TWO OPEN WINDOWS: PART II

NEW RESEARCH ON INFANT AND CAREGIVER NEUROBIOLOGIC CHANGE

In the original *Two Open Windows,* Kim and Watamura (2015) highlighted research supporting the transition to parenting as a co-occurring sensitive period — in other words, as a time in life characterized by "two open windows" where both infants and parents are especially receptive to being shaped by their environments. Here, we provide an update of research for parents, policymakers, researchers, and practitioners to inform approaches to supporting families with diverse needs, compositions, and backgrounds within a two-generation framework.

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Since 2015, new research has expanded our understanding of this window, including: (1) more evidence of brain changes in mothers during pregnancy; (2) a better understanding of brain changes in fathers, including nonbiologic fathers, which highlights that brain changes appear to occur as a result of caregiving behaviors themselves instead of via pregnancy-related changes; (3) how parents' prior experiences can shape their approach to parenting; (4) how parents in stressful situations can protect their children against "toxic stress" (which primarily differs from "tolerable stress" due to the presence of social support and in severity and/or amount); and (5) what types of programs can effectively support healthy brain changes during the transition to parenthood. Here, we provide an update of research published between 2010 and 2015. This overview is intended for parents, policymakers, researchers, and practitioners to inform approaches to supporting families with diverse needs, compositions, and backgrounds within a two-generation framework. Two-generation approaches focus on the needs of children and the adults in their lives simultaneously.

Expanding the scope of research about the parental brain beyond mothers to include fathers and non-biologic parents critically increases understanding by allowing a separation of pregnancy-induced changes and experience-based changes, while also more accurately reflecting the central role that fathers and other caregivers play in the life of young children.

PARENTING IS REWARDING, AND OFTEN DIFFICULT AND STRESSFUL

Media often conveys parenting as a positive, rewarding time. Although parenting can include many positive emotions, many find it challenging as well (Kim et al., 2013) — it is difficult to be responsible for the survival of another human. Many parents report feeling highly concerned about their baby's health or well-being. Of course, concern is normal and can even help motivate key parenting behaviors. Caring for an infant requires that parents feel motivated to respond to cues that are otherwise aversive (e.g., loud cries), can accurately perceive infant needs (e.g., the baby is crying because they are hungry versus because their diaper is soiled), appropriately attend to these needs (e.g., feed the baby, hold the baby), and manage one's own emotions to do all of this consistently (e.g., not so overwhelmed such that you cannot perform these actions, nor so disengaged that you are not attuned to the child's needs). Brain changes occurring during the transition to parenting support these demands: brains grow larger in areas that process rewards and social information and support emotion regulation; brains also respond differently when interacting with baby-related cues. These changes all represent new growth (Kim et al., 2010).

These specific changes that support the "parental brain" are thought to support parenting behavior and subsequent child

outcomes (Swain & Ho, 2017). The brain works in conjunction with other bodily changes, like the release of hormones (e.g., oxytocin; Luo et al., 2015) and activation of stress responsive systems, in order to support parenting behavior. This means that many parts of the human brain that respond to stressful situations are also involved in directing parenting behavior. Taken another way, parents who face many stressors outside of the parenting domain may face an additional burden in mobilizing these systems for caregiving as well as for survival. Recognizing this fact helps us understand how to best improve outcomes for parents and children in contexts where they may be feeling especially stressed.

NOT JUST MOTHERS: CAREGIVING ITSELF SHAPES BRAINS

Expanding the scope of research about the parental brain beyond mothers to include fathers and nonbiologic parents critically increases understanding by allowing a separation of pregnancy-induced changes and experience-based changes while also more accurately reflecting the central role that fathers and other caregivers play in the life of young children. The act of caregiving itself is a crucial factor in shaping observed brain changes during the transition to parenting — by orienting to care for an infant and engaging in behaviors to do so, the brain recalibrates to meet this new demand. Substantial evidence indicates that nonbiologic caregivers and fathers are effective parents, so it is unsurprising and yet an important finding to identify that the changes that occur in biologic mothers' brain circuits relevant to parenting also occur in other parents. Understanding brain changes due to experience allows us to better understand how caregivers become effective parents and how best to support them.

