Is It a Baby? Perceived Age Affects Brain Processing of Faces Differently in Women and Men

Alice Mado Proverbio1, Federica Riva1, Alberto Zani2, and Eleonora Martin1

Abstract

It is known that infant faces stimulate visual and anterior brain regions belonging to the mesocortical limbic system (orbito-frontal cortex, anterior cingulate cortex, and nucleus accumbens) as well as the fusiform gyrus during face coding, suggesting a preferential response to baby schema. In the present investigation, faces of infants, children, and adults were presented to 40 male and female right-handed university students with technological objects (and inanimate scenarios to serve as targets) in a randomly mixed fashion. EEG was recorded from 128 scalp sites. In both sexes, the N1 response to infant faces was larger than the response to adult faces; however, the baby-specific N1 response was much larger in women than in men across the left hemisphere. The anterior N2 response to infants was greater than the response to children only in women, whereas the response to children of any age was larger than the response to adults in men. LORETA identified the intracranial sources of N2 response to infants in the left fusiform gyrus (FG), as well as the uncus, cingulate, and orbito-frontal cortices. The FG, the limbic, and especially the orbito-frontal sources were much larger in women than in men. The data suggest a sex difference in the brain response to faces of different ages and in the preferential response to infants, especially with regard to activation of the mesocorticolimbic system.

INTRODUCTION

The baby schema is defined as a set of infantile physical characteristics, which includes a round face, high forehead, big eyes, small nose and mouth, chubby cheeks, and a large head (Alley, 1981; Lorenz, 1971) that is perceived as cute (Glocker, Daniel, et al., 2009; Koyama, Takahashi, & Mori, 2006; McKelvie, 1995). The baby schema has attention-capturing effects (Tobias, David, Gilles, & Klaus, 2008; Brosch, Sander, & Socherer, 2007) and increases the motivation for caretaking behavior in adults (Tinbergen, 1951). Furthermore, it has been shown that the preference for baby schema in humans is present not only in adult individuals but also in sexually immature children (Sanefuji, Ohgami, & Hashiya, 2007), thus supporting the hypothesis of an innate instinct related to species preservation.

Several recent neuroimaging studies (Glocker, Langleben, et al., 2008; Kringlebach et al., 2008; Strattham, Li, Fonagy, & Montague, 2008; Leibenluft, Gobbini, Harrison, & Haxby, 2004; Nitschke et al., 2004) have investigated the neural circuits subtending this specific response to infant as opposed to adult faces. These studies have identified a set of structures, predominantly involving orbito-frontal cortex (OFC) and the dopaminergic reward system (Galvan et al., 2005; Zald et al., 2004). Notably, there is a vast amount of data that supports the role of OFC in social cognition. Specifically, OFC is involved in appropriately regulating the expression of emotions in social situations and in theory of mind (Bechara, Damasio, & Damasio, 2000; Rolls, 2000). In an MEG study (Kringlebach et al., 2008), a stronger activity was found in medial OFC implicated in reward behavior and in the right fusiform face area, in response to infants as compared to adult faces: These data were interpreted as providing evidence in humans of a potential brain basis for the “innate releasing mechanisms” described by Lorenz for affection with and nurturing of young infants. Other recent neuroimaging studies (Bartels & Zeki, 2004; Leibenluft et al., 2004; Nitschke et al., 2004) have recorded brain activation in mothers viewing pictures of their own children (“maternal love”). The results showed activation of brain areas linked to affect (amygdala) and, in particular, positive emotion (OFC and connected regions belonging to the pleasure/reward circuitry, such as the periaqueductal gray matter).

