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Becoming a Parent—Biobehavioral and Brain Science Perspectives

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Abstract

This overview is a synthesis of our current understanding of parent–infant bonding, chiefly from the perspective of the parent's brain physiology. The parent–infant bond is central to the human condition, contributes to risks for mood and anxiety disorders, and provides potential resiliency and protection against the development of psychopathology throughout life. While the complex nature of the phenomena and experimental approaches leads to the consideration of many overlapping parenting brain systems, including sensory, emotion, and cognition to support behavior, a relatively small set of brain regions seem to be robustly involved. These include basal ganglia and related cortex for emotion and drive (striatum, amygdala, hypothalamus, and hippocampus), and regulatory cortical regions (anterior cingulate, insula medial frontal, and orbitofrontal cortices). Work in this field promises to link parental brain performance with resilience, risk, and appropriate treatment toward infant mental health.

Healthy Parenting—The Special Nature of the Postpartum

The human capacity to form enduring emotional attachments with others is central to mental health for both parent and infant. Parenting, a foundational component of secure attachment, may be considered in different ways as a state of mind, a culturally elaborated stage in life, a personal choice, a psychological and biological transition, and a highly evolved necessity for the species. For some, the word conjures up formative memories, for others the anticipated and desired states, and for many an idealization. These varied characterizations underscore how the real and imagined roles of parents profoundly influence our developmental and psychological landscape toward a broad range of mental and physical health profiles of risk and resilience. Given the importance of parenting, surprisingly little work has focused on how humans make the psychological and biological adjustments to accommodate infants in our lives and reach a new hedonic homeostasis.

The interaction between the primary caregiver and the infant is among the most significant of many early environmental influences. Building on the early work of Bowlby and colleagues,[1] efforts to characterize this reciprocal interaction between mother and infant in order to assess its impact on infant and child development have provided a powerful theoretical and empiric framework in the fields of social and developmental psychology. Psychologists are teaming up with neuroscientists and brain-imagers to work on linking underlying brain physiology with parental--infant behavior to develop productive new targets of risk identification and therapy.

Animal Models of the Maternal Brain

There is substantial conservation across mammalian species with respect to the central nervous system events that accompany parenting relationships.[2] Classical lesion studies in rodent model systems (rats, mice, and voles) have implicated the medial preoptic area of the hypothalamus, the ventral part of the bed nucleus of the stria terminalis, and the lateral septum as regions pivotal for regulation of pup-directed maternal behavior through a limited number of key genes and hormones, such as estrogen, prolactin, and oxytocin. Furthermore, maternal behavior in the days following birth serves to “program” the subsequent maternal behavior of the adult offspring as well as establishing the pups’ level of hypothalamic-pituitary-adrenal responsiveness to stress. Indeed, there is growing evidence in animal models that early-life programming affects long-term parenting behavior through altered gene expression and brain development toward alternate brain structure and function. The cycle repeats in the next generation of parenting behavior and infant development.[3]

Psychological Considerations

Largely, empiric studies of the early parent– child relationship have been child centered. Most reports have focused on the development of attachment behaviors in the child and on the moment-to-moment observable, behavioral functioning of the parent–infant dyad. These points of focus have revealed the highly specialized nature of verbal and nonverbal parental behaviors with very young infants. Such studies have highlighted the importance of early synchrony and reciprocity in parent– child interactions, and the critical impact of early experiences on the child’s subsequent attachment behaviors toward the parent—and later in other intimate relationships. Bowlby’s[1] efforts to characterize this reciprocal interaction between mother and infant and to assess its impact on infant and child development have provided a powerful theoretical and empiric framework in the fields of social and developmental psychology. Donald Winnicott, a pediatrician and psychoanalyst, drew attention to “primary maternal preoccupations.” He described this state as “almost an illness” that a mother must experience and recover from to create and sustain an environment that can meet the physical and psychological needs of her infant.[4] Winnicott speculated that this special state of preoccupation or heightened sensitivity develops toward the end of pregnancy and lasts for at least the first few postnatal weeks. This state may heighten their ability to anticipate the infant’s needs, learn his/her unique signals, and over time develop a sense of the infant as an individual.

The mental content of parental preoccupations includes thoughts of reciprocity and unity with the infant, as well as thoughts about the perfection of the infant; idealizing thoughts may be especially important in the establishment of resiliency and the perception of self-efficacy. In addition, these parental preoccupations also include anxious, intrusive thoughts about the infant[5] and connect with behavioral measures of parenting (Kim P, et al. Unpublished data) that likely require the appropriate orchestration of an array of social cognitive response and regulation brain systems.

