Chapter 8
Poverty, Parent Stress, and Emerging Executive Functions in Young Children

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Executive functions are higher-order cognitive abilities that guide complex goal-directed behaviors. They support decision-making, problem solving, reasoning, planning, and abstract thinking (Diamond, 2013; Zelazo, 2015). As such, these abilities are crucial to many aspects of daily functioning—especially, in those moments of our lives that require us to suppress or inhibit impulses, to flexibly shift our attention or our mindset from one position to another, or to maintain and work with information in our memory. Primarily understood to comprise the cognitive domain of self-regulation, executive functions are important for success in school (Blair, 2002; Blair & Razza, 2007); they not only help students to use numbers and apply concepts, but they also help them to be less impulsive and to focus their attention toward attaining goals. Executive function abilities are also associated with health and success throughout life (McClelland, Acock, Piccinin, Rhea, & Stallings, 2013). For instance, children who exhibit higher self-control, in which executive function is implied, tend to be more financially secure as adults, tend to have fewer run-ins with law enforcement, are less likely to use and abuse substances and more likely to enjoy better overall health as adults (Moffitt, Poulton, & Caspi, 2013).

One point that is becoming increasingly clear is that our experiences in early life have a significant influence on the development of our executive functions. This relation has to do, in part, with the effects of early life experiences on the neural and physiological substrates that underlie and support executive functions. For instance, children who experience high amounts of stress, such as children in high-poverty homes, tend to show deficits in executive functions (e.g., Hackman & Farah, 2009)

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as well as alterations to brain areas that support executive function abilities (e.g., prefrontal cortex; Hanson et al., 2013; Noble et al., 2015) and the stress response systems (e.g., the hypothalamic pituitary adrenal axis; Blair et al., 2011a) known to be involved in regulating executive functions. To be clear, evidence in support of associations among poverty, stress, and executive function does not in any way indicate that the brains of children and families in poverty are damaged or irremediably altered. In contrast, the data indicate that brain and behavior are responding exactly as would be expected in a high stress, high-poverty environment (Blair & Raver, 2016). Stress tunes the brain and the body to be more reactive and less reflective, less likely to engage the executive functions (Arnsten, 2009). Greater reactivity and less reflection are generally advantageous in high stress contexts though not without specific disadvantages. In part, this is seen in data indicating that to some extent, effects of early experience on child executive functions and early brain development are mediated through early *caregiving* and the relationship with the primary caregiver. For instance, studies are beginning to identify specific parenting behaviors that are positively correlated with executive function development in children. These behaviors include the use of verbal "scaffolding" techniques to assist children during problem solving and patterns of interaction in which parents are warm and responsive (e.g., Bernier, Carlson, & Whipple, 2010; Blair et al., 2011a). Notably, however, children and families are embedded within and stratified across socioeconomic contexts and the hardships that disadvantaged families face may be associated with parents' perceptions of stress and disrupted family functioning (see Nomaguchi & Milkie, Chap. 3). The social, economic, and institutional constraints that confront families in poverty increase stress and pressure in parents, often making it difficult for them to engage in the types of early caregiving known to support children's executive function development (McLoyd, 1998). Consequently, children's development in poverty is more likely to be shaped in ways that are appropriate for that context; that is, to be less reflective and more reactive and responsive to immediate and unpredictable aspects of the environment (Blair & Raver, 2012). In theory, poverty-related stressors shape the proximal caregiving environments of children, and this may be a primary mechanism through which the broader experience of poverty influences the development of children's executive functions.

