ERP correlates of attention allocation in mothers processing faces of their children

Damion J. Grasso *, Jason S. Moser, Mary Dozier, Robert Simons

University of Delaware, 108 Wolf Hall, Newark, DE 19716, United States

ARTICLE INFO

ABSTRACT

This study employed visually evoked event-related potential (ERP) methodology to examine temporal patterns of structural and higher-level face processing in birth and foster/adoptive mothers viewing pictures of their children. Fourteen birth mothers and 14 foster/adoptive mothers engaged in a computerized task in which they viewed facial pictures of their own children, and of familiar and unfamiliar children and adults. All mothers, regardless of type, showed ERP patterns suggestive of increased attention allocation to their own children's faces compared to other child and adult faces beginning as early as 100–150 ms after stimulus onset and lasting for several hundred milliseconds. These data are in line with a parallel processing model that posits the involvement of several brain regions in simultaneously encoding the structural features of faces as well as their emotional and personal significance. Additionally, late positive ERP patterns associated with greater allocation of attention predicted mothers' perceptions of the parent–child relationship as positive and influential to their children's psychological development. These findings suggest the potential utility of using ERP components to index maternal processes.

© 2009 Elsevier B.V. All rights reserved.

The mother–child bond plays an ethologically important role in promoting a child's survival and healthy development. As infants of many species are born completely dependent upon their mothers, the absence of a mother's attention would likely result in perilous circumstances for her infant. For example, a rat mother that does not adequately attend to her pups would fail to protect them from predators or to provide them with nourishment. Similarly, a human mother who does not attend to her infant might fail to protect the infant from unnecessary harm or to provide the nurturance necessary to promote the infant's welfare. Delineating the neurobiological mechanisms underlying maternal attention may result in a better understanding of the nature of the mother–child bond under both adaptive and maladaptive circumstances.

Whereas olfactory stimuli are the most salient social cues for many non-human mothers, visual information gleaned from facial features appears to be especially salient for humans (Zebrowitz, 2006). Facial features provide the means to recognize familiar vs. unfamiliar individuals and to ascertain valuable information such as age, race, gender, and emotional state. The perception of faces also evokes emotionally laden, affiliative memories and plays a facilitative role in forming and maintaining human affiliations (Depue and Morrone-Strupinsky, 2005). Given the social utility of faces, there are several neurological mechanisms in place to facilitate the rapid processing of facial information, including the identification of emotional or motivational significance of face stimuli (for reviews see Adolphs, 2002 and Vuilleumier and Pourtois, 2007).

Event related brain potentials (ERPs) provide a non-invasive, temporally sensitive method of studying the neural mechanisms subserving face processing. The advantage of using ERPs, characterized by their polarity and position along the waveform, is that they offer the ability to examine stimulus processing at different functional stages. In the context of the mother–child relationship, the point at which a mother's brain selectively responds to her child's face may have implications for her ability to take meaningful action towards her child under various circumstances and therefore may prove instrumental to the child's survival and healthy development.

One classic model of face processing posits the orchestration of several brain regions operating simultaneously to encode structural features of a face, as well as to extrapolate higher-level meaning and significance from face stimuli (Bruce and Young, 1986). Extensive research in this area has linked ERP components emerging at varying points along the waveform to these functionally unique but related brain processes. For example, ERP components that peak at frontocentral recording sites relatively early in the waveform, such as N1, P2, and N2, have shown increased positivity to affective face stimuli compared to neutral faces (Eimer and Holmes, 2007). Although these ERP components have also been associated with non-emotional aspects of stimulus processing when studied in different contexts (Dien et al., 2004), their positive shift following affective face

* Corresponding author. Tel.: +1 860 301 7641.
E-mail address: dgrasso@psych.udel.edu (D.J. Grasso).

stimuli has been attributed to the rapid detection of emotional content of faces (Eimer and Holmes, 2007). In fact, some evidence suggests such processing may occur pre-attentively, responding to emotional content even before conscious awareness (see Kiss and Eimer (2008)). Occurring almost simultaneously with the fronto-central P2 is the N170 component, a negative deflection typically observed at parietal and temporal electrode sites. The N170 has been shown to discriminate between face and non-face stimuli, but has not shown modulation by facial emotion (Eimer and Holmes, 2007). Some argue that the N170 reflects activity of face-specific areas of the visual cortex, namely the fusiform gyrus (Eimer and Holmes, 2007; Haxby et al., 2000). In contrast to N170, the later peaking P3 and LPP components, like the early frontocentral positive shift in N1, P2, and N2, show enhanced positivity to emotional compared to neutral faces (cf. Eimer and Holmes, 2007). However, unlike these earlier components, the effect on P3 and LPP is more broadly distributed and manifests at frontal and parietal electrode sites, suggesting recruitment of different neural mechanisms across time during affective face processing (Eimer and Holmes, 2007). The enhanced P3 and LPP to affective faces may therefore reflect further, perhaps higher-level evaluation of the emotional content of faces. Together, the early and late enhanced positivities observed in the context of affective face processing (Eimer and Holmes, 2007) may reflect an ethologically valuable facility to selectively attend to the emotional significance of face stimuli. Similar to affective facial expression, face stimuli that represent an affiliate or loved one, even if presented with a neutral expression, will possess some degree of emotional significance and so may also recruit increased neural activity (Palermo and Rhodes, 2007). Indeed, recent findings show that the P3 component, for example, is enhanced during viewing of pictures of friends and relatives compared to newly learned faces (Bobes et al., 2007). Broadly speaking, these ERP modulations may reflect what Schupp et al. (2004) refer to as motivated attention, or "[attention to]... emotionally arousing stimuli [that] activate the brain's motivational circuits..." (p. 594). Thus, whereas early frontocentral and later distributed enhanced positivities to emotional faces seem to reflect significance processing, as proposed by Bruce and Young, the N170 appears to index the structural encoding mechanism.

