

Functional MRI and parental responsiveness: a new avenue into parental psychopathology and early parent–child interactions?

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The advent of functional neuroimaging techniques has led to great advances in our understanding of some of the biological aspects of psychiatric disorders. Tools such as positron emission tomography and functional magnetic resonance imaging (fMRI) allow us to complement research from genetic, animal and clinical studies by providing information about the patterns of brain activation underlying particular behaviours, and have even begun to challenge current theories and treatments. For example, the finding that hypoperfusion of Broca's area occurs during symptom provocation in post-traumatic stress disorder suggests that these patients might find it difficult to label and describe their emotions; 'talking therapies' might therefore be of limited value during some phases of post-traumatic stress disorder (Hull, 2002).

However, certain fields of research, despite an extensive 'non-imaging' literature, appear so far to have escaped the neuroimaging revolution. One field of great relevance to psychiatry is that of parental responsiveness and parent–child interactions. At first glance, the lack of research in this area may be explained by the apparent absurdity of trying to study these issues within, for example, the confines of an MRI scanner. However, on closer inspection, relatively straightforward functional neuroimaging studies could be conducted that would help to illuminate the neural processes underlying parental emotional responses to children. Furthermore, because distortions from 'normal' interactions (especially in the context of parental psychiatric disorder) might adversely influence child development, it is important that this line of research be pursued.

SENSITIVE PARENT–CHILD INTERACTIONS

Good quality parent–infant interactions require reciprocity. One example of reciprocity

can be observed in a 'protoconversation', where the mother and infant demonstrate turn-taking patterns of vocalisations (we refer to 'the mother' merely because most of the research has been conducted with mothers). The responses of each partner are contingent on those of the other, and a matching of infant and maternal emotional expressions occurs. These early types of communication are thought to promote language development and emotional regulation in infants. Infants as young as 2 months of age are sensitive to the timing and emotion of maternal expressions, and become confused and distressed if the mother is instructed to keep a still face and ignore the infant's emotional cues (Trevathan & Aitken, 2001).

Of particular concern to clinicians are cases where mothers fail to respond sensitively to infants' emotional cues. For example, mothers with postnatal depression may show intrusive or withdrawn behaviour in interactions with their infants. These impaired interactions have been shown to be associated with adverse effects on the child's later socio-emotional and cognitive development (Murray & Cooper, 1997).

Electroencephalographic studies have further revealed that infants of depressed mothers often show asymmetries in frontal activation, which may affect their social, attentional and emotional regulation development (Dawson & Ashman, 2000).

RECOGNITION AND RESPONSE TO INFANT CUES

At the simplest level, mother–child interactions are built up from the mother and the infant recognising and responding to each other. It is the parental recognition of, and emotional response to, infant cues that we propose could be studied using fMRI. Techniques based on simple infant responses (e.g. non-nutritive sucking to elicit the presentation of a particular stimulus)

have revealed that even 2-day-old infants recognise their mother's face, voice and odour of her breast milk (Bremner *et al*, 1997; Porter & Winberg, 1999). This recognition is reciprocal; mothers can recognise their infants by sight, by their cry, by smell and even touch within a few hours of birth (Kaitz *et al*, 1992). If mothers and infants are predisposed to attend to sensory cues from one another, it might be expected that there could be a biological basis for this recognition. Papoušek (2000) noted that some maternal responses to infant cues occur so quickly (within 200–400 ms) that they are considered too fast for conscious perception. In earlier work, Papoušek also observed mothers responding to infant behavioural cues (such as different hand positions during different states of alertness), even though they reported being unaware of such signals. This further suggests that there may be some relatively automatic parenting responses to infant-specific sensory and behavioural cues ('intuitive parenting' responses) (Papoušek, 2000).

Animal models highlight the biological basis of parent–child interactions; infant-specific stimuli (e.g. visual appearance, odour, vocalisation) can elicit maternal behaviour in many species (Rosenblatt & Snowdon, 1996). These maternal behaviours (e.g. nest building, pup-licking, grooming, carrying and arched-back nursing) are particularly easy to observe in rodents, and many of the neurobiological, genetic and hormonal determinants of these behaviours are now well established (Leckman & Herman, 2002). Lesion studies in rats have implicated roles for various brain regions (e.g. the medial preoptic area of the hypothalamus, the ventral part of the bed nucleus of stria terminalis and the lateral septum). Although comparisons between species should be made with caution, these findings provide a starting point for hypothesis-driven investigations into the patterns of activation that one might expect to find in humans.