This chapter has a number of specific aims. The first aim is to briefly review some of the neurobiological foundations of executive functions and the developmental trajectory of these skills across the childhood years. The second aim is to outline what is known about the relation between poverty and executive function development in children. In doing so, we attempt to leverage what is known from neuroscience and developmental psychology about the neurophysiological and behavioral mechanisms of this relation to better understand the means through which poverty gets "under the skin" to influence children's executive function development. The third aim is to highlight the extent to which aspects of executive function development, and the development of the neurophysiological systems supporting executive functions, are socially mediated in early life. Studies of humans and non-human animals enhance our understanding of the ways in which the caregiving environment in general and early life experiences with parents in particular shape the developmental trajectories of executive functions and early self-regulation at several levels. The fourth aim is to place family processes and the proximal caregiving environments of children within larger socioecological contexts that include the communities and neighborhoods that families reside in—not only to consider the effects of these larger contexts on children's self-regulation development, but also the effects on parent well-being and family functioning. Lastly, we address how the context of poverty and experiences of early life adversity affect caregivers at neural and physiological levels and consider the extent to which these effects represent mechanisms through which the context of poverty and environmental stress influence parents' interactions with their children and ultimately, their children's self-regulation development. Understanding the ways in which poverty-related stress influences parents at psychobiological and behavioral levels is crucial from the perspective of designing and assessing targeted interventions to support parents and families and to reduce stress at multiple levels.

Executive Functions: Development and Neurophysiological Foundations

Executive functions comprise three distinct but related domains of functioning—attention shifting, working memory, and inhibition (Blair & Ursache, 2011; Friedman et al., 2006; Miyake et al., 2000; Wager, Jonides, & Reading, 2004). Attention switching or the ability to shift one's mental set involves the ability to flexibly switch attention between multiple competing tasks, or, within a task or problem, the ability to easily switch one's mental set between multiple operations or rules. A common task to assess this ability in children is the Dimensional Change Card Sort (DCCS; Zelazo, 2006) in which children are asked to sort several cards according to one dimension (e.g., shape) until a "post-switch" phase in which children are asked to sort according to a different dimension (e.g., color). Difficulties in mental set or attention shifting manifest as erroneous perseverative responses in which children fail to make the switch in the sorting rule. Working memory is the ability to hold in mind and to actively manipulate task-relevant information (Baddeley & Hitch, 1974). In one working memory task (Willoughby, Blair, Wirth, & Greenberg, 2010), children are presented with a line drawing of a house, inside of which is a drawing of an animal (e.g., a fish) and a colored dot (e.g., a blue dot). Next, the animal and colored dot disappear leaving only the drawing of the empty house, at which point children are asked to recall which animal was in the house (or, in another condition, are asked to recall which color was in this house). Successful completion of this task requires children to hold both pieces of information (i.e., the type of animal and the color of the dot) in memory, but to bring only one of these pieces of information to mind. Inhibition involves one's ability to inhibit a dominant response in favor of a sub-dominant response (Miyake et al., 2000). A common task for assessing this in children is the Day-Night task (Gerstadt, Hong, & Diamond, 1994) in which children are instructed to say "day" when shown a picture of a moon and to say "night" when shown a picture of a sun. Successful completion of this task involves the ability to overcome the dominant impulse to answer congruently with the picture scene.

An extensive neuropsychological literature has established that executive functions are supported by the prefrontal cortex (PFC) of the brain (see Fuster, 2015). The developmental course of the PFC is somewhat distinct from other areas of the human brain in that it experiences an enormous amount of synaptic growth and development in the first years of life but does not reach maturity until much later in young adulthood (Huttenlocher, 2002). Consistent with this, children show rapid improvements in executive function abilities throughout the toddler, preschool, and early childhood years (Diamond, 2006) and continue showing improvement (albeit at a slower rate) throughout adolescence and young adulthood (De Luca & Leventer, 2008; Zelazo, Craik, & Booth, 2004). The prolonged developmental course of the PFC also makes this brain area especially amenable to environmental influence, that is, to experiential input.

