Understanding How Motherhood and Poverty Change the Brain

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The cost of poverty is high for not only maternal mental health but also infant development and mental health risk. Low-income mothers are at far greater risk to develop postpartum depression compared to middle-income mothers (Goyal, Gay, & Lee, 2010; Segre, O'Hara, Arndt, & Stuart, 2010). Poverty is also associated with mother's inadequate parenting, which can lead to harmful effects on the infant's development (Gunnar, 2000). In the United States, nearly one in four families with infants now live in poverty. Thus, millions of low-income mothers and their children are exposed to greater risks for maternal depression and harsh parenting. Recent neuroimaging studies with human mothers reveal adaptive changes in mothers' brains supporting their transition to parenthood during the postpartum period. In this article, we review normative changes in the maternal brain, how poverty may disrupt such normative changes, and how these factors may in turn increase risk for postpartum depression and harsh parenting. Finally, we discuss how a greater understanding of the maternal brain may inform interventions and treatments for mothers in poverty.

Poverty, Postpartum Depression, and Early Mother–Infant Bonding

The quality of early parental care sets the stage for lifelong health and well-being (Gunnar, 2000; Samerroff, Seifer, & McDonough, 2004). Compared to their middle-income counterparts, low-income mothers are far more likely to be depressed and experience high levels of stress which together compromise their ability to be sensitive and responsive parents. In fact, the postpartum period may be an especially vulnerable time for low-income mothers. Studies of low-income mothers report significantly higher rates of postpartum depression (e.g., 60% in a Medicaid sample; Walker, Timmerman, Kim, & Sterling, 2002) than those observed in the general population (10-15%; Beck, 2001; O'Hara & Swain, 1996; Singer et al., 1999). Greater exposure to chronic and daily stressors experienced by low-income women place them at increased risk for developing depressive symptoms. Women living under severe financial strain have smaller and less diverse social networks, are exposed to multiple psychosocial and physical stressors at home (e.g., divorce, family conflicts, poor housing quality, noise, and crowding; Dohrenwend, 1973; Evans & Kim, 2007), in the community (e.g., violence; Attar, Guerra, & Tolan, 1994) and experience more discrimination (Schulz et al., 2006). Such exposure to chronic stress is associated with greater psychological and physiological stress and mood dysregulation (Evans & Kim, 2012; Evans, Saltzman, & Cooperman, 2001; Lukkes, Mokin, Scholl, & Forster, 2009).

Abstract

Poverty-associated chronic stress is a serious threat not only to a mother's mental health but also to maternal functioning. Recent neuroimaging studies suggest that a mother's brain undergoes dynamic changes to support her transition to parenthood, including better emotion regulation and heightened sensitivity to infants. However, we propose that the chronic stress experienced by low-income mothers may result in damage to such adaptive neural changes, and in turn increase risk for postpartum depression and harsh parenting. Understanding of the neurobiological risk markers involved may help develop more precise interventions and treatments aimed at improving low-income mothers' psychological health and mother–infant relationships.

There is a strong base of evidence demonstrating the deleterious effect that postpartum depression has on a mother's future mental health status, parenting, the mother–child relationship, and child development. For example, mothers who experience postpartum depression are twice as likely to have a later episode of depression (Cooper & Murray, 1995). Also, first onset of postpartum depression and level of severity has been associated with poor infant cognitive functioning (Murray, 1992). Furthermore, depressed mothers are less likely to provide stimulating books and toys for their children and less likely to participate in interactive learning such as singing, imitation, and the telling of stories (Bus, van IJzendoorn, & Pellegrini, 1995; Field, 2010; Haydari, Askari, Nezhad, 2009).

