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Mothers with depressive symptoms display differential brain activations when empathizing with infant faces

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ABSTRACT

Maternal care during the first year of life provides the foundation for the infant's emotional and cognitive development. Depressive symptoms in mothers can undermine their early dyadic interaction, which may lead to various psychopathological disorders with long-term consequences. During this period, the mother-child interaction is exclusively preverbal and is based on the mother's ability to understand her infant's needs and feelings (i.e., empathy) and on reciprocal imitation of facial expressions that promote a social dialog that influences the development of the infant self. To study the effects of maternal depressive symptoms on neural circuits underlying these processes, we studied 16 healthy mothers (H) and 14 mothers with depressive symptoms (D), as assessed by the Center for Epidemiologic Studies Depression Scale. Subjects underwent functional magnetic resonance during observation/empathizing (OE) and imitation (IM) of the faces of both their own child and of that of an unknown child aged between 6 and 12 months. During OE, D deactivated the orbital and medial prefrontal cortex to a greater extent (compared with H), thus pointing to an increased internally focused cognitive style during rest. Moreover, D, in respect to H, displayed a greater reactivity of the right amygdala, which may be an expression of emotional dysregulation.

1. Introduction

Depression represents a complex psychiatric condition whose prevalence is particularly high within the female population (Kessler et al., 1993). Indeed, during pregnancy and in the postpartum phase, up to 20% of the women report high levels of depressive symptoms (Gotlib et al., 1995; Kessler et al., 1993). Even when criteria for major depression are not met, depressive symptomatology may impact the quality of parenting, mainly by influencing the quality of mother–child interactions. When compared with non-depressed mothers, mothers with marked depressive symptoms are more likely to perceive themselves as less adequate and less competent in the parenting role (Field et al., 1985; Teti and Gelfand, 1991; Whiffen and Gotlib, 1989).

Imitation and empathizing are thought to be the core of communication between a mother and a child during the preverbal period (Tronick, 2007). Infants are sensitive to the quality of the mother's affective expressions, a mechanism that enables emotional exchanges between mother and child. A highly sensitive mother is inclined to imitate her infant demonstrating that she is able to read the infant's feeling state promoting a social dialog that shapes the infant's self-development (Field et al., 2009; Tronick, 2007). Furthermore, we know that imitative capabilities are present also in the newborn from the very first days of life, thereby making mother-child reciprocal imitation a very common form of communication (Meltzoff and Moore, 1977). Maternal empathy and responsiveness are also crucial for the building of the attachment bond, which, according to the attachment theory (Bowlby, 1958), subsequently determines the nature of the infant's future relationships (Bowlby, 1958; Meltzoff and Moore, 1977; Weinberg and Tronick, 1998). Reciprocal imitation during face-to-face interactions are much less present in mothers with depressive symptoms; moreover, depressive symptomatology impairs the mother's empathic abilities and understanding, thereby

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contributing to interaction disturbances with long term consequences in the future adult (Coyne et al., 2007; Field, 2010).

A series of studies based on functional magnetic resonance imaging (fMRI) performed on healthy parents exposed to their own child's stimuli have shown the activation of subcortical and cortical systems, including fronto-temporal and striatal areas, as well as the thalamus/hypothalamus, insula, orbitofrontal cortex, and anterior cingulate cortex (Lenzi et al., 2009; Swain, 2008; Swain et al., 2014). These areas are believed to underlie reward and motivational processes as well as empathic and regulating elements, which are needed to build a sensitive parental response.

Social neuroscience studies conducted on the neural bases of imitation and empathy have found that these functions rely, at least in part, on the so-called mirror neurons, which are located mainly in fronto-parietal and medial temporal areas (Bernhardt and Singer, 2012; Cattaneo and Rizzolatti, 2009; Gallese, 2013; Iacoboni, 2005; Mukamel et al., 2010).

Further studies designed to investigate the neural substrate of maternal depression have identified dysregulation in neural circuits involved in normal parental response (Laurent and Ablow, 2012; Price and Drevets, 2012). In particular, areas in the orbitomedial frontal cortex (OMPFC, which encompasses the anterior cingulate) have revealed a reduced neural response to various child stimuli (pictures, words and sounds) (Laurent and Ablow, 2013, 2012; Moses-Kolko et al., 2010; Silverman et al., 2007). A circuit that links the OMPFC to limbic areas, which include the amygdala and cingulum, is reported to be centrally involved in mood disorders (Öngür and Price, 2000; Price and Drevets, 2012). In particular, depression is believed to arise from limbic hyperactivity and inadequate regulation by the OMPFC (Suslow et al., 2010; Victor et al., 2010). These latter sets of areas are known to be also part of the so-called default mode network (DMN), i.e. sets of areas that are more active at rest than during tasks in humans (Fox et al., 2005a, 2005b; Qin and Northoff, 2011). In early imaging studies, primarily focused on the brain response to active tasks (activation), the rest > task difference was termed “deactivation” and was observed in DMN areas (Raichle et al., 2001). Further studies revealed that the DMN showed functionally correlated activity during extended periods of continuous rest–while a person was engaged in “stimulus independent thought” (Fox et al., 2005). In particular, depressive symptoms such as rumination, increased self-referential activity and poor attentional control have been reported to be associated with changes in the DMN, mainly in terms of increased connectivity (Bartova et al., 2015; Broyd et al., 2009; Fox et al., 2005; Smith et al., 2009; Whitfield-Gabrieli and Ford, 2012).