Studies in fathers have clearly established that many of the same neurobiological mechanisms supporting sensitive parenting behaviors in mothers are also present in fathers (Abraham & Feldman, 2018; Abraham et al., 2018; Feldman et al., 2019; Kim et al., 2015; Li et al., 2018; Rajhans et al., 2019), underscoring two major components of parenthood: there are not as many inherent differences in the parenting biology of mothers and fathers, and caregiving experience alone is enough to induce biological changes that support parenting. Since 2015, research has added nuance to how mechanisms supporting adaptive caregiving may subtly differ for fathers, including neural and hormonal mechanisms. For example,

the transition to parenthood appears to differentially affect mothers and fathers in their tendency to interpret happy and unhappy infant faces as extremely positive or negative: fathers rate emotional infant faces less intensely compared to non-fathers, whereas mothers tend to interpret these faces with more intensity compared to non-mothers (Parsons et al., 2017b). This suggests that fathers and mothers may on average differ in how they reach the "sweet spot" of perceiving an emotional infant face as positive or negative enough to warrant approach. Additionally, older fathers with more caregiving experience were found to be less responsive to infant cries in areas of the brain responsible for emotional responses, empathy, and pain (Li et al., 2018). When viewing a representation of their own upset infant face, expectant fathers show increased brain activation in areas involved in planning movements (van't Veer et al., 2019). This study also found that the expectant fathers who used more protective behavior with their own unborn child have greater brain activation to infant distress in frontal regions. Hormone changes from before and after infant birth predicts greater engagement in infant care tasks for men but not women (Bos et al., 2018; Edelstein et al., 2017), and lower testosterone levels after infant birth were linked to higher paternal involvement (Kuo et al., 2018). For fathers, their own experiences of supportive early caregiving may critically shape how vasopressin, a hormone that facilitates bonding, promotes adaptive brain responses to processing infant cries (Thijssen et al., 2018). This recent research shows that there are shared biological mechanisms underlying parenting behaviors between genders, but there are also subtle differences in the way fathers and mothers process infants' emotional information and tune their subsequent behavior.

Taken together, caregiving experience alone appears enough to induce biological changes supporting parenting behavior (e.g., Parsons et al., 2017a), which indicates that nonbiologic caregivers *should* have similar brain circuitry changes during the transition to parenthood. In a study conducted in Israel, brain activation differences were examined in heterosexual couples as well as in homosexual male-male couples. In the homosexual male couples, one father was biologically related to the child and the other was not. Analyses revealed no differences in parent sex (male versus female), nor between biological and nonbiological parents. However, results showed stronger activation to infant cues in primary versus

secondary parents (as identified by parents), regardless of parent sex or biological relatedness (Abraham et al., 2014). Another study in Mexico found that adoptive and biological mothers demonstrated similar overall electroencephalography (i.e., EEG) activity to viewing a smiling or crying baby, whereas non-mothers in the sample did not show this pattern (Hernández-González et al., 2016). Taken together, these studies further emphasize the role of caregiving experiences in shaping brain circuitry related to parenting and underscore the validity of nonbiologic caregivers in being effective caregivers; this information is highly relevant for policy advocacy in adoption and foster care systems.

Fathers who spend more time alone with their child (with direct responsibility) demonstrate stronger connections between brain areas involved in detecting cues and social cognition; also, their pattern of brain response was similar to those of primary-caregiving mothers (Abraham et al., 2014). This indicates that the changes in the brain seen in the transition to parenthood are less shaped by the biological changes due to becoming a parent and more shaped by the degree of caregiver involvement (as well as the types of behaviors that are exhibited).

Different types of parents provide different approaches to caregiving that support complementary developmental skills. These approaches are prototypically gendered, but they do not have to be. Research on fathers suggests that they tend to provide "rough and tumble" play (e.g., throwing kids in the air) that can support good self-regulation in children compared to mothers who tend to provide more consistent but lower arousing interactions (Abraham & Feldman, 2018; Rajhans et al., 2019). This research indicates that each parent can bring their own distinct style and emphasizes unique contributions of different parenting behaviors to children's outcomes. For nonbiologic caregivers or single parents, intentionally playing in different "styles" may help stimulate their infant in new ways.

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Studies comparing co-parenting (i.e., involving both fathers and mothers) and fathering behavior have demonstrated the presence of fathers improves children's self-regulation and attachment outcomes (Feldman et al., 2019; Miller et al., 2019). Fathers' involvement reduces anxiety and aggression and improves social behavior and reward sensitivity (Feldman et al., 2019). Fathers who provide sensitive caregiving may protect child mental health against negative effects associated with chronic maternal depression (Vakrat et al., 2018). Importantly, this research has ONLY been conducted with heterosexual co-parents, but there is no reason to believe that findings would differ

for other types of parents. Taken together, this suggests that having two effective caregivers present — regardless of degree of biological relation to the child — benefits a child's well-being.

