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Parental brain and socioeconomic epigenetic effects in human development

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Abstract

Critically significant parental effects in behavioral genetics may be partly understood as a consequence of maternal brain structure and function of caregiving systems recently studied in humans as well as rodents. Key parental brain areas regulate emotions, motivation/reward, and decision making, as well as more complex social-cognitive circuits. Additional key environmental factors must include socioeconomic status and paternal brain physiology. These have implications for developmental and evolutionary biology as well as public policy.

Bonding between parents and offspring constitutes the earliest and most influential relationship (Feldman 2007). Building on the work of Bowlby (1978), characterizations of this reciprocal interaction between mother and infant and the impact on infant and child development provide powerful theoretical and empirical frameworks within social and developmental psychology (Cassidy & Shaver 1999). Despite increased physiological, emotional, and economical stress (Barclay et al. 1997), both mothers and fathers typically find themselves highly motivated care for their infants' needs (Goodman 2002; Mercer 1985). Sensitive parenting can diminish anxiety and aggression (NICHD Early Care Research Network 2006) and cultivate resilience after stress (Korosi & Baram 2010). Thus, adults' caregiving for their infants may have roots in early-life experiences with parents (Swain et al. 2012). The possibility that maternal behavior depends on the simultaneous regulation of avoidance and approach motivation raises intriguing questions about possible health implications of maternal caregiving because both motivations are tied to the regulation stress response (Brown et al. 2012). In addition to early-life programming through altered expression of genes in animal models (Champagne 2010), altered brain structure and function in circuitry are directly implicated in the regulation of maternal behavior in humans (Kim et al. 2010b). However, reversal of maladaptive brain outcomes with psychotherapy remains to be shown.

Attempts to understand the human maternal brain with brain-imaging studies of mothers listening to baby stimuli highlight an array of emotion response and regulation circuits, including amygdala (alarm), striatum/nucleus accumbens (NA; motivation and reward), and cingulate (decision making). In humans, cortical regions that have not been highlighted so much in the rodent literature have also been described, including the inferior frontal gyrus (IFG), orbitofrontal cortex (OFC), insula, periaqueductal gray (PAG) and dorsomedial

prefrontal cortex (dmPFC), that regulate complex social-cognitive functions that are selectively engaged when the maternal brain responds to infant stimuli. (For reviews, see Barrett & Fleming 2011; Swain 2011.) Direct studies of baby brain structure and function in response to parenting cues have not been done; however, a pioneering neuroimaging study of mothers showed how perceived maternal care (a proxy for the animal models' licking and grooming behaviors) affects both brain structures and functional response to own-baby cries (Kim et al. 2010b). In this study, mothers who reported higher maternal care in their own childhood showed higher gray-matter density, proportional to the number of neurons, in a range of higher cortical areas and executive function areas, including the insula, superior and middle frontal gyri, orbital gyrus, superior temporal gyrus, and fusiform gyrus. There were also increased functional responses in a number of frontal brain regions and the insula in response to own-baby cries.

Besides the distant effects of mothers' own early-life experiences, the transition to parenthood also involves maternal brain plasticity around childbirth. In the first prospective longitudinal study of gray-matter changes over the first few months of motherhood, gray-matter volume of the insula, prefrontal cortex, parietal lobes, and midbrain areas between 2–4 weeks and 3–4 months postpartum increased (Kim et al. 2010a). Furthermore, greater gray-matter volume in the midbrain (including the hypothalamus, substantia nigra, and amygdala) was associated with maternal positive perceptions of her baby. In contrast, the associated chronic stress of low socioeconomic status (SES) involve the amygdala, hippocampus, and PFC (Hackman et al. 2010; McEwen & Gianaros 2010). Also, young adults' recollection of lower SES from their own childhood was reported to be associated with greater amygdala reactivity to threatening but not nonthreatening faces (Gianaros et al. 2008). Interestingly, current levels of perceived SES were unrelated to amygdala reactivity to threatening face stimuli – only perceived SES in childhood mattered. Indeed, low-SES parents are themselves more likely to exhibit harsh or unresponsive parenting toward their children, and poverty is also associated with a higher incidence of child abuse and neglect (Conger & Donnellan 2007; McLoyd 1998). Low-quality parenting is furthermore associated with altered neurological development, as evidenced by the effects of early-parental care on hippocampus structure. In humans, adults who experienced adverse parenting during their own childhood have significantly smaller hippocampus volumes in adulthood (Buss et al. 2007; Woon & Hedges 2008). However, these studies have not included direct measures of childhood poverty, participants' experiences of either concurrent or childhood chronic stress, or the experience of parenting behaviors. Adults with lower subjective social status had reduced gray-matter volume in the perigenual anterior cingulate cortex (ACC) region of the PFC (Gianaros et al. 2007). These environmentally sensitive brain regions are involved in many cognitive and emotional regulatory functions, including the appraisal of salient events and emotional experiences, as well as the complex behaviors and possibly cardiovascular reactivity in response to environmental demands (Evans 2003; McEwen & Gianaros 2010).

Harsh early-childhood parenting environments also show high amygdala reactivity during an emotion labeling task, positively correlated with high right-ventrolateral-prefrontal-cortex (rvlPFC) activity (Taylor et al. 2006). This can be potentially interpreted as decreased ability of rvlPFC to modulate amygdala activation. Along the same lines, exposure to parental

corporal punishment in childhood is associated with reduced gray-matter volume in mPFC, dorsolateral-PFC, and ACC (Tomoda et al. 2009). On the other hand, lower social status may result in increased sensitivity of mentalization circuits some circuits (Muscatell et al. 2012). Despite a growing literature on the brain physiology important for parenting (Swain 2011), it remains to be shown how the chronic stress of poverty affects these circuits longitudinally. The environmental role of the father brain is also just beginning to be examined (Swain et al., under review). Recent studies demonstrate epigenetic paternal effects (Chong et al. 2007), including the transmission of stress-induced pathologies such as depression (Dietz et al. 2011; Dietz & Nestler 2012). The effects of early-experience on the developing brain for emotion regulation may be further linked to next generations' capacity for sensitive parental behaviors (Francis et al., 1999; Kim et al. 2010b; Meaney 2001) with resulting implications for public policy (Dawson et al. 2000).

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