



The functional neuroanatomy of the evolving parent–infant relationship

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ABSTRACT

Infant survival and the development of secure and cooperative relationships are central to the future of the species. In humans, this relies heavily on the evolving early parent–infant social and affective relationship. While much is known about the behavioural and psychological components of this relationship, relatively little is known about the underlying functional neuroanatomy. Affective and social neuroscience has helped to describe the main adult brain networks involved, but has so far engaged very little with developmental findings. In this review, we seek to highlight future avenues for research by providing a coherent framework for describing the parent–infant relationship over the first 18 months. We provide an outline of the evolving nature of the relationship, starting with basic orienting and recognition processes, and culminating in the infant's attainment of higher socio-emotional and cognitive capacities. Key social and affective interactions, such as communication, cooperative play and the establishment of specific attachments propel the development of the parent–infant relationship. We summarise our current knowledge of the developing infant brain in terms of structure and function, and how these relate to the emergent abilities necessary for the formation of a secure and cooperative relationship with parents or other caregivers. Important roles have been found for brain regions including the orbitofrontal, cingulate, and insular cortices in parent–infant interactions, but it has become clear that much more information is needed about the developmental time course and connectivity of these regions.

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Abbreviations: PFC, prefrontal cortex; OFC, orbitofrontal cortex; ERP, event-related potential; Nc, negative central; NIRS, near-infrared spectroscopy; PET, positron emission tomography; fMRI, functional magnetic resonance imaging; IFG, inferior frontal gyrus; EEG, electroencephalography; STG, superior temporal gyrus; MEG, magnetoencephalography; BOLD, blood-oxygen-level dependent; DTI, diffusion tensor imaging; SSP, strange situation paradigm; AQS, attachment Q-set.

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1. Introduction

Early relationships between infants and parents are of fundamental importance for the survival and development of one's own infant, and ultimately ensure the survival of the species (Darwin, 1872; Lorenz, 1943). Humanity is a very social species that invests heavily in nurturing and protecting the young. Accumulating evidence indicates that early life experiences have a major impact upon adult mental and physical health (Shonkoff et al., 2009).

These important early parent–infant interactions are central to understanding human nature and have over the years been the subject of a large body of behavioural research (e.g., Papousek and Papousek, 1983; Stern, 1985; Tomasello et al., 2005; Trevarthen and Aitken, 2001). However, it has only recently become possible to link aspects of these interactions to brain activity in both infants and parents using advanced neuroimaging techniques. Affective and social neurosciences have begun to emerge as exciting disciplines characterising the brain networks involved in the processing of reward, pleasure, emotion, empathy and related behaviours (Adolphs, 2003; Brothers, 1990; Cacioppo et al., 2007; Decety and Ickes, 2009; Dolan, 2002; Fiske and Taylor, 2008; Frith, 2007; Frith and Frith, 2007; Frith and Frith, 2010; Harris, 2003; Kringelbach and Berridge, 2009a; Lieberman, 2007). While a substantial volume of evidence has served to elucidate the intricacies of the social and affective brain in adults (Kringelbach, 2004), less is known about its development in the early years.

In this review, we focus on synthesising current knowledge about the development of the functional neuroanatomy of the evolving parent–infant relationship. We start by providing a coherent framework for describing and understanding the nature of early parent–infant interactions that has emerged from the behavioural literature. Using this behavioural framework, we describe what is known about the construction of the infant brain and the emerging abilities used to process uni- and multimodal sensory stimuli. Over time, these fundamental abilities allow infants to engage in complex social relationships with parents, caregivers and others. We also describe how the complementary parental responses change over the course of infant development, and the neural basis of such responses. We have chosen to focus largely on the human literature, since the translation between animal and human work remains speculative, and much of the

research on early non-human relationships has been reviewed elsewhere (e.g., Insel, 1997; Young et al., 2008).

Here, we focus on the first 18 months of life, since the middle of the second year is, in many respects, a developmental landmark which signifies the end of infancy. While the first few years are particularly important because vital development occurs across all domains, there is good evidence that major elements of the social and affective brain continue to develop well past early childhood (Meltzoff et al., 2009). The fundamental research presented here has important clinical applications because disturbances to normal early interactions, particularly in the context of parental psychological disorder, increase the risk of difficulties in child development (Squire and Stein, 2003; Stein et al., 2009). A better understanding of the development of the functional neuroanatomy of the early parent–infant relationship could thus have direct implications for enhancing affective development and experience (Kringelbach and Berridge, 2009b).

2. A behavioural framework for the early parent–infant relationship

From the existing behavioural literature, it is clear that there are a number of important components in the development of the parent–infant relationship. Based on current evidence, we have classified and further described six major components of the relationship: (1) orienting system; (2) recognition system; (3) intuitive parenting; (4) attachment relationships; (5) intersubjectivity; and (6) higher socio-emotional and cognitive functions (Fig. 1).

2.1. Orienting system

The early parent–infant relationship is defined by the immediate propensity of infants and parents to be attracted to and seek contact with one another. This *orienting system* serves to bring about close proximity between the two members of the dyad, thereby facilitating their interaction. On the part of the parent, there is attraction to infant characteristics, such as 'cuteness' (Darwin, 1872; Lorenz, 1943), which help to secure parental attentiveness. This orienting response of attraction to infants is present in adults who are not parents, and may be linked to evolutionary mechanisms ensuring survival of the species. From early postpartum, the orienting system helps to initiate interper-

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