Although several neuroimaging studies did investigate the brain response to infantile cues (Glocker, Langleben, et al., 2009; Kringlebach et al., 2008; Strattham et al., 2008; Leibenluft et al., 2004; Nitschke et al., 2004), these studies did not specifically distinguish between babies or infants and the baby schema. The first study to dissociate the baby schema from the infants that carry it, by parametrically manipulating the baby schema content in an all-infant set of cues, was performed by Glocker, Langleben, et al. (2009). In that fMRI study, 16 nulliparous female participants viewed a pseudorandom sequence of unknown infant faces while rating the pictures for cuteness. Although all infant faces elicited an activation of the fusiform gyrus, thalamus, cingulate gyrus, insula, and OFC, faces judged

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as cuter revealed significant clusters of activation in the nucleus accumbens, ACC, the left precuneus, and the left fusiform gyrus. The activation of the nucleus accumbens suggests that the baby schema is a positive incentive (rewarding sensory stimulus) that provides motivational drive to caretaking behavior. It should be mentioned that the latter study was carried out solely in female subjects; therefore, it is not possible to draw any specific inference with regard to the existence of sex differences in the baby schema-driven brain response. Other behavioral studies, however, seem to corroborate the hypothesis that women might be more responsive to baby schema than men (Glocker, Daniel, et al., 2009; Proverbio, Matarazzo, Brignone, Del Zotto, & Zani, 2007; Alley, 1981) and are better able to decode infant expressivity (Proverbio et al., 2007; Babchuk, Hames, & Thompson, 1985). We previously carried out an electrophysiological study (Proverbio, Brignone, Matarazzo, Del Zotto, & Zani, 2006b) aimed at investigating the neural response to baby schema in female and male adult individuals who either were parents themselves of infants of the same age, or nulliparous, as in the Glocker, Langleben, et al. study. ERP results revealed a larger sensory P100 response to faces in women than in men (irrespective of parental role), a greater P100 response in the left hemisphere in mothers than in nulliparous women, and larger P3 amplitudes in mothers versus all other groups (including fathers and nulliparous women). These findings may be interpreted as a sign of greater perceptual sensitivity or increased arousal response in mothers at the view of unrelated infants.

Other studies utilizing the auditory modality have demonstrated a female versus male preference for infant vocalizations (cry and laughter), supporting the hypothesis of a sex difference in the parental response to infantile communicative signals. For example, an fMRI study (Seifritz et al., 2003) provided evidence of a difference in brain response to social stimuli in women and men listening to infants crying and laughing. Women but not men showed deactivation in ACC in response to both infant crying and laughter. This gender effect per se was interpreted as a preference of female individuals for specific sensory signals (infant vocalizations). In a more recent study (Sander, Frome, & Scheich, 2007), infant laughter and crying elicited stronger activation in the amygdala and ACC of women than men. According to the authors, this indicated that women were neurally predisposed to respond to preverbal infant vocalizations.

The specific aim of this study was to further investigate this matter by trying to elucidate whether the preferential response to infants (measured in terms of amplitude of visual ERP responses to faces) extends to the faces of prepubertal children, potentially leading to differences in the amplitude of ERP component as a function of perceived age. Neural responses to human faces of different ages (infants, children, and adults of both sexes), as well as control stimuli (objects), were compared to investigate whether there was an effect of perceived age on face processing, possibly leading to differences in bioelectrical responses to infant versus child or adult faces. Indeed, on the basis of previous neuroimaging investigations, supporting the notion of a preferential response to infant faces (and baby schema), we expected an effect of perceived age on visual (N1) as well as more anterior brain responses (such as N2; Proverbio, Adorni, Zani, & Trestianu, 2009; Proverbio, Zani, & Adorni, 2008). We expected to observe greater potentials in response to faces with a higher baby schema value (infants vs. children). Indeed, even without specifically manipulating baby schema, it is intrinsic in the face morphology of 7- to 11-year-old children that their faces have a lower baby schema value (as previously defined; Alley, 1981; Lorenz, 1971) than those of infants. We also expected sex differences in the hemispheric lateralization of the N1 component, and possibly, in the amplitude of brain response to infantile versus adult faces. These effects have already been shown in previous evoked potential studies (Proverbio, Riva, Martin, & Zani, 2010; Proverbio et al., 2006b).

