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Listening to a baby crying induces higher electroencephalographic synchronization among prefrontal, temporal and parietal cortices in adoptive mothers

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ABSTRACT

Women who adopt babies show caring behaviors and respond to stimuli from their infants just as biological mothers do, but several studies have shown that the cerebral functionality of biological mothers (BM) and adoptive mothers (AM) changes in relation to the type and emotional mean of the stimuli they receive from their babies. The complex perception and processing of different stimuli with emotional content (such as those emitted by babies) require functional synchronization among different cortical and subcortical brain areas. To determine whether the degree of functional synchronization between cortices varies when they perceive such stimuli, this study characterized the degree of cortical electroencephalographic (EEG) synchronization (correlation) among prefrontal, temporal and parietal areas in BM, AM and non-mothers while listening to a recording of a baby crying. BM showed a decreased EEG synchronization between the prefrontal and temporal cortices that may indicate a decrease in the modulatory control that the former exerts on the posterior cortices, and could be associated with deeper emotional involvement and increased sensitivity to the baby crying. The AM, in contrast, had higher degree of EEG synchronization between cortical areas in both hemispheres, likely associated with a greater modulation of the affective information of the crying baby, which allowed them to perceive it as less unpleasant. These data enrich our knowledge of the neurofunctional changes involved in motherhood, and of the neural processes that allow mothers (biological and adoptive) to be sensitive to their infants' cues and respond appropriately.

1. Introduction

After parturition, women show maternal behaviors that promote the newborn's well-being (Pryce, 1992). Maintaining these caring behaviors is facilitated by hormonal influences (Bridges, Numan, Ronsheim, Mann, & Lupini, 1990; Fleming, Steiner, & Corter, 1997; Gordon, Zagoory-Sharon, Leckman, & Feldman, 2010; Stolzenberg et al., 2009) and the quality and intensity of the exteroceptive and somatosensory stimuli that mothers receive from their infants (Numan, 1994). Mothers must be sensitive to their infants' cues and it has been shown that crying is one of the most attractive and salient exteroceptive

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stimuli in terms of inducing caring behaviors in mothers. Human mothers can even recognize different types of crying (Donovan, Leavitt, & Walsh, 1998;Stallings, Fleming, Corter, Worthman, & Steiner, 2001) and seek proximity to the infant upon hearing them (Bell & Ainsworth, 1972), while also manifesting important changes in cerebral functionality in response to them (Hernández-González, Hidalgo-Aguirre, Guevara, Pérez-Hernández, & Amezcua-Gutiérrez, 2016; Lorberbaum et al., 1999, 2002; Laurent & Ablow, 2012; Seifritz et al., 2003).

Though several brain structures have been associated with the detection and processing of a baby's crying in biological mothers (Lorberbaum et al., 1999, 2002; Laurent & Ablow, 2012; Seifritz et al., 2003), much more information is needed concerning the neural activity and connectivity of these regions. The electroencephalogram (EEG) is defined as a mixture of rhythmic sinusoidal-like fluctuations in voltage generated by the brain. In humans, the frequency spectrum of EEG is divided into five bands: gamma, beta, alpha, theta and delta. The gamma band (31–60 Hz) has been associated with cognitive processing and perceptual experience (Rieder, Rahm, Williams, & Kaiser 2011); while beta, with frequencies of 13–35 Hz and low amplitude, is seen under conditions of arousal (Coull, 1998) and increased alertness (Murthy & Fetz, 1992), or as a response to optimal sensory stimuli. Alpha (8–13 Hz with variable amplitude) is normally recorded in awake individuals with eyes closed, or under conditions of physical relaxation and relative mental inactivity. A decrease in alpha is an index of increased brain activation associated with the processing of emotional responses to relevant stimuli (Andreassi, 2000; Ray & Cole, 1985; Steridae, 2005). Theta includes frequencies of 4–8 Hz and is normally seen in drowsiness and during the lighter stages of sleep, as well as in pleasant (Sammler, Grigutsch, Fritz, & Koelsch, 2007), relaxed (Cervantes, Ruelas, & Alcala, 1992), and positive emotional states (Aftanas & Golocheikine, 2001), whereas delta (frequencies <4 Hz with high amplitude) is recorded in the deeper stages of sleep and during states of motivational urges triggered by biological rewards, attention and salience detection (Knyazev, 2012).