Poverty is also associated with lower quality maternal care and higher risk for child abuse and neglect (Grant et al., 2003; Repetti, Taylor, & Seeman, 2002). It has been reported that poverty is associated with an up to 22-fold increase in risk for child abuse and neglect (Sedlak & Broadhurst, 1996; Widom & Nikulina, 2012). Postpartum depression in combination with increased stress due to lack of financial resources, reduced social support, and risky home and neighborhood environments directly affect parenting efficacy among new mothers in poverty. In addition, associated risk factors such as increased likelihood of single parenthood, poor access to health care, lower educational attainment, and increased drug and alcohol use among low-income mothers serve as indirect factors by which poverty has a detrimental influence on parenting. As demonstrated by Conger and Elder's (1994) family stress model, high levels of finance-related stress have negative effects on parental psychopathology and interparental conflict, which then disrupts effective parenting practices, resulting in damage to children's mental health and well-being. Among low-income mothers of 6- to 36-month olds, economic pressure has been associated with increases in maternal depression and somatization which significantly predict lower levels of sensitive, supportive parenting (Newland, Crnic, Cox, & Mills-Koonce, 2013). Given this wealth of evidence linking poverty to adverse parenting and child outcomes, it is essential that researchers identify points at which prevention and intervention programs can be most effective. In the next two sections, we first review normative and expected changes in maternal brain structure and functioning during the early postpartum period and then discuss how poverty-related stress can disrupt such normative changes in mothers' brains.

Normative Changes in Mothers' Brains

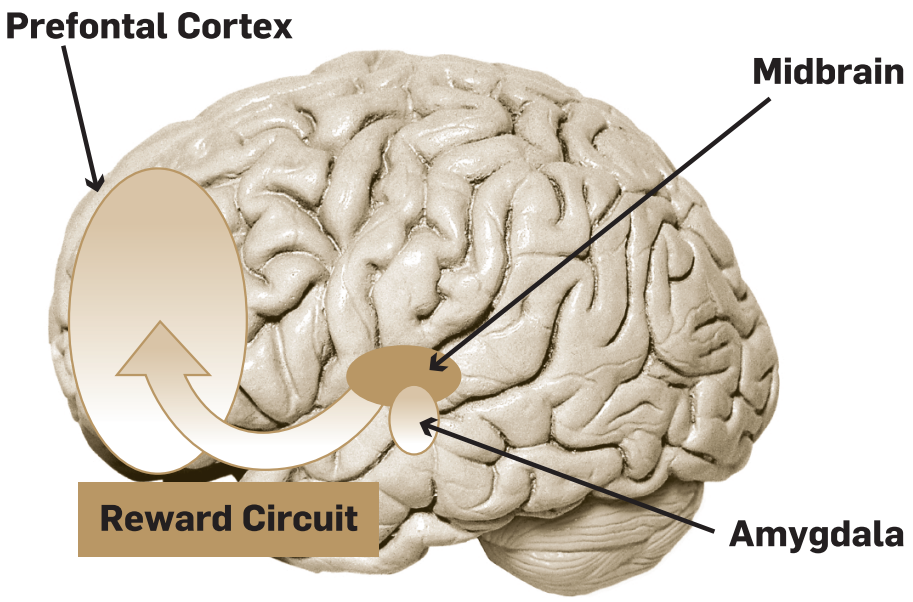
During the early postpartum period, there are normative biological changes that support women's adaptation to parenthood. We will focus on two major changes—the first being reduced stress reactivity and the second being mothers' increased sensitivity to infants.

A dampening of mothers' stress reactivity is a normative process during the postpartum period. Behaviorally, healthy mothers typically report declines in negative moods (Kim, Mayes, Feldman, Leckman, & Swain, 2013). In addition, new mothers exhibit dampened physiological stress reactivity in response to acute stress, indexed by dampened stress hormone (cortisol) responses (Mercer, 1985). In rats, lactating dams also show lower physiological stress responsivity to various stressors, including restraint, forced swimming, noise, and novelty (Neumann, Torner, & Wigger, 2000; Walker et al., 2004).

Such reduced behavioral and neuroendocrine stress reactivity during the postpartum period is mediated by increased levels of parental hormones such as oxytocin. Oxytocin has been found to decrease physiological stress reactivity and to have a calming effect on animals in stressful situations. Oxytocin helps to reduce anxiety via decreased activation of the amygdala (Figure 1), a brain area that assists in the regulation of fear and anxiety, because of an abundance of oxytocin receptors in the amygdala's central nucleus (Bale, Davis, Auger, Dorsa, & McCarthy, 2001). In fact, higher levels of oxytocin have been shown to be associated with decreases in amygdala activation in response to threatening and stressful emotional information such as fearful faces (Kirsch et al., 2005). Postpartum mothers have higher levels of oxytocin than nonmothers and they exhibit reduced amygdala responses to negative emotional information such as fearful faces compared to nonmothers (Rupp et al., in press). The reduced amygdala responses to negative emotional expressions help promote reduced stress reactivity and better emotion regulation. Such dampened stress reactivity can further reduce negative and anxious responses to infant cues such as infant cry sounds and allow mothers to respond to their infants in a more sensitive way. In addition, among nonparent women, acute administration of oxytocin while listening to infant cry sounds results in decreased amygdala activity, indicating reduced negative emotional reactions and increased activity in other brain regions that are important for parenting (Riem et al., 2011).