The PFC has long been considered the cognitive control center of the brain—the part of the brain that exerts "top-down" control over our behavior and mind, helping us to organize our thoughts and actions in ways that are volitional, intentional, and goal-directed. Importantly, however, PFC activity is modulated by neurochemicals produced in the brainstem and the limbic system—structures and neural systems both phylogenetically and ontogenetically older than the PFC. These neural systems and their chemical mediators (e.g., glucocorticoids and catecholamines) serve critical bodily functions including visceral and metabolic regulation, sympathetic nervous activity, and attentional processes, and are key players in the body's stress response to perceived environmental threat. As a product of this integrated system, executive functions are organized in a bi-directional manner by both "top–down" (intentional/reflective) and "bottom-up" (automatic/reactive) processes that are ultimately shaped by acute and chronic experiences (Blair & Ursache, 2011). Glucocorticoids (i.e., cortisol in humans) and catecholamines (i.e., norepinephrine and dopamine) exert influence on the PFC in an inverted-U shaped function. For example, it has been shown that executive functions are optimized and that synaptic potentiation in the PFC is at its highest when glucocorticoids and catecholamines are circulating at moderate levels—both under- and over-activation of adrenergic, dopaminergic, and endocrine pathways in the contexts of sleepiness and acute stress, respectively, has been associated with decrements in executive functioning and decreased cell communication in the PFC (Arnsten, 2009; de Kloet, Oitzl, & Joëls, 1999; Lupien, Maheu, Tu, Fiocco, & Schramek, 2007). Chronic exposure to adversity in early life (i.e., early experiences that engender high amounts of stress) has been associated with long-term alterations to these neural and physiological systems, and this has consequences for executive function development in children.

Poverty and Executive Function Development

Children living in poverty often endure an enormous amount of stress as a result of the psychosocial and physical environments in which they grow up. Children from poor families are more likely than children from non-poor families to be exposed to violence both in and out of their homes and are more likely to be exposed to pollutants and toxins, and the neighborhoods that their families reside in are often substandard (Evans, 2004). Eviction is a frequently occurring stress exposure associated with poverty leading to increased material hardship, job loss, homelessness, psychological distress, and increased and prolonged poverty and residential instability. Rates of eviction in high-poverty neighborhoods in major metropolitan areas are extremely high, disproportionately affecting women and children (Desmond, 2012). Especially, relevant to the current volume, children from poor families, as a consequence of the aforementioned stressors, also tend to have interactions with parents that are less warm and supportive, experience high amounts of household chaos and instability in caregivers, and their home learning environments tend to be poorer in terms of the psychosocial and material resources they have available to them for learning and success in school (Bradley & Corwyn, 2002; Bradley, Corwyn, McAdoo, & Coll, 2001; Brooks-Gunn, Duncan, & Aber, 1997; Duncan & Brooks-Gunn, 2000; Evans, 2004; Foster & Brooks-Gunn, 2009). A number of studies have indicated that the neural systems supporting executive functions are among the most negatively affected by the stress of poverty (Noble et al., 2015; Noble, McCandliss, & Farah, 2007). Consistent with these effects, differences in executive functioning have been observed across the socioeconomic spectrum. Associations between socioeconomic status (SES) and executive functions have been explored in a number of studies with preschool-aged children (e.g., Blair et al., 2011b; Carlson, Mandell, & Wiliams, 2004; Hughes & Ensor, 2005, 2009; Rhoades, Greenberg, Lanza, & Blair, 2011), after the transition to school (e.g., Engel, Santos, & Gathercole, 2008; Hughes, Ensor, Wilson, & Graham, 2009; Mezzacappa, 2004; Noble et al., 2007; Noble, Norman, & Farah, 2005), and during later childhood (e.g., Ardila, Rosselli, Matute, & Guajardo, 2005; Evans, 2003; Evans & English, 2002; Evans, Gonnella, Marcynyszyn, Gentile, & Salpekar, 2005; Farah et al., 2006; Hackman, Gallop, Evans, & Farah, 2015; Sarsour et al., 2011). Together, these studies suggest that children from lower SES families show reduced executive function abilities relative to children from higher-SES families, on average (but see Engel et al., 2008 for an exception).