Studies of brain functioning during maternal responses have used measurements of scalp-recorded EEG activity (Cervantes et al., 1992; Grasso, Moser, Dozier, & Simons, 2009; Hernández-González et al., 2016for a review, see Maupin, Hayes, Mayes, & Rutherford, 2015) and have demonstrated that certain EEG parameters may be useful in reflecting substantial changes during affective-emotional responses to stimulation emitted by babies. For example, Cervantes et al. (1992) reported higher synchronic activity of 6–10 Hz EEG waves in the central–parietal and parietal–temporal derivations of a primiparous mother while she was breastfeeding her own child. Similarly, Killeen and Teti (2012) found that during observation of videos of their 5–8-month-old infants, mothers presented greater right frontal activation, regardless of the emotional valence.

Maternal behavior, like other processes – including cognition and emotion – depends on the integration of activity in different brain regions (Nunez, 1981; Pribram & Luria, 1973; Thatcher et al., 1986). In fact, the complex perception and processing of different stimuli with emotional content (such as the crying emitted by babies) require functional synchronization among different cortical and subcortical brain areas (Rudrauf et al., 2008), defined not only by anatomical pathways but also by the synchrony of neural activity that occurs in distant areas during mood and cognitive states (for a review, see Guevara & Corsi-Cabrera, 1996; Harris & Gordon, 2015; Lopes da Silva, 1991). Although several measures are available for quantifying EEG synchrony (Alba, Marroquin, Peña, Harmony, & Gonzalez-Frankenberger, 2007; Dauwels, Vialatte, Musha, & Cichocki, 2010), two of the most common methods in the literature are coherence and correlation analysis. Both are mathematical indices that allow the determination of the degree of synchronization between two EEG signals that may be associated with functional coupling (Shaw, 1981) in different brain areas. The coherence of EEG activity measures the relation between two pairs of signals as a function of frequency (Shaw, 1981) and is affected by power and phase changes (Guevara & Corsi-Cabrera, 1996). EEG correlation, meanwhile, is calculated in the time domain (Shaw, 1984) and is sensitive to both phase and polarity, regardless of amplitude. Hence, when interest focuses primarily on waveform and time-coupling between two sites, correlation is a better choice than coherence (Guevara & Corsi-Cabrera, 1996).

It is well-documented that over the course of pregnancy and through the postpartum period, dramatic structural and functional changes occur in the woman's neural system that may, in fact, be a consequence of the construction of the maternal brain (Fleming, Steiner, & Corter, 1997; Gordon, Zagoory-Sharon, Leckman, & Feldman, 2010; Kinsley & Meyer, 2010; Leuner et al., 2010 Leuner, Glasper, & Gould, 2010). Maternity, however, does not refer only to a blood relation, for it also exists in cases of adoption. While, obviously, adoptive mothers (AM) do not experience the physiological changes of pregnancy as biological mothers (BM) do, they care for, and protect their babies (Fontenot, 2007; Juffer & Rosenboom, 1997; McKay & Ross, 2010; Suwalsky et al., 2008), respond in a similar way to babies' cues, and the maternal attachment they show does not differ from that which is typical of BM (Espinoza, Yuraszeck, & Salas, 2004; Grasso et al., 2009; Singer, Brodzinsky, Ramsay, Steir, & Waters, 1985). To date, few studies have evaluated EEG activity in adoptive mothers. Grasso et al. (2009) recorded EEG activity and used the visually-evoked, event-related potential (ERP) technique to compare the responses of these two types of mothers while observing their own children, one familiar and one unfamiliar child, and one familiar and one unfamiliar adult. They found that in both groups, the N1, P3 and LPP components were significantly more positive in fronto-central and parietal–central regions in response to pictures of their own children, which suggests that the electrophysiological indicators of cognition and emotion are modulated similarly in BM and AM. Another study determined that BM and AM showed similar EEG responses to the pleasant, emotional-affective state generated by observing videos of babies' smiles; whereas only the latter presented more marked EEG changes in prefrontal, parietal and temporal areas while viewing videos of a baby crying (Hernández-González et al., 2016).

Though various experiments have reported that the structure of the mother-baby behavior repertoire (Juffer & Rosenboom, 1997; Singer et al., 1985; Suwalsky et al., 2008) and the EEG activity of cortical areas is similar in BM and AM (Hernández-González et al., 2016), the last are faced with an even more challenging task than BM because they must