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Observing videos of a baby crying or smiling induces similar, but not identical, electroencephalographic responses in biological and adoptive mothers

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ABSTRACT

It is well-known that adoptive mothers respond to cues from their babies in similar ways to biological mothers, and that cortical processing is critical for adequate motive–emotional maternal responses. This study used electroencephalographic activity (EEG) to characterize prefrontal, parietal and temporal functioning in biological mothers (BM), adoptive mothers (AM), and non-mothers (NM), while viewing videos of a baby smiling or crying. The BM presented higher absolute power (AP) in the delta and theta bands (associated with pleasant, positive emotional experiences) in the frontal and parietal areas under all conditions. In response to the smiling video, both types of mothers presented a lower AP in alpha1 in the three cortices (indicative of increased attention) and, mainly in temporal areas, a higher AP in the fast frequencies (beta and gamma, reflecting increased alertness to sensory stimuli and cognitive processing). This EEG pattern in the BM and AM could reflect the greater attention and, probably, the positive mood caused by the smiling video, showing that both are sensitive to these pleasant stimuli. When viewing the video of a baby crying, the AM had higher AP in the fast frequencies (temporal and parietal areas), indicating that they were more reactive to this unpleasant video, while the NM presented only a lower AP in alpha1 in all cortices, a finding that could be associated with the general activation induced by these unpleasant stimuli as a consequence of their lack of maternal experience. These findings should help improve our understanding of the neural mechanisms involved in the processing of sensorial stimuli that establish affective-emotional links during motherhood.

1. Introduction

Studies have demonstrated that sensory stimulation from the newborn is capable of regulating and maintaining maternal behavior (Rosenblatt, 1994; Díaz-Rosello & Ferreira-Castro, 2008). The efficacy of different sensory stimuli in inducing maternal behavior is species-dependent; *e.g.*, while olfactory stimuli are the most salient social cues for many non-human mothers, such as rodents (Fleming & Rosenblatt, 1974; Lévy & Keller, 2009), facial expressions of emotions are key regulators

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in humans (Trevarthen & Aitken, 2001; Zebrowitz, 2006). Research has also shown that, for example, the perception of facial expressions, such as a baby crying or smiling, causes different intensities of motherly feelings (Noriuchi, Kikuchi, & Senoo, 2008) and affiliative memories that facilitate the formation and maintenance of human bonds (Depue & Morrone-Strupinsky, 2005).

Diverse cortical and subcortical structures have been related to maternal responsiveness and the interpretation of facial emotional expressions (Nitschke et al., 2004; Ranote et al., 2004) to affective photographs (Leibenluft, Gobbini, Harrison, & Haxby, 2004), or film clips (Strathearn, Li, Fonagy, & Montague, 2008). One cortical area that plays an important role in maternal responses is the prefrontal cortex (PFC), which mediates the stimulus salience, executive function, affective valence, affect regulation and working memory of motivated behaviors (Groenewegen & Uylings, 2000). Lesions in this area result in deficits of sequential execution and spatial orientation of motivated behaviors, including maternal behavior (Afonso, Sison, Lovic, & Fleming, 2007). In humans, the dorsolateral PFC is activated when mothers see their own children (Noriuchi et al., 2008), while a variety of infant stimuli, including positive or negative photographs and video clips, induce activation of several sub-regions of this cortex (Strathearn et al., 2008; Nitschke et al., 2004; Leibenluft et al., 2004). Two additional cortical areas that, it has been suggested, also participate in the maternal response, are the temporal and parietal lobes. The former, specifically the left posterior superior temporal sulcus, is activated to a greater extent when subjects observe emotional expressions as opposed to neutral expressions (Lenzi et al., 2009), and when mothers observe children (Leibenluft et al., 2004). The parietal cortex, meanwhile, participates in several functions of the processing of infant-related tactual experiences and is related to the suckling stimulus, as both animal (Xerri, Stern, & Merzenich, 1994) and human models (Cervantes, Ruelas, & Alcala, 1992) have shown.