Another normative change is that mothers report declines in negative moods in tandem with heightened sensitivity to their infants during the first several months postpartum (Belsky & Jaffee, 2006; Coussons-Read, Okun, & Nettles, 2007; Mascaro, Hackett, &

Figure 1. Human brain regions that are important to emotion regulation and parenting. The figure does not show the two-dimenstional location within the brain. The reward circuit includes the midbrain, striatum, and medial prefrontal cortex that are not visually specified here.



Rilling, 2013; Mercer, 1985). In terms of behavior, mothers typically exhibit heightened sensitivity toward infant cues such as cries, smells, and smiles. This is demonstrated by the ability of an infant's gaze to elicit exaggerations in maternal vocalizations, facial expressions, and gazing during mother–infant interactions (Feldman, 2003; Papousek & Papousek, 2002). Infant cries are particularly effective in drawing a mother's attention and bringing her physically close to the infant.

In animals, virgin rats avoid pup stimuli but during the postpartum period pup stimuli activate maternal motivation through the reward system in the brain. Rat pups emit ultrasonic calls as an auditory cue when they are in distress, cold, or far from their mother. Whereas virgin rats tend to neglect or even kill pups, rat mothers respond to the calls by locating pups and retrieving them during the postpartum period (Brewster & Leon, 1980). The reward system facilitates mothers' positive perception of pup stimuli and, in turn, pup stimuli prompt responsive maternal behaviors (Numan, 2007). The maternal motivation areas include the medial preoptic area and the reward circuit along the mesolimbic dopaminergic pathways (Mello & Villares, 1997). The activation of these regions in response to pup stimuli increases dopamine levels in the brain. Such an increase can make pup stimuli appear more positive and rewarding to mothers, who may feel more motivated to respond to their pup's cues. On the other hand, lesions in these areas significantly disrupt maternal behaviors (Numan & Numan, 1997).

In humans, during the postpartum period, typical mothers exhibit increased neural sensitivity to infant cues, such as crying sounds (Feldman, 2007; Feldman, Gordon, Schneiderman, Weisman, & Zagoory-Sharon, 2010; Kim, Mayes, et al., 2013). Functional magnetic resonance imaging (fMRI) studies suggest that increased activity in the midbrain (e.g., ventral tegmental area, substantia nigra), striatal, and medial prefrontal cortex is positively associated with maternal responses to infant cry. The midbrain, striatum, and medial prefrontal cortex (see Figure 1) are major parts of the mesocorticolimbic dopamine pathway and are critically involved in caregiving motivation in animals (Ferris et al., 2005; Numan & Insel, 2003) and humans (Barrett & Fleming, 2011; Kim, Leckman, Mayes, Feldman, et al., 2010; Rutherford, Williams, Moy, Mayes, & Johns, 2011; Swain, 2010; Swain, Kim, & Ho, 2011; Swain, Lorberbaum, Kose, & Strathearn, 2007). Such increased neural activity in the reward circuit is positively associated with maternal sensitivity observed during interactions with infants such as more positive emotions, affective touch, and direct gaze (Atzil, Hendler, & Feldman, 2011; Kim et al., 2011; Musser, Kaiser-Laurent, & Ablow, 2012). Among typical mothers, positive perceptions of their own baby (e.g., adorable, perfect, beautiful, special) also predict an increase in the structure of the midbrain, a key part of the reward circuit (Kim, Leckman, Mayes, Feldman, et al., 2010).

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During the early postpartum period, there are normative biological changes that support women's adaptation to parenthood.

The neural activations in the reward circuit play an important role for mothers in facilitating motivation to provide sensitive care to their infants. By 3 to 4 months postpartum, infants are more socially interactive, and parents increasingly engage in reciprocal positive interactions. These positive interactions further help a mother to strengthen her attachment and heighten the experience of positive feelings toward her infant (Mercer, 1985). As they successfully feed, take care of, and build affectionate connections with their infant, mothers develop positive feelings and self-confidence about parenting (Benedek, 1954). Positive feelings about her infant and her parenting experience may play a critical role in pathways engaging the mother's dopamine-oxytocin reward circuit (MacDonald, 1992; Numan & Insel, 2003). Thus, interactions with their infant may enhance parental oxytocin and dopamine release and foster the maintenance of positive parental behaviors along with associated attentiveness and sensitive caregiving.