**METHODS**

**Participants**

Forty healthy right-handed University students (20 men and 20 women) participated in this study as unpaid volunteers. They earned academic credits for their participation. Their mean age was 22 and ranged from 19 to 27 years. All had normal or corrected-to-normal vision, and reported no history of neurological illness or drug abuse. Their handedness was assessed by the Italian version of the Edinburgh Handedness Inventory, a laterality preference questionnaire reporting right-handedness and right ocular dominance for all participants. Experiments were conducted with the understanding and the written consent of each participant. Two men and two women were excluded from statistical analysis because of a noisy EEG. The experimental protocol was approved by the ethical committee of the University of Milano-Bicocca. All participants were nulliparous and had no daily contact with children (<9 years). A specific questionnaire excluded the presence of siblings and young relatives in the subjects’ families and verified that none of the study participants was engaged in professional activities related to child care (such as educator, teacher, babysitter, nurse, etc.).

**Stimuli and Materials**

The stimulus set comprised 520 color pictures depicting good-looking male and female faces of various ages (150 adults, 130 prepubertal children, and 130 infants) and 130 technologic/electronic objects of similar size and spatial distribution (see Figure 1). Because all persons were anonymous, their ages were actually unknown but were estimated on the basis of facial resemblance by four independent judges. Adult face attractiveness was also
established by the same judges but without a specific rating procedure. Potentially gender-biased objects (such as an electric iron or shaver) were not included. Faces included the neck and the upper portion of the chest. Normal proportions were maintained between infants and adults to preserve the authenticity of the perceptual experience. Except for the infant category (for which sex was sometimes indistinguishable), all faces depicted an equal number of females and males. All people were smiling or showing a positive facial expression. There was no difference in facial expression between age classes (closed mouth smile: adults = 50, children = 54, infants = 58; open-mouthed smile: adults = 80, children = 76, infants = 72). Faces and objects were presented randomly mixed with 44 equiluminant infrequent targets depicting natural or urban landscapes without visible persons (e.g., streets, offices, countryside, seascape). Stimulus size was 9° 56′ × 8° 23′ 1″, and average luminance was 16.2 cd/cm². ANOVA showed no difference in stimulus luminance as a function of stimulus type (faces: adults = 16.4, children = 15.6, infants = 16.7. Objects = 16 cd/cm²). Each slide was presented for 800 msec at the center of a PC screen with an ISI ranging from 1300 to 1500 msec. The outer background was dark gray.

**Procedure**

In order to keep the subject’s attention focused on visual stimulation, the task consisted of responding as accurately and quickly as possible to photos displaying landscapes (urban or natural scenarios without visible humans) by pressing a response key with the index finger of the left or right hand while ignoring all other pictures. The two hands were used alternately during the recording session. The order of the hand and task conditions was counterbalanced across subjects. Participants were comfortably seated in a darkened, acoustically and electrically shielded test area, facing a computer screen located 90 cm from their eyes. Participants were instructed to fixate on the center of the screen, where a small transparent circle served as fixation point, and to avoid any eye or body movements during the recording session. Stimuli were presented foveally and subject’s eyes were aligned to the eyes of photographed persons. Sequence presentation order differed across subjects. An implicit task was employed to observe face-related attention-capturing effects.

**EEG Recording and Analysis**

EEG was continuously recorded from 128 scalp sites located according to the 10–5 International System (Oostenveld & Praamstra, 2001), at a sampling rate of 512 Hz. Horizontal and vertical eye movements were also recorded. Linked ears served as the reference lead. The EEG and electrooculogram were amplified with a half-amplitude band pass of 0.016–100 Hz. Electrode impedance was kept below 5 kΩ. EEG epochs were synchronized with the onset of stimuli presentation. Computerized artifact rejection was performed before averaging to discard epochs in which eye movements, blinks, excessive muscle potentials, or amplifier blocking occurred. The artifact rejection criterion was based on peak-to-peak amplitude exceeding 50 μV, and the rejection rate was ∼5%. ERPs were averaged off-line from −100 msec before to 1000 msec after stimulus onset. ERP components were identified and measured, with reference to the average baseline voltage over the interval from −100 msec to 0 msec, at sites and latency when maximum amplitude was achieved.