In humans, the first months of motherhood are accompanied by structural and functional changes in the brain regions implicated in maternal behavior (Kim et al., 2010a). Noriuchi et al. (2008), for example, evaluated responses to infant cues using video clips to demonstrate, through functional magnetic resonance imaging (fMRI), that several brain areas are involved in recognizing one's own infant, including the orbitofrontal cortex and the anterior insula, among others. Similarly, using fMRI Ranote et al. (2004) found an activation of visual processing regions during maternal responsiveness to infants in the dorsolateral and medial prefrontal cortices, the orbitofrontal cortex, and the post-central gyrus, among other areas.

The recording of the electroencephalographic activity (EEG) is a useful tool that allows us to ascertain brain functionality in relation to specific emotional, cognitive and behavioral situations. In humans, the frequency spectrum of EEG activity is broken down into five bands: delta, theta, alpha, beta and gamma. The delta band contains frequencies below 4 Hz and is normally seen in the deeper stages of sleep and during states of motivational urges triggered by biological rewards, attention and salience detection (Knyazev, 2012). The theta band includes frequencies of 4 to 8 Hz and is normally seen during the lighter stages of sleep, pleasant (Sammler, Grigutsch, Fritz, & Koelsch, 2007) and relaxed states (Cervantes et al., 1992), and positive emotional experiences (Aftanas & Golocheikine, 2001). The alpha band covers the range from 8 to 13 Hz and is normally recorded in awake subjects with eyes closed, or during physical relaxation and relative mental inactivity. The decrease of alpha is an index of increased brain activation, associated with processing of emotional responses to relevant stimuli. The beta band includes frequencies of 13 Hz to 30 Hz and is seen under arousal (Coull, 1998), increased alertness (Murthy & Fetz, 1992), or as a response to optimal sensory stimuli. Finally, the gamma band (from 31 to 60 Hz) has been associated with cognitive processing and perceptual experience (Rieder, Rahm, Williams, & Kaiser, 2011).

The EEG recording method has been used in several studies to investigate the neural bases of parenting (Maupin, Hayes, Mayes, & Rutherford, 2015). For example, in a primiparous mother, Cervantes et al. (1992) found a prevalence of synchronic 6–10 Hz EEG waves in the central–parietal and parietal–temporal derivations (predominantly on the right side) while she was breastfeeding her own child, a finding that they interpreted as an association between these periods of synchronic 6–10 EEG waves and the pleasant or relaxed experiences elicited during suckling. In another EEG study, Killeen and Teti (2012) assessed the frontal asymmetry of mothers and found that during observation of videos of their 5-to-8-month-old infants expressing three emotional states (joy, anger/distress, and neutral interest) they presented a greater right frontal activation regardless of the emotional valence. They interpreted their results as a major empathetic response by the mothers to their infants' emotions.

Adoptive mothers—*i.e.*, women who have not experienced the hormonal changes of pregnancy or breastfeeding– display adequate caring behaviors, protection and responsiveness toward a baby's cues (Singer, Brodzinsky, & Ramsay, 1985; Juffer & Rosenboom, 1997) in ways similar to those manifested by biological mothers (Juffer & Rosenboom, 1997; Suwalsky, Hendricks, & Bornstein, 2008). At present, however, the literature includes only one study in which EEG recordings – specifically, event-related potentials (ERPs) – were used to examine brain functionality in birth *vs.* foster/adoptive mothers while viewing pictures of their children. The authors found that all mothers, regardless of type, exhibited ERP components that reflect greater attention allocation to a mother's own children. These processes were recruited very quickly from the faces of one's own child and similarly by birth mothers and foster/adoptive mothers, suggesting that, like biological mothers, adoptive mothers devote greater attention to the sensory stimuli emitted by their own infants (Grasso, Moser, Dozier, & Simons, 2009).

Although various behavioral experiments have reported that the structure of the mother–baby behavior repertoire is similar in dyads by birth and dyads by adoption (Singer et al., 1985; Juffer & Rosenboom, 1997; Suwalsky et al., 2008), the neural processes that participate in maternal responses to a baby's cues in these two types of mothers are unknown.

We were interested in characterizing the cortical EEG of biological and adoptive mothers while viewing videos of a baby smiling and crying. In light of Leibenluft and colleagues' study (2004), in which stronger responses in brain areas associated