NEUROIMAGING HUMAN MATERNAL BEHAVIOUR

To date, it has been difficult to examine the biological origins of parental responsiveness in humans. It is generally not feasible to use fMRI with infants, but fMRI has expanded our understanding of the neurobiological basis of emotion perception in adults and has provided implications for

psychiatry (Phillips, 2003). Adult faces are the stimuli that are typically presented, but similar procedures using photographs or video clips of infant faces would provide an easy starting point for examining patterns of adult brain activation in response to infant cues. Increasingly, fMRI is being used with olfactory and tactile cues and, in the future, it may present the opportunity to examine brain activity in response to infant-specific cues in these other sensory modalities. The existing neuroimaging evidence also allows hypotheses concerning areas of activation that one might expect to find; these might include the amygdala, hippocampus, anterior cingulate and insula, which are all important in memory of emotionally salient material and social signalling (Phillips, 2003). Some of these areas also overlap with those believed to be involved in maternal behaviour (e.g. hippocampus and amygdala; see Leckman & Herman, 2002).

Functional MRI also provides the opportunity to identify changes in neuronal processing independently of any measurable behavioural change (such as amygdala activation during subconscious processing of fearful faces; see Phan *et al*, 2002). Therefore, fMRI might further our knowledge of the neural basis of 'subconscious' or 'automatic' parental responses, such as those described by Papoušek (2000). Combined with measurements of physiological variables (to help interpret blood-oxygen-level-dependent signals), fMRI could reveal more about variations in parental responsiveness that have been demonstrated sometimes in the absence of behavioural differences. For example, when viewing videotapes of smiling and crying infants, mothers with and without a childhood history of physical abuse report similar affective states but show differences in patterns of skin conductance (Casanova *et al*, 1994).

An extensive literature search of peer-reviewed journals identified only one study using fMRI to study maternal human behaviour (Lorberbaum *et al*, 2002). In this study, brain activation was recorded as mothers heard the sound of an infant crying, white noise sounds (matched for intensity with the cry) or nothing. The results provide some evidence for the role of thalamocingulate circuitry in maternal responses and revealed that, in general, the activations observed were consistent with neuro-anatomical studies of rodent maternal behaviour (including activation in the bed

nucleus of stria terminalis and in the lateral septum). It was also noted that activation unique to the cry signal was predominantly right-sided, consistent with accounts of emotion lateralisation (Best *et al*, 1994). However, Lorberbaum *et al* (2002) did not present mothers with the sound of their own infant crying, and behavioural evidence suggests that this is likely to influence the response (Cismaresco & Montagner, 1990). Additionally, studies of different types (e.g. basic *v.* pain) of infant cry and cries from different groups of infants (e.g. full term *v.* preterm) have been shown to elicit different subjective and physiological responses in adults. Although Lorberbaum *et al* used two cry stimuli – one from a low-risk and one from a high-risk infant – they do not report whether these different cries produced different patterns of brain activations. Because differences in the fundamental frequency of the cry may reflect the neurophysiological status of the infant signal, it is also problematic that the white noise stimulus used by Lorberbaum *et al* was not frequency-matched with the cry.

Close examination of the innovative Lorberbaum *et al* study therefore highlights the need for carefully designed control stimuli (as with all functional neuroimaging studies) if we are to be able to draw conclusions concerning maternal responsiveness. Nevertheless, the study illustrates the feasibility of using functional neuroimaging to investigate maternal responsiveness and raises many questions for future investigation.

IMPLICATIONS FOR PSYCHIATRY

One question raised by Lorberbaum *et al*'s study is whether mothers with depression, who have been shown behaviourally to be less responsive than non-depressed mothers to infant distress cries, show systematic differences in brain activation in response to hearing infant cries. Similar questions could be posed of parents with different psychiatric disorders and in response to different infant cues (e.g. facial expressions). Recent work by Harmer *et al* (2003) suggests that antidepressants can lead to changes in healthy adult responses to facial expressions. If it were found that such medications modulated mothers' responsiveness to infant facial cues, then this could be important in guiding treatment (e.g. psychotherapy *v.* medication) for depression in the postnatal period. Some

behavioural interventions aimed at improving maternal sensitivity (in both 'normal' and high-risk groups) have proved successful already, particularly when the interventions involve fewer than five sessions, are focused at enhancing sensitivity and start at least 6 months after birth (Bakersmans-Kranenburg *et al*, 2003). The finding that the success of interventions is dependent on their specificity and timing suggests further that there may be central pathways of parental responsiveness at work. If the neural correlates of parental behaviour could be identified, then eventually it may be possible to target interventions more specifically and evaluate their mechanisms of action.

In the same way that neuroimaging has provided a framework for research and evaluation of treatment in post-traumatic stress disorder, we suggest that fMRI has the potential to elucidate pathways of parental responsiveness that might potentially inform the development and evaluation of interventions in parental sensitivity.

DECLARATION OF INTEREST

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