Becoming a new parent often comes at high physiological and mental cost with the events of pregnancy and childbirth. After giving birth, nursing and feeding are critical parental behaviors during which women describe feeling uniquely close at times with sensual experiences that bring a particular unity between the mother and her infant. For nursing mothers there is the need to increase their caloric intake as well as to remain well hydrated. There is also a revaluing of what is important in life. Care-giving is just one of several competing motivational systems for parents. Parents must also consider the needs of any other children in the family, their occupational duties, the needs of any marital relationship, and the demands of the larger social group so that the advent of a new infant comes with the large and necessary parental emotional adjustment as they make room for a new family member and prepare to enter into a strong and reciprocal relationship with their baby.

Finally, too much or too little primary parental preoccupation may be problematic. Too much can lead to obsessive-compulsive-like states, while too little may set the stage for abuse or neglect in vulnerable, high-risk families. One condition that has been repeatedly associated with disrupted mother–infant attachment and poses a risk factor for children's development across life is maternal postpartum depression. In terms of the primary parental preoccupations, depressed mothers reported fewer preoccupations, particularly related to the building of a meaningful relationship with the infant, such as interacting with the infant in a special way, calling him/her by a nickname, imagining the infant's future, or idealizing the child.[5] These data suggest that depression interferes with the capacity of new parents to invest in forming the relationship with the new infant. Given the importance of normal and impaired psychological functions of parenting, brain imagers have begun to study the underlying neurophysiologic functions.

Functional Neuroimaging of the Maternal Brain in Humans

The use of functional brain imaging designed to examine human brain responses to emotionally charged relationship stimuli, such as baby cries and photographs, is itself in its infancy,[2] but growing rapidly,[6] and investigating brain activity in response to such stimuli as basic baby cries, own baby cries, still pictures, and more recently sophisticated and compelling audiovisual stimuli and analyses. Researchers are moving toward more ethologically authentic and interactive paradigms as well as probes to investigate specific cognitions, using analyses that may yield useful parental brain models.

By way of the briefest introduction, structural, as well as functional data may be gathered by measuring the physical and blood-oxygen-dependant signals in response to infant auditory and visual stimuli. Thus, brain activity is indirectly measured as changes in regional blood oxygenation, between states of action and inaction, for instance, that provide characteristic magnetic signals localized to millimeters as detected by scanners positioned around each subject's head. An important caveat throughout the interpretation of parenting functional magnetic resonance imaging studies, however, is that that although electrical activity of the brain may be nearly instantaneous, with this technique it lags several seconds as blood flow changes, and it is integrated over a few or tens of seconds. Despite limitations, ongoing work is beginning to identify the brain circuits that regulate behavior across parental gender, experience, and timing in mental health, risk, and illness circumstances.

Human brain imaging studies are building on a large literature on animal models that have identified parenting brain circuits, and the central view that evolution has wired them to have many shared features. Indeed, in response to baby cries, a range of human brain systems respond in patterns that agree with much of this animal literature as well as in cortical areas that do not exist in nonhuman animals. These include sensory processing auditory and emotion regulation regions, including auditory and superior temporal gyri, anterior and posterior cingulate cortices, insula and orbitofrontal cortex (OFC), as well as deeper brain motivation and reward centers, including the medial thalamus, ventral striatum, hypothalamus, and midbrain.

Also, consistent with emerging data across species of the importance of oxytocin in regulating social bonds and parenting in particular (as well as the function of breastfeeding itself), recent parent brain neuroimaging papers are showing that the brain circuits that respond to the highly evolved and compelling own baby-cry stimuli are associated with this hormone. Grouping parents according to vaginal vs Caesarean delivery, brain activity is higher in response to own vs other baby-cry in emotion regulation and limbic regions.[7] Further brain-imaging evidence that oxytocin is important for parenting is that mothers grouped by breastfeeding vs formula feeding show increases in connected brain regions.[8]

Another set of pioneering neuroimaging studies shows how perceived maternal care (a human parenting proxy for the animal models' early life licking and grooming) affects both functional response to own baby-cry as well as brain structure.[9] Mothers who reported higher vs lower maternal care in childhood also showed more gray matter volume in higher cortical executive function areas, including the superior and middle frontal gyri, orbital gyrus, superior temporal gyrus, and fusiform gyrus.[9] In the first prospective longitudinal study of gray matter changes early in parenthood,[10] gray matter volumes were compared at 2–4 weeks to 3–4 months postpartum. Within these 3 months of the early postpartum, there were increases in density of the prefrontal cortex, parietal lobes, and midbrain. Furthermore, increased volume in midbrain, a region that drives parenting in animal models was correlated with human maternal positive perception of her baby.