Poverty, Chronic Stress, and Changes in Mothers' Brains

However, as mentioned earlier, mothers in poverty experience high levels of chronic stress in multiple contexts: at home, in their communities, and interpersonally. The exposure to chronic stress associated with poverty may interrupt these adaptive processes by influencing the brain regions responsible for emotion regulation and maternal sensitivity. We discuss the potential changes in mothers' brains that can contribute to the increased rates of postpartum depression and harsh parenting observed among mothers in poverty.

First, studies with typical populations suggest that poverty and chronic stress have been associated with neural dysregulation of emotion including increased amygdala reactivity and reduced prefrontal cortex (PFC) activity in response to negative emotional stimuli (Gianaros et al., 2008; Gianaros et al., 2011; Lupien, McEwen, Gunnar, & Heim, 2009; Taylor, Eisenberger, Saxbe, Lehman, & Lieberman, 2006). While the amygdala plays a central role in reactivity to negative stimuli, the PFC (particularly ventrolateral and dorsolateral PFC) is also important to successful down-regulation of negative emotions (see Figure 1; McRae et al., 2012; Ochsner, Silvers, & Buhle, 2012). In an fMRI study with 49 young adult participants who did not have children, we found that low childhood family income was associated with reduced ventrolateral and dorsolateral PFC activity and increased amygdala activity during effortful emotion regulation (Kim, Evans, et al., 2013). Chronic stress was assessed by a cumulative risk index of psychosocial (i.e., child–family separation, violence, family turmoil) and physical (i.e., noise, crowding, housing quality) risk factors. Exposure to chronic stress in childhood mediated the relationships between childhood family income and adult ventrolateral and dorsolateral PFC activity (Kim, Evans, et al., 2013).

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Mothers typically exhibit heightened sensitivity toward infant cues such as cries, smells, and smiles.

Such neural alterations (i.e., increased amygdala and reduced PFC activity) are consistent with well-documented abnormal neural activity in individuals with mood disorders (Phillips, Ladouceur, & Drevets, 2008). In fact, Moses-Kolko et al. (2010) found that depressed mothers exhibited reduced dorsomedial PFC activation as well as reduced connectivity between the amygdala and dorsomedial PFC while viewing negative emotional faces (e.g., fear and anger) during the postpartum period compared to healthy mothers. The increased amgydala activation was further associated with depression severity among these mothers. Therefore, poverty and chronic stress experienced by new mothers may disrupt normative biological changes involved in enhancing stress and emotion regulation, resulting in potential increases in risk for postpartum depression.

Second, poverty and related chronic stress can dampen maternal motivation and sensitivity toward infants by disrupting normative changes supporting adaption to parenthood. In fact, low-income mothers tend to perceive infant cry sounds to be more negative and interact with their infants less, compared to middle-income mothers (Hart & Risley, 1995). Mother rodents and primates under chronic stress (induced by unstable living arrangements) are less motivated to care for their offspring (Herzog et al., 2009). Mothers in poverty are also more likely to have experienced harsh parenting during their own childhood. We found that such chronic stress (i.e., low perceived quality of maternal care in childhood) was associated with reduced medial and superior PFC responses to infant cry in new mothers during the first 3 months postpartum (Kim, Leckman, Mayes, Newman, et al., 2010). Therefore, poverty and chronic stress experienced by new mothers may also injure the adaptive biological changes to support enhanced sensitivity and parental motivation toward infants, which in turn contribute to harsh parenting.

Lastly, the increased amygdala responses to infant cues among depressed mothers may further increase the likelihood that mothers in poverty will perceive their infant's cries as more hostile and distressing and thus respond less sensitively. Mothers who experience postpartum depression demonstrate reduced responses to their own baby's cry in brain regions that process reward stimuli and promote maternal motivation as well as in regions that help with regulating negative emotions such as the PFC (Laurent & Ablow, 2011). Similarly, mothers who use one or more teratogenic substance (e.g., tobacco, alcohol) show reduced responses to low-distress infant cries in the PFC, insula, and amygdala (Landi et al., 2011). Postpartum depression and addiction to substances are more prevalent among low-income mothers and they are associated with disrupted mother–infant relationships. Such psychological issues in low-income mothers may lead to abnormal mother–infant relationships, mediated by a mother's reduced neurobiological sensitivity toward her infant.