The peak amplitude of the occipito-temporal P1 component was measured at P9 and P10 in the 100–140 msec time window. The mean amplitude voltage of the N1 component was measured at P9, P10, PPO9h, PPO10h, TPP9h, and TPP10h electrode sites during the 150–180 msec time window. The mean amplitude voltage of anterior N2 was measured at PF1, PF2, AF3, AF4, A FP3h, and AFp4h sites during the 250–300 msec time window. Mean amplitude voltage of the N400/P400 complex was quantified at Fp1, Fp2, P1, P2, O1, and O2 electrode sites during the 400–500 msec time window.

ERP data were subjected to multifactorial repeated measures ANOVA with one factor between groups (sex: males, females) and three factors within groups. The within factors for ERP data were: stimulus content (adults, children, infants, and objects), hemisphere (left, right), and electrodes (depending on the ERP component of interest). Specifically, the electrode factor had three levels for the N1 component (occipito-temporal, lateral/occipital, and temporoparietal), three levels for

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**Figure 1.** Human faces of different sex and age (infants, children, and adults) along with an example of the target stimulus (scenario without visible humans) and control stimulus (technological object).
anterior N2 response (prefrontal, anterior frontal, anterior fronto/parietal), and three levels for N400/P400 mean area (prefrontal, parietal, occipital). Face-specific N2 response was quantified only for infant, child, and adult faces. Multiple post-hoc comparisons were performed by means of Tukey’s test. Low-Resolution Electromagnetic Tomography (LORETA) was performed on ERP waveforms for each ERP component of interest.

LORETA, which is a discrete linear solution to the inverse EEG problem, corresponds to the 3-D distribution of neuronal electric activity that yields maximum similarity (i.e., maximum synchronization), in terms of orientation and strength, between neighboring neuronal populations (represented by adjacent voxels). In this study, an improved version of standardized weighted low-resolution brain electromagnetic tomography (sLORETA) was used. This version incorporates a singular value decomposition-based lead field weighting: swLORETA (Palmero-Soler, Dolan, Hadamschek, & Tass, 2007). Source space properties were: grid spacing (the distance between two calculation points) = 5 points; the estimated signal-to-noise ratio (SNR, which defines the regularization; a higher value for SNR means less regularization and less blurred results) was 3. LORETA was performed on group data to identify

Figure 2. Grand-average ERP waveforms recorded at lateral-occipital (PPO9h/PP9010h), occipito-temporal (P9/P10), and temporo-parietal (TPP9h/TPP10h) sites in response to the four stimulus types, separately for women (A) and men (B). Strong sex differences in the hemispheric distribution and sensitivity to stimulus content (object vs. face for P1 response, perceived age effect for N1 response) are visible. The arrow indicates the presence of a larger P1 in response to faces when compared to objects in the female brain and the lack of P1 modulation in the male brain.

![Figure 2](http://direct.mit.edu/jocn/article-pdf/23/11/3197/1776810/jocn_a_00041.pdf)
statistically significant electromagnetic dipoles \((p < .05)\)—the larger the magnitude, the more significant the group differences.

RESULTS

Figure 2 shows grand-average ERP waveforms recorded at posterior sites in response to face and technological objects in women (A) and men (B). Consistent content-dependent modulation of both sensory and cognitive components can be observed in viewers of both sexes.

P1 Latency

The P1 component was measured at P9 and P10 sites located at lateral occipital/inferior-temporal sites. Statistical analyses demonstrated the significance of stimulus content \([F(3, 102) = 24.39, p < .00001]\). Post-hoc comparisons showed slower P1 responses to objects than human faces (see P1 latency values in Figure 3A).

P1 Amplitude

Overall, P1 response was of larger amplitude in women (5.16 \(\mu V, SE = 0.39\)) than in men (3.50 \(\mu V, SE = 0.39\)), as shown by the sex factor \([F(1, 34) = 8.89, p < .006]\) and topographic maps (Figure 4). The P1 component was strongly modulated by stimulus content \([F(3, 102) = 15.42, p < .00001]\). Post-hoc comparisons showed significantly larger P1 responses to faces \((p < .0001)\) than objects, regardless of face age (see waveforms in Figure 2). However, the further interaction of Sex × Stimulus content \([F(3, 102) = 4.73, p < .004]\) and relative post-hoc comparisons showed that P1, in response to faces of all ages, was larger in women \((p < .001)\) than in men. Furthermore, larger P1 potentials were elicited toward faces than objects only in the female brain, whereas stimulus content had no effect, at this latency stage, in men (see amplitude values in Figure 3B).

