



Neuroanatomical and neurochemical basis of parenting: Dynamic coordination of motivational, affective and cognitive processes



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ABSTRACT

This article is part of a Special Issue “Parental Care”.

Becoming a parent is arguably the most profound transforming experience in life. It is also inherently very emotionally and physically demanding, such that the reciprocal interaction with the young changes the brain and behavior of the parents. In this review, we examine the neurobiological mechanisms of parenting primarily discussing recent research findings in rodents and primates, especially humans. We argue that it is essential to consider parenting within a conceptual framework that recognizes the dynamics of the reciprocal mother–young relationship, including both the complexity and neuroplasticity of its underlying mechanisms. Converging research suggests that the concerted activity of a distributed network of subcortical and cortical brain structures regulates different key aspects of parenting, including the sensory analysis of infant stimuli as well as motivational, affective and cognitive processes. The interplay among these processes depends on the action of various neurotransmitters and hormones that modulate the timely and coordinated execution of caregiving responses of the maternal circuitry exquisitely attuned to the young’s affect, needs and developmental stage. We conclude with a summary and a set of questions that may guide future research.

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Introduction

Transition to and the experience of parenting transforms the brain, including structural and functional modifications to behaviorally adjust to the new demands of caring for the young. Even under optimal conditions, motherhood is inherently very physically and emotionally demanding, in which a healthy reciprocal interaction with the young is instrumental in developing and maintaining the balance required for both the mother’s physiological and mental health and the development and well-being of her young.

Perhaps one of the most fundamental and important changes in recent years has been the conceptual shift in the approach to the study of parental behavior that now considers the complexity of this experience requiring dynamic coordination of multiple interacting brain systems and processes. New understandings of parenting as a complex and multifaceted relationship process (involving both agency and action) rather than a simple stimulus–response reflexive behavior, is changing the traditional paradigm of maternal behavior research. Converging evidence from both human and animal studies highlights the intricate interplay of numerous neural, mental and behavioral processes of perception, motivation, affect, cognition

(learning and memory, attention, behavioral flexibility, and decision making processes) and motor performance in shaping the mother’s behavior to engage in a selective and enduring reciprocal emotional relationship with the young (Gonzalez et al., 2012; Leuner et al., 2014; Lovic and Fleming, 2004; Pereira et al., 2014). Significantly, accumulating evidence indicates that many mammalian species besides humans have affective experiences, including a capacity for empathy (Bartal et al., 2011, 2014; Campbell and de Waal, 2011; Chen et al., 2009; Clay and de Waal, 2013; Custance and Mayer, 2012; Foote and Crystal 2007; Langford et al., 2006; Mogil, 2012; Panksepp and Lahvis 2011; Silk, 2007), and that empathy and related pro-social behaviors are key to parenting (Atzil et al., 2012; Decety, 2011; Feldman, 2012; Watt, 2005).

In this review, we survey and integrate current understanding of the functional neural circuitry that subserves mammalian parenting, with a special emphasis on affective, motivational and cognitive processes. In mammals, the mother is most typically the primary caregiver of the young, and thus most research findings discussed in this review are from studies performed in mothers. However, we acknowledge the emerging evidence from animal and human studies regarding the brain basis of parenting in biological fathers and adoptive parents that indicate common neurobiological mechanisms underlying parenting in all caregivers (Abraham et al., 2014; Atzil et al., 2012; de Jong et al., 2009; Dulac et al., 2014; Franssen et al., 2011; Kim et al., 2014; Kozorovitskiy et al., 2006; Lambert et al., 2011; Lee and Brown, 2007; Parker et al., 2001; Rosenblatt et al., 1996).

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Studying parenting in the context of social understanding: a mother becomes a mother through a relationship with her young

We argue that the conceptualization of parenting in the context of the dynamics of the reciprocal relationship between a mother and her young is fundamental to this new approach (Fig. 1). Within this framework, parenting is the result of a process of interaction between a mother and her offspring that impacts the brain and behavior of both members of the dyad, to which the offspring makes as important a contribution as the mother. The mother's interpretation of these social interactions depends on a combination of many factors, including genetics, as well as early-life and current experiences, and is organized by motivational, affective and cognitive processes that coordinate the mothers' contingent responses at different levels to attend to the infant's social, psychological, behavioral, and physiological needs, and provides the foundation for the infant's well being, development and social adaptation (Bowlby, 1969; Francis et al., 1999; Maestripieri et al., 1997; Trevarthen, 2009 – see Fig. 1). This parental capacity of social understanding, that is to perceive and interpret the offspring's affects, signals and/or actions, and to respond appropriately (i.e., timely and contingently) to their needs exists in most mammalian species, with many cognitive refinements in humans (Ainsworth et al., 1974; Atzil et al., 2014; Bowlby, 1969; Carter and Keverne, 2002; Panksepp et al., 1994; Watt, 2005). In humans, culture is another important factor influencing parenting and the mother–infant relationship (Keller et al., 2008). Importantly, not all mothers mother the same, nor each mother mothers the same at all times. We argue that within- and between-individual variation in parenting is the outcome of the mothers' unique interpretation and coordination of caregiving responses during and in each one of these mother–infant everyday interactions (Atzil et al., 2011; Barrett and Fleming, 2011; Keller et al., 2008; Moses-Kolko et al., 2014).