PARENTS EXPERIENCING STRESSORS ARE ABLE TO PROTECT THEIR CHILDREN FROM THEIR NEGATIVE EFFECTS

The public conversation on parents who experience poverty sometimes suggests that such parents struggle to care for their children and provide punitive or harsh discipline. However, all types of parenting styles are found across different socioeconomic classes — rich and poor alike (Glasgow et al., 1997). Many parents who experience poverty demonstrate sensitive caregiving, warmly interacting with their children and attending to their needs in a supportive and nonintrusive manner — in doing so, these parents can facilitate their child's healthy pattern of coordinated response between emotions and physiology during a stressful situation (Blair et al., 2015). Not only are they able to do so directly when their child is experiencing a stressor, but they can also shape healthier patterns of how children respond to their daily stressors (Berry et al., 2017). The same parents who showed sensitive caregiving behaviors were able to deeply connect to their children and match their child's physiological stress levels even across a difficult and challenging task (Hibel et al., 2015). Although it is possible for caregivers to sensitively support their children in the context of low economic resources, the added burden of high environmental demand and caregivers' own dysregulated stress response systems can sometimes get in the way of high-quality care (Finegood et al., 2016). Therefore, programs directly tackling sources of stress (e.g., cash transfer, reducing structural barriers) and offering concrete supports, including for adult stress management and emotion regulation, likely have downstream effects on parenting behaviors and child well-being.

Taken together, caregiving experience alone appears enough to induce biological changes supporting parenting behavior, which indicates that non-biologic caregivers should have similar brain circuitry changes during the transition to parenthood.

PARENTS' OWN EXPERIENCES CAN SHAPE HOW THEY INTERACT WITH THEIR INFANT

Unsurprisingly, what we have experienced during our lives can influence our subsequent behaviors — particularly while parenting. Exposure to stressful conditions (e.g., lacking access to food and healthcare) and/or a history of childhood adversity (e.g., abuse, lacking a stable caregiver) can make it more difficult for parents to sensitively attend to their own children's needs. Again, this is not deterministic — many parents who experienced poverty and even maltreatment in childhood go on to be sensitive parents (Berlin et al., 1981). However, mothers experiencing economic hardship and excess stressors have shown different activation in stress-responsive brain areas that are also important for directing parenting

behavior, including the prefrontal cortex, amygdala, and ventral striatum (Kim, 2016). Brain areas that process infant cries can activate more strongly to distressed infant cues and less strongly to positive infant cues in mothers experiencing stress (P. Kim et al., 2017; Swain & Ho, 2017). This suggests that hearing an infant cry may be more aversive or arresting for those mothers who experienced adversity and thus may make it more difficult to respond sensitively to an infant's needs. Alternatively, they may not feel as rewarded when interacting with their infant if their brain does not respond as strongly to positive infant cues (Kim et al., 2016). Although overemphasizing distress may aid infant and parent survival in adverse circumstances, that may come at the cost of sensitive interactions in responding to non-distress signals. Indeed, mothers who experienced adversity are less likely to demonstrate sensitive caregiving behaviors and more likely to be intrusive with their infant (Lomanowska et al., 2017). Experiencing adversity can yield changes in multiple biological systems. For example, neurotransmitters that guide and support behaviors can differ in function based on adversity exposure. Vasopressin, which normally supports restfulness and preserves energy, instead can become involved in threat detection. Although oxytocin is often popularly labelled as the "love hormone," these close feelings are limited to select individuals, and oxytocin normally supports careful social distancing with strangers. Another study found that in the context of adversity, oxytocin does not support this careful social distancing (Perry-Paldi et al., 2019). This cumulatively highlights that hormones generally supporting adaptive parenting behaviors may work differently for parents who have a history of adversity. Although collectively these differences likely bias the individual and parent-child pair toward survival, an excessive focus on survival can limit opportunities for thriving.

Although it is known that substance use during pregnancy (e.g., tobacco, opiates, cocaine, cannabis) negatively affects birth outcomes (Chabarria et al., 2016; Gray et al., 2010; Yazdy et al., 2015) with deleterious downstream effects (Smith et al., 2004), emerging studies have only begun to examine how

substance use may impact brain changes seen in the transition to parenting. Substance abuse can disrupt brain reward systems that are highly relevant to parenting and motivate caretaking behaviors (Rutherford et al., 2011). Studies in human mothers have shown that using substances during pregnancy is associated with reduced brain activation to infant faces and cries in areas responsible for processing reward, auditory information, and emotions (S. Kim et al., 2017; Landi et al., 2011). This indicates that substance use in the transition to parenthood is not only a risk for the infant directly through exposure to substances in utero or via breastmilk (Baker et al., 2018; Fríguls et al., 2010), but may also disrupt ideal mother and infant development due to changes in the brains of both generations. Currently, there is a dearth of research quantifying the direct effects of mother's prenatal substance use on infant brain development, but our understanding of placental transfer of substances from mother to infant and adverse birth outcomes suggests that the infants of mothers using substances while pregnant would likely show differences in their brain's structure and function.