To our knowledge, there are no studies that have examined visually evoked ERP correlates of attention allocation to one's children. In fact, very little work in general has explored neurological mechanisms involved in the processing of stimuli relating to one's children. One study reported increased attention and arousal in postpartum mothers to their own infants' cry vs. a neutral word stimulus compared to non-mothers, as indexed by a frontocentral negative deflection occurring 100 ms after stimulus onset (i.e., the auditory N1 ERP component; Purhonen et al., 2001). Similarly, one fMRI study reported high levels of activation in prefrontal regions and areas associated with motivation and reward including the ventral tegmental area, retrorubral field, and nucleus accumbens when mothers listened to infant cries (Lorberbaum et al., 2002). Other researchers have studied maternal attentional processes using paradigms in which mothers viewed facial pictures of their children. Leibenluft et al. (2004) showed that when mothers viewed pictures of their own children compared to pictures of other children they exhibited increased activation in the right amygdala and left anterior insula, both associated with responses to emotionally significant stimuli. In another fMRI study, postpartum parents viewing own and other infant pictures exhibited increased activation in the anterior cingulate, thalamus, amygdala, putamen, and insula, particularly in parents demonstrating high sensitivity to their children as determined by observational coding of parent–child interactions (Swain et al., 2007).

Considering the dearth of research examining neural correlates of attentional processes in human mothers and the ability of ERPs to reveal temporally sensitive cognitive and emotional processes, the primary aim of the current study was to examine ERPs while mothers passively viewed pictures of their children and other, familiar and unfamiliar, children and adults. In so far as frontocentral and parietal positive shifts reflect enhanced processing of emotionally significant stimuli, we hypothesized that mothers would show more positive N1, P2, N2, P3, and LPP responses to their own children compared to familiar and unfamiliar children and adults (cf. Eimer and Holmes, 2007). Modulation of the N170 component was not expected, as it is mainly associated with the structural encoding of facial stimuli (Eimer and Holmes, 2007).

In order to help rule out the possibility that ERP patterns were the result of greater familiarity of faces and not their emotional significance per se, we compared ERPs generated in response to familiar vs. unfamiliar faces of children and adults. Like others (e.g., Bobes et al., 2007) we chose to control for familiarity by including newly learned faces as opposed to faces of acquaintances in order to prevent varying degrees of familiarity between subjects caused by differences in the amount of time spent with acquaintances.

Another goal of the study was to investigate possible differences in ERP patterns between mothers who had given birth to their child and surrogate mothers who had not given birth to the child in their care (i.e., birth mothers vs. foster/adoptive mothers). This comparison is interesting given two competing perspectives: that birth mothers attend to their children's needs to a greater degree than foster/adoptive mothers vs. that foster/adoptive mothers are more attentive to their children's needs. Evidence favoring birth mother advantages suggests that the hormonal changes that occur during pregnancy and the period of mother–child bonding immediately following birth critically influence subsequent maternal behavior (reviewed in Numan and Insel (2003)). In addition, some evolutional theorists maintain that because foster/adoptive parents and their children do not share biological ties that they invest fewer resources in their children than do birth parents (Hamilton et al., 2007). To our knowledge the only empirical research in support of this perspective was conducted by a group of anthropologists who reported decreased parental investment in stepfathers of non-kin children (Anderson, 2005; Anderson et al., 1999a; Anderson et al., 1999b). In contrast, a different theory asserts that adoptive parents show greater investment than birth parents because of a motivation to compensate for not being their children's natural parents (Hamilton et al., 2007). Indeed, foster/adoptive parents typically must complete rigorous training regimens and are often considered to have a unique, altruistic motivation to care for children, and in some cases to reverse the negative consequences of their children's early adversity. Hamilton et al. (2007) compared birth and adoptive parents on a number of variables and reported that adoptive parents allocated more resources (i.e., economic, cultural, social, interactional) than birth parents but attributed some of these effects to adoptive parents' older age, higher education, and greater socioeconomic status. We considered our comparison of birth and foster/adoptive parents to be important, but entertained both possibilities and thus made no specific hypotheses regarding differences in ERP responses to their own children vs. other children and adults.

We also sought to investigate possible differences in mothers' ERP patterns as a function of individual differences in caregivers' perceived relationships with their children, specifically caregivers' perception of their relationships as positive (i.e., Acceptance), permanent (i.e., Commitment), and important to the child's emotional and psychological development (Awareness of Influence; Bates and Dozier, 1998). These constructs may be useful