Abnormal neural activations in response to stress and infant-related stimuli can act as biomarkers that are associated with risk for postpartum mood disorders and harsh or neglectful parenting. However, existing studies have tended to focus on middle-income mothers. Thus, currently, very little is understood about the neurobiological mechanisms by which chronic stress influences postpartum moods and parenting among at-risk and low-income mothers.

Potential Implications for Interventions and Treatment

Low-income mothers and expectant mothers are a vulnerable population that has both a high level of need and great potential to benefit from health care and support services. However, in addition to financial considerations, economically strained families face many barriers to receiving adequate services such as perceiving that treatment is demanding and of little relevance, difficulty accessing safe and reliable transportation, and daily stressors that interfere with scheduling (e.g., obtaining child care; Ingoldsby, 2010). As discussed earlier, it is critical that interventions act to not only address and overcome the multitude of stressors that low-income mothers face but also provide support around adaptive ways to cope with chronic stress.

Several government- or state-funded intervention programs exist that offer support and assistance specifically to low-income, new mothers and their infants. Home visiting programs are one such model that offer a number of services including intervention for the promotion of healthy pregnancies and infant care, parent education, social support, and the prevention of child abuse and neglect. These services are provided in the home and thus overcome several barriers by reaching families that may not otherwise have access to health care and support programs. Home visiting programs operate under the general assumptions that parents are often the most consistent caregivers; that parents can be responsive and effective when provided with the necessary knowledge, skills, and support; and that parents' psychological and physical needs must be met in order for them to be effective parents (Reppucci, Britner, Woolard, 1997). In a home visiting intervention follow-up assessment, researchers found that mothers of 6-year-old children who had been participating in the intervention beginning prior to birth had fewer subsequent pregnancies and births, longer relationships with their current partner, and fewer months of using welfare and food stamps compared to their counterparts assigned to a comparison condition. In addition, children of participating families were more likely to be enrolled in out-of-home care, demonstrated higher intellectual functioning, and had fewer clinical or subclinical behavioral problems compared to the control group (Olds et al., 2004).

Other evidence-based interventions and treatments have been adapted to better fit

the needs of low-income mothers by including strategies that focus on coping with stressors they experience. Grote, Swartz, and Zuckoff (2008) adapted a brief form of interpersonal psychotherapy to meet the needs of low-income, depressed mothers and expectant mothers. Interpersonal psychotherapy is an evidence-based treatment, developed to assist individuals in learning to appropriately connect affect with life events so as to improve social functioning and reduce depressive symptoms (Markowitz & Weissman, 2012). Because of the increased risk for reduced social networks, increased interpartner conflict, and subsequent strain placed on parent–child relationships, interpersonal psychotherapy's focus on interpersonal relationships and functioning makes it an especially relevant treatment for low-income individuals. Results from a randomized-controlled trial found that an adapted version of interpersonal psychotherapy targeting the needs of low-income women resulted in greater engagement and retention as well as significant reductions in depression diagnoses and depressive symptoms both prenatally and postpartum compared to women receiving enhanced usual care (Grote et al., 2009).

However, overall, prevention and early intervention efforts targeting reductions in postpartum depression have, unfortunately, remained limited (Beeber, Perreira, & Schwartz, 2008; Belsky & Jaffee, 2006; Dennis, 2005). One potential reason for this is the fact that treatments and interventions to date have primarily focused on one of two goals—alleviating symptoms of maternal depression or improvement of the mother–infant relationship—but rarely on both goals. However, research suggests that targeting postpartum depression alone is not sufficient for repairing the mother–child relationship (Murray, Cooper, Wilson, & Romaniuk, 2003) nor that decreases in maternal depressed mood correspond to improved child outcomes (Forman et al., 2007). In addition, it has been suggested that interventions must target the disruption to mother–infant relationship created by postpartum depression in order to be effective (Cramer, 1993). Other existing studies also support the claim that interventions are more effective when both depression and parenting are addressed together rather than separately (Beeber et al., 2008; Belsky & Jaffee, 2006).