Studies on maternal amygdala show that its activity is linked to personal relevance and is part of the healthy response to infant stimuli (Lenzi et al., 2009; Strathearn and Kim, 2013). Reports on depression show contradictory results and found amygdala hypoactivity as well as hyperactivity in depressed subjects. In particular, in one study on maternal post-partum depression amygdala reduced activity was correlated with disease severity and impaired maternal attachment processes during an emotional face-matching task (Moses-Kolko et al., 2010). Conversely, others found greater activation of the amygdala in depressed subjects compared to healthy subjects (Hamilton and Gotlib, 2008; Sheline et al., 2001; Siegle et al., 2002). In our opinion, the coexistence of both increased and decreased activity in these kind of patients could be explained by other psychological factors, such as emotional dysregulation, often seen in depression (Beauregard et al., 2006).

On the basis of these findings, we have investigated in a previous study the neural correlates of maternal communication studying imitation and empathizing with own infant faces in healthy mothers (and compared with an unknown child) and described the brain areas involved in normal mother–child interaction (Lenzi et al., 2009). The aim of the present study, which is a continuation of it, was to further investigate how maternal depressive symptoms can affect these fundamental systems. In particular we studied children expressing the typical emotions of that period of life i.e. joy, distress, ambiguity and neutrality (Izard et al. 1983).

On the basis of the afore-mentioned scientific background, we hypothesize that mothers with depressive symptoms show, when compared with healthy mothers, reduced brain activation in areas normally involved in imitation and empathizing of any faces and especially when comparing own child versus an unknown child as well as differences in limbic activation during emotional tasks when compared with neutral ones. We also expected to find increased activation during the rest phase with respect to active phase in areas known to be part of the DMN as a result of increased internally focused attention, exacerbated when the subject is not involved in externally driven activity. To test these hypotheses, specifically we focused on (i) main effects of both groups for all conditions together (regardless of child type or expression), in terms of both activation and deactivation, to better describe areas related to imitation and empathizing; (ii) main effects of emotion versus neutral and differences between the two groups to better study limbic and paralimbic areas; (iii) main effects of own child versus other child and differences between the two groups to better isolate maternal brain circuits; and (iv) the interaction between these last two factors for specific effects.

2. Methods

2.1. Subjects

We recruited 30 right-handed primiparous mothers, aged from 23 to 42 years (mean 31.5, SD 4.8 years): 16 subjects were without psychopathological symptoms (H) while 14 were at risk of post-maternal depression (D). The mothers' children were all first-born, non-adopted (12 females and 18 males) and aged between 7 and 12 months (mean 9.4, SD 1.3 months).

Exclusion criteria were as follows: (a) history of major medical illnesses, (b) presence of other psychopathological symptoms, (c) on-going medical therapy, (d) pregnancy, (e) MRI contraindications. All participants gave their informed consent and the study was approved by the local ethics committee.

2.2. Psycho-diagnostic screening and psychological testing

The Center for Epidemiological Studies Depression Scale (CES-D) (Radloff, 1977; Pierfederici et al., 1982) was administrated to quantify depressive symptomatology. Mothers with scores exceeding 20 on the CES-D were considered at risk for depression (mean 29.4, SD 5.56; range 23–42); normal mothers had a mean CES-D score of 13.5 (SD 4.7; range 3–18).

The Symptom Checklist-90-Revised (SCL-90R) (Derogatis, 1977) was administered to exclude any other psychopathological symptoms.

2.3. fMRI

2.3.1. Stimuli

Each baby was videotaped during a face-to-face interaction with the mother; 48 full-face, color pictures, with eye gaze on the center, were then selected from each video-recording. Video-recordings were analysed to define specific affective configurations, according to various precise, coded combinations of the changes observed in the forehead, nose and mouth. Four expressions (distress–S, ambiguous–A, joy–J, and neutral–N) per child (own