Identifying ways to support mothers managing substance use and addiction during the transition to parenthood can help improve outcomes for both mother and child. Mothers struggling with substance use and abuse are often most motivated to change when they are pregnant (Fergusson et al, 2012), and this is often the time when they have the most contact with healthcare services: therefore, this period can be leveraged to provide a nonjudgmental evidence-based perspective and improve health outcomes for mom and baby. Indeed, parenting interventions have been successfully delivered to mothers concurrently receiving treatment for substance abuse who experience high levels of psychological distress (Paris et al., 2015; Suchman et al., 2017). Although current studies on substance use in caregivers primarily focus on mothers, substance use in other caregivers can also negatively affect child outcomes (Osborne & Berger, 2009), and, concomitantly, the transition to parenthood is a time of increased motivation to change that can be leveraged.

These studies collectively show that the transition to parenting, which can be a stressful time for any new parent, can be harder for those experiencing additional stress and adversity or struggling with substance use. However, it is important to also recognize that, despite the specific brain

response differences described above, brain changes in response to parenting have been observed in parents experiencing stress and adversity as well as those in more favorable environments and those experiencing better mental health. This underscores several fruitful avenues from a policy and practice standpoint to improve outcomes for families. Because parents are more sensitive to external inputs during the transition to parenting, this time period represents a potentially meaningful support point for parents with histories of adversity or those in high-stress contexts. Furthermore, intervention during early childhood has been linked with long-lasting and high returns on investment for child outcomes (Heckman, 2011), with the possibility of even earlier intervention points having greater return. This indicates immense opportunity to leverage the neural plasticity during early life and the transition to parenthood to effect changes that can improve outcomes for parents and children alike.

WE CAN EFFECT CHANGE

Empowering parents with new knowledge and skills and supporting them during the transition to parenting appears to change how the parental brain processes baby-related cues, like cries and emotional faces. MomPower© is a therapeutic program for parents experiencing elevated risk that includes several components common to many parenting programs, such as parenting education (e.g., Incredible Years®), stress management techniques (e.g., Triple P®), and a focus on parent-child interactions (e.g., Parent-Child Interaction Therapy). In the first intervention study addressing changes to the parenting brain following parenting intervention, a group of mothers (half of whom met the clinical cutoff for depression) involved in the MomPower© intervention evidenced increases in brain response in areas that help with emotion regulation and reflective self-awareness while listening to their baby cry (Swain et al., 2017). These exciting results suggest that MomPower© and interventions that target similar core parenting dimensions may have the power to support brain changes that might not naturally occur. This is important, as greater brain activation is related to more positive views of one's infant (Kim et al., 2015) and to more sensitive caregiving (Kim et al., 2017). One likely mechanism of change is reducing perceived stress, which has been found to be a key link between experiencing lower income and showing less adaptive brain responses to infant cries (Kim et al., 2016). Lowering perceived stress can occur via increasing access to resources, supporting adult goals (education, job training, improved relationships, improved environments), and/or teaching stress management

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techniques. These important results need to be extended to other caregivers, and with other interventions.

Child protective services-referred mothers who participated in an attachment program, Attachment and Biobehavioral Catch-up (ABC), showed more adaptive changes in their EEG activity when seeing emotional baby faces compared to those who participated in another intervention; this, in turn, helped increase their sensitive parenting behaviors (Bernard et al., 2015). Despite not including neural outcome data in studies of program efficacy (due to the high costs of brain scanning), other parenting programs likely support similar adaptive brain changes through teaching new parenting behaviors and stress management techniques. Taken together, these results broadly indicate that two-generation programming that targets adult needs, child needs, and parent-child relationships should support healthy brain changes to support parenting. These programs may most significantly improve outcomes for those most in need, particularly those with prior or current adversity, low income, and/or current mental health concerns.

CONCLUSION

The transition to parenting is a sensitive period that provides a unique opportunity to support children and the adults in their lives together. Research highlights that parenting brain changes happen in biologic mothers, biologic fathers, and nonbiologic parents alike in response to the caregiving role. Parents are able to buffer children from negative environmental conditions like low income, although providing support to parents and ameliorating their own experienced stressors bolsters this ability. Facing repeated stressors and trauma can affect some of the same brain areas associated with parenting; therefore, caregivers with these histories may not experience brain changes to the same degree as parents without these histories. Without this supportive parental neurobiology, parents may find it more challenging to sensitively respond to infant cues. Two-generation approaches that directly target adult mental health, including prior trauma, to cultivate well-being and enhance parent-child relationships may be especially powerful.