N1 Amplitude

N1 amplitude was strongly modulated by stimulus content \([F(3, 102) = 61.8, p < .000001]\). N1 amplitude was significantly \((p < .001)\) larger in response to infant \((-2.41 \mu V, SE = 0.40)\) as compared to adult \((-1.66 \mu V, SE = 0.40)\) faces, and larger in response to human faces as compared to objects \((0.82 \mu V, SE = 0.34)\), as also visible in topographic maps (Figure 5). The interaction of Hemisphere × Sex \([F(1, 34) = 9.17, p < .005]\) indicated a hemispheric asymmetry, with N1 being greater over the right hemisphere than the left hemisphere in men, and over the left hemisphere than the right hemisphere in women (see waveforms of Figure 2A vs. B). The interaction of Hemisphere × Sex × Stimulus content \([F(3, 102) = 3.35, p < .02]\) indicated a lack of age coding effect over the left hemisphere in men, where N1 was larger in response to infant faces as compared to adult faces in women \((p < .01)\). N1 to infants was much larger in women \((-3.25 \mu V, SE = 0.58)\) than in men \((-1.17 \mu V, SE = 0.58)\) over the left hemisphere \((p < .001)\).

N2 Amplitude

Figure 6 shows grand-average ERP waveforms recorded at anterior sites in response to faces in women (A) and in men (B). Mean area amplitude of anterior N2 was quantified in the 250–300 msec time window only for the face category because this parameter is likely to reflect some sort of face-specific processing, as illustrated in Figure 7. ANOVA showed that N2 was strongly affected by the

Figure 3. (A) P1 latency values recorded at left and right occipito-temporal sites as a function of stimulus content (left). (B) P1 amplitude values recorded as a function of stimulus content, hemisphere of recording, and viewer’s sex (right). The sex difference in the P1 response to face versus objects is visualized in the left lateral-occipital area.
age of persons depicted \( F(2, 68) = 42.42, p < .000001 \), with larger amplitudes in response to infants \( \text{INF} = -4.06 \mu V, SE = 0.46 \) than children \( \text{CHIL} = -3.31 \mu V, SE = 0.45 \) and larger amplitudes in response to children than adults \( -2.49 \mu V, SE = 0.46 \), as shown by post-hoc comparisons. The interaction of Sex × Stimulus content \( F(2, 68) = 3.4, p < .003 \) showed a sex difference in anterior N2 response, with a greater response to infant than

![Figure 4](http://example.com/fig4.jpg)

**Figure 4.** Topographic maps of voltage distribution recorded in the 100–130 msec time window in response to the four stimulus categories in women and men (back-right view). P1 was greater to faces than objects in the female brain.

![Figure 5](http://example.com/fig5.jpg)

**Figure 5.** Topographic maps of voltage distribution recorded in the 150–180 msec time window in response to the four stimulus categories in women and men (back-right view). The blue area indicates the concentration of a negative potential (N170). The electrodes considered for N1 measurements are highlighted as shown here. For both sexes, N1 was larger for infant faces when compared to adult faces across the right hemisphere.
child faces only in female individuals (see Figure 6A vs. B), whereas N2 response to children was of equal amplitude for the two age classes of children (infants and children) but the N2 response to adult faces was smaller in males. Post-hoc analysis of mean values given in Table 1 showed no sex difference in the N2 response to children, but a much larger N2 response was shown toward infants in women ($p < .01$) than in men.

In order to investigate the neural bases of infant-specific face response in the two sexes, two LORETA source reconstructions were applied to the difference waves, obtained by subtracting ERPs to adults from ERPs to infants, in the 250–300 msec time window (see Figure 8). A list of significant sources of activation explaining the surface difference voltage is presented in Table 2. The main sources of activation included the left and right medial occipital/fusiform gyrus (BA 19), the right uncus (BA 20/36), the right medial orbito-frontal gyrus (BA 11), and right ACC (BA 23), which are mostly involved in affective processing of faces. Notably, the orbito-frontal source was much stronger in women (11.03 nA m) than in men (7.03 nAm).