We speculate that the reason intervention efforts targeting both maternal depression and mother–infant relationships result in more advantageous outcomes is because poverty likely causes changes in both neural circuits in emotion regulation and in maternal motivation. As we reviewed in the previous section, poverty-related chronic stress may negatively impact brain regions that are important for emotion regulation and parental sensitivity. The resulting neural dysfunctions of emotion regulation may lead to aversive emotional responses to a mother's own infant while neural dysfunction of parental motivation may lead to low motivation to care for one's infant. Moreover, the neural dysfunctions of emotion regulation may disrupt mothers' neurobiological and behavioral systems for parental motivation. The reduced maternal motivation and increased challenges of bonding with one's own infant could also amplify a mother's neurobiological and behavioral reactivity to stressors and negative emotional information in a mother's life. Therefore, identifying the neurobiological mechanisms by which poverty and chronic stress influence maternal caregiving can provide empirical support and scientific understanding for why interventions targeting both maternal mood symptoms and parenting skills are more effective than interventions targeting only one of these factors.

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By 3 to 4 months postpartum, infants are more socially interactive, and parents increasingly engage in reciprocal positive interactions.

Another important strength of neuroimaging data is that it may help to better detect early risk markers that may not be clear from behavioral or self-report measures. Assessments of emotion regulation and parental motivation based on self-report have been found to suffer biases due to social desirability or individual variance in the ability to understand the questions being asked. Neuroimaging techniques are able to provide a sensitive measure of neurobiological changes as a result of intervention and treatment such as increased neural activation in the PFC for emotion regulation or changes in the reward circuit in response to infant stimuli (Harmer, Cowen, & Goodwin, 2011; Harmer et al., 2009). Thus, neuroimaging data can be used as a sensitive measure to accurately identify early problems in emotion regulation and parenting among mothers. Therefore, understanding neurobiological mechanisms helps to better characterize who is at risk and why, allowing for the development of more precise and efficacious prevention targets that will improve mothers' health as well as reduce the transmission of poverty and chronic stress effects to their infants.

Conclusions

A large body of literature suggests that poverty has adverse effects not only on mothers' psychological well-being but also on their parenting abilities. Inadequate and harsh parenting during infancy has pervasive long-term effects on neural, physical, and psychological development. We suggest that the severe and chronic stress low-income mothers experience may cause changes in the brain, particularly in the regions that are important for emotion regulation and maternal motivation. Such changes in both processes (emotion regulation and maternal motivation or sensitivity) may contribute to difficulties that low-income mothers experience during the transition to parenthood such as postpartum depression and abnormal mother–infant emotional bonding. We also propose that such neurobiological changes in both processes may explain why interventions and treatments targeting both maternal moods and parenting

skills are more effective than those targeting only one or the other.

Because existing neuroimaging studies focus on middle-income mothers or typical adults, increased research efforts targeting low-income mothers are urgently needed to inform interventions and treatments with mothers experiencing financial hardship. When studying low-income mothers, future research should also examine several factors that are associated with poverty and which could impact mothers' neurobiological adaptation to parenthood. First, prenatal depression is one of the strongest predictors of postpartum depression, and women in poverty also suffer from higher rates of prenatal depression (Goyal et al., 2010). Therefore, it is important to understand prospective effects of prenatal depression on the maternal brain and moods during the postpartum period. Second, poverty more often occurs among mothers with minority backgrounds (Belle, 1984). Ethnicity is associated with different parenting styles and minority backgrounds are associated with additional stressors such as cultural differences and discrimination based on ethnicity. However, despite the fact that many mothers who participate in existing intervention programs are minorities, very little is understood about differences in neurobiological adaptations during the postpartum period between minority and nonminority women. Third, poverty is linked to a higher rate of teen pregnancy. Teen pregnancy is further associated with increased risk for maternal depression and harsh parenting (Woods et al., 2003). During the teen years, the brain is not fully matured, and the areas involved in emotion regulation, social information processing, and decision making (i.e., the PFC) are not fully matured (Pfeifer & Blakemore, 2012). Therefore, the immaturity of the brain may cause teen mothers to be even more vulnerable to maternal depression and harsh parenting. Thus, future research would benefit from examining teen mothers' neurobiological adaptations to parenthood during the postpartum period. Having a better understanding of the roles prenatal depression, minority backgrounds, and teen motherhood play in the relationship among poverty, the maternal brain, and postpartum adaptation will enhance current and future interventions for low-income mothers to support optimal development in the next generations.

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