Taken together, recent evidence highlights that programming traditionally designed for mothers can work and be adapted for other types of caregivers. We collectively need to think bigger about how policy can support all caregivers, regardless of sex or biologic relationship to the child. Advocating for policy and programming inclusive of all caregivers would help improve outcomes for caregivers and children alike.

RECOMMENDATIONS FOR PRACTICE

- Expand parenting programs to include fathers and nonbiologic caregivers and include them in communications (e.g., "ParentPower").
- When working with caregivers to change parenting behaviors, acknowledge that one's own history of adversity or trauma and/or current mental health symptoms can make the monumental task of parenting even more difficult. Focusing on the caregivers' own personhood and need for well-being prior to and alongside child needs is key.
- Screen all caregivers for mental health difficulties (e.g., anxiety, depression, PTSD) and provide appropriate, varied, non-stigmatized resources as needed. Recognize that while prenatal and postnatal health care is often the best point of contact for providing caregivers experiencing adversity and struggling with mental health symptoms with additional services, the type of services may need to be adapted for the life stage (e.g., medication vs. therapy; peer vs. medical provider; addressing barriers like diaper need, schedule and transportation constraints). Build understanding that postpartum mental health symptoms may be the first time a person has experienced a mental health challenge, and this is very common in the postnatal period for both new mothers and new fathers.
- Include this research in awareness-raising, education, and training efforts to ensure pediatric and workforce practitioners are informed.
- Ensure parents have access to the research discussed in this report and that their expertise and experience inform program design to ensure programs can help parents take advantage of the opportunities presented by the transition to parenting.

RECOMMENDATIONS FOR POLICY

- Expand who are considered as important caregivers beyond only mothers. For example, incentivize and support fathers and nonbiologic parents to access social and mental health services designed to improve caregiving outcomes and to engage in caregiving.
- Remove non-empirically supported and discriminatory heteronormative laws surrounding adoption and foster care that prevent recognition of nonbiologic and homosexual caregivers, who play important roles in fostering infant and child outcomes.
- Improve screening for and access to mental health services for all caregivers, and support programming that directly improves caregivers' stress management.
- Tackle policies that result in major structural inequities that lead to health disparities.
- Expand access to paid leave and affordable child care to support the critical role of caregiving.

THE AUTHORS

Andrew Erhart has a background in developmental psychology and neuroscience. He is interested in how research on families' environments and biology can be used to support policy and intervention. He enjoys sharing his research and communicating difficult topics in psychology to students.

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Tiffany Phu is building a research program examining the early biological embedding of risk and resilience across several biological systems and implications for child physical and mental health, with attention to family cultural context. Specifically, biological and developmental processes of interest include sleep, HPA axis functioning, and the sympathetic-adrenal-medullary system. She has previously conducted research in health psychology and dissemination and implementation science, which has strengthened her commitment to translating basic science to intervention work and attending to policy implications of developmental science.

Dr. Sarah Watamura is a professor of psychology and chair at the University of Denver, where she directs the Child Health and Development Lab and co-directs the Stress, Early Experience and Development Research Center. She has longstanding interests in children's physiologic regulation, their development within caregiving contexts, and understanding mechanisms and trajectories from early life stress to later physical, mental health, cognitive/educational, and socio-emotional outcomes. Her work examines the unique stressors and buffers in families experiencing poverty and among newly immigrated families, and includes testing promising intervention approaches.

ORGANIZATIONS

Stress, Early Experiences and Development (SEED) Research Center: The SEED Research Center is focused on understanding and mitigating the effects of early life stress utilizing a psychobiological approach. In particular, we focus on explicating the mechanisms underlying the effects of early life stress on physical and psychological health and development. Our current cluster utilizes cutting-edge methodologies, including neuro-imaging (i.e., functional and structural magnetic resonance imaging, and diffusion tensor imaging), genotyping, bioassays (e.g., hormones, immunological markers, indices of cellular aging), and in-depth behavioral and observational approaches (e.g., neurocognitive assessments of children and adults; assessments of emotional regulation, temperament, and parenting; noise-level monitoring; and neighborhood and housing quality indices). Our innovative approach employs prospective longitudinal designs and sophisticated statistical analysis techniques in order to identify pathways from the prenatal period through adolescence by which early life stress lead to increased disease risk. Further, we focus on important contextual and relational influences (e.g., parenting, culture) on the experience of early life stress — including both the contributing and buffering potential of caregivers. http://www.du.edu/ahss/psychology/seedresearch/index.html

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