In addition to baby *cry* stimuli, parental brain responses to baby *visual* stimuli have also been studied. Following the hypothesis that reward and emotion circuits, which are important for aspects of romantic love, might also be involved in maternal love, new parents responded to photographs of own, familiar, and unfamiliar children with activations in anterior cingulate, insula, basal ganglia, and midbrain. These regions may mediate the emotionally rewarding aspects of maternal behavior and downregulate activity in areas for negative emotions, avoidance behavior, and social assessment.[11] Thus, there may be a push--pull mechanism for maternal behavior in which child stimuli activate reward and shut down avoidance circuits. Presenting blocks of silent video of own vs other infants to mothers, Ranote and colleagues[12] reported activations in the amygdala, temporal pole, and occipital regions. Considering the contribution of an infant's affect to maternal brain function prompted an extension of the video stimuli to include silent video clips of own babies in play or separation.[13] Increased activity was found to be associated with recognizing own baby pictures, in certain brain regions, including cortical orbitofrontal, anterior insula, and precuneus cortical areas as well as subcortical regions, including the periaqueductal gray and putamen areas active in arousal and reward learning. Furthermore, there were differential responses of mothers' brain to her own-infant's distress in substantia nigra, caudate nucleus, thalamus, posterior and superior temporal sulcus, anterior cingulate, dorsal regions of OFC, right inferior frontal gyrus, and dorsomedial prefrontal cortex. These activations may be part of circuits required for the execution of well-learned movements, and/or part of emotion regulation and habitual behavioral response systems. They also found relationships between responses in OFC and superior temporal regions and emotion, consistent with the emerging importance of these areas in social behaviors. Further brain imaging evidence of hormone regulators of parent emotion has been demonstrated[14] using baby pictures of different emotions to affect parent emotion regulation areas (cingulate), reward regions (striatum), and hormone-control regions (hypothalamus)—proportional to a measure of serum oxytocin. Finally, conceptualizing empathy as a key part of parenting in a study of maternal brain function while observing and imitating faces of their own child and those of someone else, mirror neuron systems responded. These include insula and amygdala, which were more active during emotional expressions from a mother's own child, with insula responses correlating with maternal reflective function, conceptualized as a measure of empathy. Also, across identity, baby joy expressions evoked mostly right limbic and paralimbic areas important to emotional processing, whereas ambiguous expressions elicited responses in left-sided, high-order cognitive and motor areas, reflecting different aspects of maternal thought processing by different brain areas.

Special Parental Populations

Combining brain imaging approaches with psychological measures in parental research is starting to address significant public health issues, such as postpartum depression. One of the first hints at utility showed correlations between depression and brain responses to own baby-cry in frontal control regions that separated vaginal from Caesarean delivered mothers.[7] This suggests that higher depressive symptoms may require more activity for baby response in frontal executive function regions. In a study of frankly depressed mothers relative to healthy mothers,[15] there was significantly reduced left dorsomedial prefrontal cortical face-related activity in response to fear and anger faces as well as inverse relationships. Furthermore, reduced amygdala response to these negative stimuli was associated with depression severity and maternal attachment processes. This suggests that postpartum depression may effectively disconnect the circuit between cortex and amygdala—despite the importance of such regulation for baby response. Further studies with own baby stimuli may reveal the brain basis of depressed maternal function as well as how they recover toward optimizing early detection, prevention, and treatment of parent–infant problems that may be designed to target specific brain regions.

Conclusions

This review is an attempt to synthesize our current understanding of parent–infant bonding from the perspective of the parent's brain physiology. The parent–infant bond is so central to the human condition, contributes to risks for mood and anxiety disorders, and has the potential for resiliency and protection against the development of psychopathology throughout life, not to mention the far-reaching aspects of human attachment across individual behaviors and between cultures. On the one hand, the complex nature of the phenomena and experimental approaches leads to the consideration of many overlapping brain systems of sensory, emotion, and cognition to support behavior. However, in contrast on the other hand, a relatively small set of brain regions seem to be robustly involved across many studies, including the basal ganglia and related cortex for emotion and drive (including striatum, amygdala, hypothalamus, and hippocampus), and regulatory cortical regions of anterior cingulate, medial, frontal, and orbitofrontal cortices that may point to prevention strategies and optimizing treatments for dyadic problems.

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