From this conceptual framework we derive two important corollaries. First, these motivational, affective and cognitive processes are dynamic, in that they are capable of a high degree of plasticity over time

to attune caregiving to the rapidly changing needs of the young. Thus, mothers are able to adjust their caregiving acutely to match the physiological and behavioral needs and demands of their young at a given time (Pereira and Ferreira, 2006), as well as over time to the developmental stage of the young (Grota and Ader, 1969, 1974; Pereira et al., 2008; Reisbick et al., 1975; Rosenblatt, 1975). Importantly, mothers of many mammalian species also coordinate their affective behaviors (e.g., expression of positive affect, affectionate touch, vocalizations, social play, maternal mirroring) to moments of young responsiveness (Bowlby, 1969; Cohn and Tronick, 1987; Feldman et al., 1999b; Trevarthen, 2001). These exquisitely attuned maternal responses to the young in the context of everyday interactions have been proposed as especially significant in the developmental course and outcome of the young (Bowlby, 1969; Feldman et al., 1999a,b; Rosenblatt et al., 1985; Trevarthen, 2001).

Our second implication is that integration within this group of dynamic cognitive, motivational, and affective processes occurs at multiple levels of information processing (involving cortical and subcortical structures), and composes the critical range of domains of functioning subserving parenting. This functional integration may change in phylogeny, with recruitment of higher-order cortical structures as increasingly critical for parenting (e.g., from simple fundamental emphatic capacities in rodents to more complex phenomena of empathy in humans – Panksepp and Panksepp, 2013; Watt, 2005). In addition, natural variations in the functional integration of these cognitive, motivational, and affective processes (i.e., differences in the weighting of these processes on the maternal circuitry) likely underpin individual variability in mothering styles (Atzil et al., 2011; Barrett and Fleming, 2011; Moses-Kolko et al., 2014).

Transition to motherhood

The interplay among these motivational, affective and cognitive processes depends on the action of various hormones (estrogens, progesterone, and lactogens), neuropeptides/neuromodulators (oxytocin and

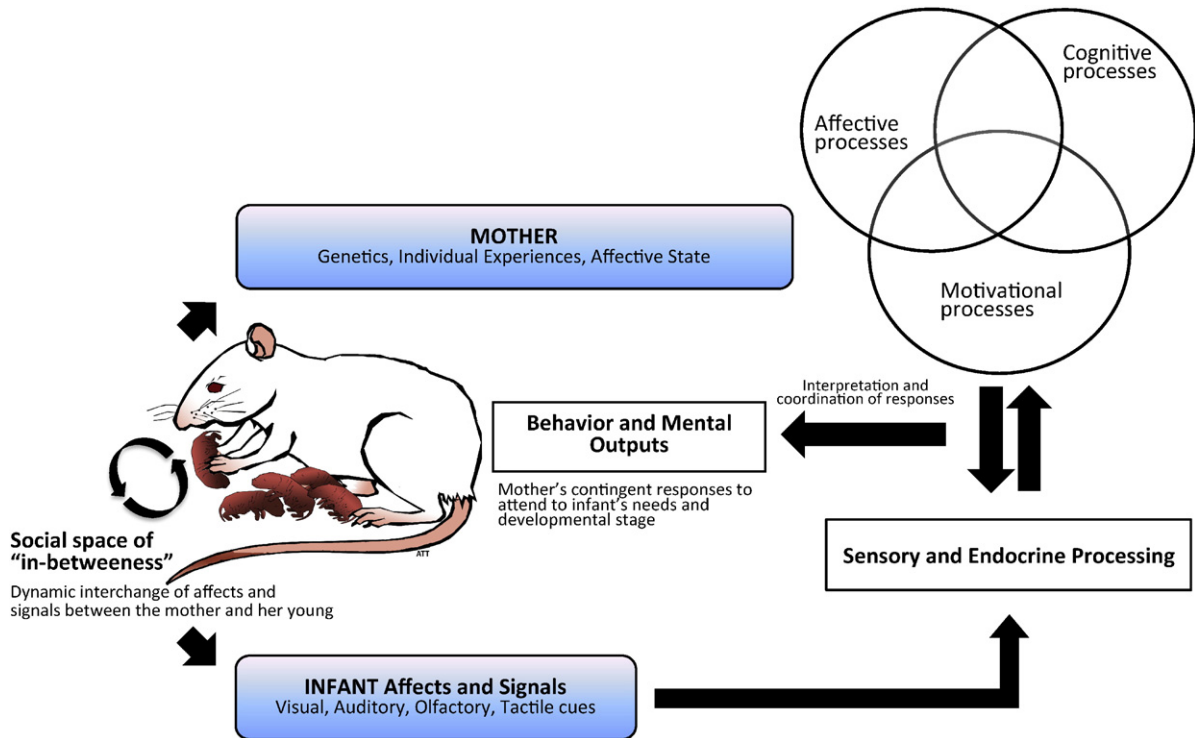


Fig. 1. Parenting in the context of the dynamics of the reciprocal relationship between a mother and her young. The mother's interpretation of her offspring's affects, signals and/or actions depends on a combination of many factors, including genetics, as well as early-life and current experiences, and is organized by motivational, affective and cognitive processes that coordinate the timely and contingent maternal responses to attend to the infant's needs.

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