini et al., 2011; Pascalis, de Schonen, Morton, Deruelle and Fabre-Grenet, 1995). In the present study of Mosuo preschool children, we replicated the right-lateralized N170 response to familiar faces observed in previous research, and we extended prior findings to show a larger left-lateralized N170 response to the mother's face than to an equally familiar aunt's face. Altogether, these results suggest that a mother's face (compared to other faces) is special in at least three ways: (a) it elicits greater attentional resources very early in the process of face perception, as reflected in the N1 component; (b) it undergoes more extensive feature processing, as reflected in the larger bilateral N170 component; and (c) it elicits greater motivational resources to support an approach response, as reflected in the P300 component. These three successive processing stages may serve as a special supplement to the two-stage model of face processing (i.e., structural encoding and subsequently personal identification) proposed by Bruce and Young, 1986.

Acknowledgements

This research was supported by the 973 Program (2011CB711000, 2014CB744600), NSFC (91132704), and the Fundamental Research Funds for the Central Universities.

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