**N400/P400 Amplitude**

In the 400–500 msec time window, N400 over anterior brain regions was larger in response to objects than faces (as displayed in Figure 7), whereas P400 over posterior brain regions was larger to objects than faces (as clearly visible in Figure 2). ANOVA showed the significance of Stimulus content × Electrode [$F(6, 204) = 44.1$, $p < .00001$], indicating much larger N400s to objects than faces at prefrontal sites (with no effect of face age), much larger P400 to objects than faces at occipital sites (with no effect of face age), and no stimulus content effects at parietal sites.

**DISCUSSION**

The study’s goal was to investigate the time course and brain topography of neural processing of human faces of increasing age, as opposed to objects, as a function of the viewer’s sex. The hypothesis, supported by current ethologist models that relate perceived face cuteness with increased brain response, was that in adult individuals the
youngest faces (baby schema) stimulated the brain reward system to a greater extent than the older faces. We also expected greater female than male interest or attentional allocation toward childish faces (Proverbio et al., 2006b; Babchuk et al., 1985) or faces per se (Proverbio et al., 2008). An implicit task was employed to observe attention-capturing effects.

Latency of the P1 sensory response showed the prioritized processing of biologically relevant information (faces vs. objects) in both sexes. These data are consistent with previous electrophysiological evidence (Proverbio et al., 2009) that visual cortex responds with greater amplitude to images displaying persons than to scenes of equal average luminance. However, only women showed a modulation of P1 amplitude in response to faces versus objects. This evidence is consistent with that provided by neural markers of greater female responsivity to unattended social signals such as faces (Proverbio, Brignone, Matarazzo, Del Zotto, & Zani, 2006a, 2006b) or persons (Proverbio et al., 2008). Because faces and objects were actually task irrelevant and, therefore, unattended (the task being responding to landscapes without humans), this pattern of results might suggest either that irrelevant faces tend to attract women’s attention to a greater extent than men’s attention (Brosch et al., 2007), or that humans faces are intrinsically more relevant to women than men.

The presence of an asymmetrical N1 is also consistent with the right-lateralization of functions related to face coding in men (Proverbio et al., 2006a, 2010), as revealed by the amplitude of face-related N1 responses. Related ERP data are paralleled by behavioral studies on chimeric face processing demonstrating bilateral face processing in women (Bourne & Maxwell, 2010; Bourne, 2005). Indeed, N1 (known in the literature as N170) is a negative occipito/temporal response that is usually larger to faces

<p>| Table 1. Mean Amplitude Values of N2 Response Recorded in Women and Men as a Function of the Face Age |
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<table>
<thead>
<tr>
<th>Sex</th>
<th>Face Age</th>
<th>Mean (μV)</th>
<th>SE</th>
<th>-95%</th>
<th>+95%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Women</td>
<td>Adults</td>
<td>-3.0382</td>
<td>0.65292</td>
<td>-4.3651</td>
<td>-1.7113</td>
</tr>
<tr>
<td>Women</td>
<td>Children</td>
<td>-3.4575</td>
<td>0.64314</td>
<td>-4.7645</td>
<td>-2.1504</td>
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<tr>
<td>Women</td>
<td>Infants</td>
<td>-4.5764</td>
<td>0.61641</td>
<td>-5.8291</td>
<td>-3.3237</td>
</tr>
<tr>
<td>Men</td>
<td>Adults</td>
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<td>0.65292</td>
<td>-3.2697</td>
<td>-0.6159</td>
</tr>
<tr>
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<td>Children</td>
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<tr>
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<td>Infants</td>
<td>-3.5518</td>
<td>0.61641</td>
<td>-4.8045</td>
<td>-2.2991</td>
</tr>
</tbody>
</table>
than control objects (such as cars and words) (Rossion, Joyce, Cottrell, & Tarr, 2003). N1 is thought to reflect the activity of face-specific coding areas such as the fusiform gyrus (Itier & Taylor, 2004; Henson et al., 2003; Liu, Higuchi, Marantz, & Kanwisher, 2000). The finding that N1 was affected by face properties over the left hemisphere only in women strongly agrees with fMRI findings (Glocker, Langleben, et al., 2009), showing that baby schema specifically increases left fusiform gyrus (FFA) activity in women, independent of activity in the mesocortical limbic system (nucleus accumbens).

In our study, the amplitude of orbito-frontal negativity (N2) indicated an enhanced response to infants as opposed to adult faces. Source reconstruction analysis relative to this signal identified the left fusiform gyrus (BA 19) and OFC (BA 11) as the main sources of activation for the infant response (along with other areas related to the affective processing of faces, such as uncus and cingulate cortex). This finding agrees fully with available neuroimaging literature (Glocker, Langleben, et al., 2009; Kringelbach et al., 2008; Strathearn et al., 2008; Leibenluft et al., 2004; Nitschke et al., 2004), suggesting the existence of a preferential response driven by the view of infants and, particularly, by the so-called baby schema. Bartels and Zeki (2004) have elucidated the correlation between the so-called maternal love and the activation of the pleasure circuit. The authors used fMRI to measure brain activity in mothers while they viewed pictures of their own and of acquainted children. The results showed strong activation of the orbito-frontal and anterior cingulate cortices, as well as the periaqueductal gray matter, which has direct links to OFC and contains a high density of receptors for vasopressin and oxytocin, which are attachment-mediating neurohormones (Loup, Tribollet, Dubois-Dauphin, & Dreifuss, 1991). The present data suggest the presence of a preferential response to infants (extended to unknown individuals), especially in the female brain.

LORETA’s inverse solution is consistent with available neuroimaging evidence, suggesting the existence of a neurophysiologic mechanism by which infant faces can stimulate the mesocorticolimbic system. It was presently found that this neural circuit is more intensely activated in females than in males. We found stronger electromagnetic signals during perception of infant as compared to adult faces in the fusiform gyrus (left in women, right in men) (Proverbio et al., 2010). The fusiform gyrus is devoted to face processing but has a major entry node in the ventrally located extended limbic and prefrontal face network. OFC (BA 11) and ACC (BA 24) were also strongly activated by infant faces (more in women than in men). Notably, ACC projects onto the nucleus accumbens and is activated during reward-based decision-making (Bush et al., 2002). On the other hand, the increased activation of FG might suggest that the baby schema allocates increased attention resources to infant faces, which might be reflected in the attention-capturing effects of infant faces (Tobias et al., 2008; Brosch et al., 2007). Unlike the MEG study by Kringelbach et al. (2008), which found an medial orbito-frontal (mOBF; 130 msec) and then an FFA (165 msec) increase in response to infant faces, we are unable to establish whether the neural circuit implies an mOBF modulation of FFA cortex. However, these areas (along with other limbic and temporal regions) were strongly modulated in women as compared to men and in response to infant as compared to adult faces.

Interestingly, the male brain observed in the present study did not react differently to children as a function of their age, whereas the female N2 orbito-frontal response was of greater amplitude to faces with a high baby schema value (infants) as compared to older children, indicating that infant faces are more rewarding to female than male observers.

At this point, it may be interesting to compare the temporal component of responses found in the present and in the MEG study by Kringelbach et al. (2008), which, unlike other fMRI studies, can provide some temporal resolution. In our study, occipito-temporal cortex indexed by the N1 component displayed a relatively early modulation of its activity as a function of perceived age of faces (at about 160 msec), which is fully compatible with the differences in power between infant and adult faces found around 165 msec, in the 20–25 Hz band in the
FFA (possible generator or N1 response) (Kringelbach et al., 2008). As for the anterior brain, in the MEG study, the first significant difference in power between infant and adult faces was found at \( \sim 130 \) msec (in the 10–15 Hz band) in mOBF cortex. It is entirely possible that the earlier effect reported for OBF cortex depends on methodological differences between the studies. For example, in the MEG study, faces were emotionally charged (happy, neutral, and sad faces), and it is well known that negatively valenced expressions are processed faster than positive or neutral faces. Furthermore, in our study, landscapes with no humans elicited responses, whereas in the MEG study, participants were required to maintain fixation at all times and to press a button whenever the fixation cross changed color from red to green (pictures were never targets). It is also possible that increases in synchronized postsynaptic potentials are detected later than changes in EEG power. Kringelbach et al. also observed important effects for the viewing of infants versus adults during the 250–350 msec time window (in the 10–30 Hz EEG band).

One possible limitation of the present study is that faces were not actively attended to (attention was paid to landscapes), and this might have affected the sex difference. Another possible limitation concerns the limited spatial resolution of the LORETA inverse solution in determining intracranial generators of surface brain activity. However, the validity of our results is supported by the similarities between the neurally significant sources of activation

<table>
<thead>
<tr>
<th>Magnitude</th>
<th>x [mm]</th>
<th>y [mm]</th>
<th>z [mm]</th>
<th>Hem</th>
<th>Lobe</th>
<th>Area</th>
<th>BA</th>
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<td>P</td>
<td>Inferior parietal lobule</td>
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| Men       |        |        |        |     |      |      |    |
| 11.18     | 50.8   | −66.1  | −10.9  | R   | T    | Fusiform gyrus | 19 |
| 11.03     | −38.5  | −86.4  | −12.4  | L   | O    | Inferior occipital gyrus | 18 |
| 8.01      | −38.5  | 27.2   | −11.2  | L   | F    | Inferior frontal gyrus | 47 |
| 7.93      | 1.5    | 38.2   | −17.9  | R   | F    | Medial frontal gyrus | 11 |
| 6.81      | −38.5  | −15.3  | −29.6  | L   | T    | Inferior temporal gyrus | 20 |
| 6.80      | 21.2   | −0.6   | −28.2  | R   | Limbic | Uncus | 36 |
| 6.57      | 1.5    | 16.2   | −4.5   | R   | Limbic | Anterior cingulate | 25 |
| 6.48      | 11.3   | 4.3    | 11.6   | R   | Sublobar | Caudate, caudate body |
| 5.20      | 1.5    | −5.6   | 28.5   | R   | Limbic | Cingulate gyrus | 24 |
| 3.00      | −38.5  | −21    | 35.7   | L   | P    | Postcentral gyrus | 3 |
| 2.28      | −18.5  | −73    | 49.2   | L   | P    | Precuneus | 7 |

Table 2. Talairach Coordinates Corresponding to the Intracranial Generators Explaining N2 Surface Voltage Recorded by Subtracting ERPs to Adults from ERP to Infants in the 250–300 msec Time Window, According to sLORETA, in Women (Power RMS = 34.7 \( \mu \)V) and Men (Power RMS = 29.7 \( \mu \)V)

Grid spacing = 5 mm; estimated SNR = 3; unit = nAm.
provided by LORETA and those provided by neuroimaging and MEG studies on the same topic.

Conclusions

In summary, MEG (Kringelbach et al., 2008) and fMRI (Glocker, Daniel, et al., 2009) evidence support the existence of a visual (left FFA) and orbito-frontal response triggered by baby schema in humans. In both studies, the gender of viewers was not considered, either because subjects were all females (Glocker, Daniel, et al., 2009) or because males and females were considered as a single group. To our knowledge, the present investigation is the first study where the brain response to faces was investigated by varying the age of infants and by examining both sexes. We discovered that the visual response and the prefrontal response exhibited gradients that were inversely correlated with the age of the individuals depicted by the stimulus material. Women showed a greater modulation of brain responses as a function of face age. Women showed earlier face/object discrimination (at the P1 rather than the N1 level), adult/infant discrimination in both left and right visual areas at the N1 level (instead of only over the right hemisphere as in men), but especially in the anterior response to baby schema (N2 level), with N2 of greater amplitude in response to infants than children. Notably, the study participants (neither male nor female) had no particular familiarity with children’s faces, as the presence of siblings and young relatives in the subjects’ families and involvement in professional activities related to childcare were criteria for exclusion from the study. For this reason, we believe that visual familiarity with baby schema was matched between sexes and that sex differences were more likely to be due to neurobiological factors (such as attention, motivation, and social instinct) as opposed to cultural factors.

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REFERENCES


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