In terms of executive function development or change across childhood, several recent longitudinal studies have assessed the extent to which SES is associated with children's rate of executive function growth. Studies suggest that while children from lower SES families perform worse on measures of executive function than their higher-SES counterparts, findings relating SES to children's rate of executive function growth are mixed. Whereas some prior studies have found preliminary evidence that static measures of SES did not predict change in executive functions over time (Hackman et al., 2014, 2015; Hughes et al., 2009), changes in the socioeconomic circumstances of families across time have been associated with children's rate of growth in executive functions across childhood. Specifically, reductions in family income across the elementary school years have been associated with reduced growth in executive functions across that time (Hackman et al., 2015). In the context of deep poverty, it may be the instability associated with high-income volatility that is most damaging to executive function development during childhood. In a large population-based sample of children and families in predominantly low-income and rural communities, other factors including the amount of time per week that children spend out of highly chaotic homes have been positively associated with executive function abilities (Berry et al., 2016) and Kuhn, Willoughby, Vernon-Feagans, Blair, and The Family Life Project Key Investigator (2016) found that children's rate of vocabulary growth was associated with child executive function at age 3 years and with the trajectory of executive function from age 3 to age 5.

There are multiple potential explanations for the robust association between SES and children's executive function development. Evidence is mounting to suggest that poverty and early life adversity have long-term effects on the physiological stress response systems that regulate prefrontal activity and executive functions. One such physiological system associated with environmental stress is the hypothalamic pituitary adrenal (HPA) axis. In response to a perceived environmental threat, for instance, the HPA axis releases the glucocorticoid hormone cortisol into the bloodstream where it mobilizes energy stores to prepare the body for action. In the brain, high levels of glucocorticoids signal the need to be *reactive* rather than *reflective*—as it may be more advantageous in a moment of acute stress to direct one's energy toward quick attentional processes and visceral functions rather than toward slower and more reflective or planful processes. The prolonged release of glucocorticoids under conditions of chronic stress, however, can have toxic effects on the brain and body—a state known as allostatic load (McEwen, 2000), in which individuals show under- or over-arousal and general dysregulation of this stress regulation system. Growing up in poverty has been linked with alterations in the functioning of the HPA axis that are consistent with the notion of allostatic load. Studies have shown, for instance, that low-SES children evidence higher baseline levels of cortisol (Evans & English, 2002; Lupien, King, Meaney, & McEwen, 2000, 2001) as well as more dysregulated daily rhythms of HPA axis activity than higher-SES children (Wolf, Nicholls, & Chen, 2008). Other studies have found evidence for patterns of under-activation of the HPA axis associated with the context of poverty (Badanes, Watamura, & Hankin, 2011; Chen & Paterson, 2006; Kliewer, Reid-Quiñones, Shields, & Foutz, 2008; Kraft & Luecken, 2009). These discrepant findings reflect the fact that poverty and poverty-related stress are not one-dimensional. It may be that under-activation of the HPA axis is associated with exposure to severe forms of early life adversity including child abuse, neglect, and maltreatment (Gunnar & Donzella, 2002). In fact, children raised in low-SES families are at a higher risk for experiencing these severe forms of adversity and whether the HPA axis evidences under- or over-activation as a function of early life adversity likely has to do with the particular form, chronicity, and severity of the stress exposure (Badanes, Watamura, & Hankin, 2011; Gunnar & Donzella, 2002). Moreover, the timing of stress exposure in a child's life (whether stress occurs prenatally, post-natally, or later in childhood) may also play a role in the extent of influence that glucocorticoids including cortisol have on prefrontal cortex and self-regulation development (Neuenschwander & Oberlander, Chap. 6).

Children in poverty tend to be exposed to more daily stressors than their middle-income counterparts, and because of this, measuring the multiple risks that children are exposed to may be a better predictor of their physiological and neurocognitive functioning than their poverty status alone (Evans & English, 2002; Sameroff & Fiese, 2000). Indeed, the number of psychosocial and physical environmental risks that a child is exposed to (i.e., exposure to crowded households, noise, violence, family turmoil, and separation from family) has been shown to be positively associated with measures of children's allostatic load—increased levels of circulating glucocorticoids and catecholamines in their bodies (Evans, 2003). Furthermore, Evans and colleagues (2003; Evans and English 2002) have shown that the number of poverty-related psychosocial and physical risk factors that children face in their environments is associated with children's ability to delay gratification at age nine. Thus, it may not be exposure to income poverty, per se, that is damaging to children's emerging self-regulation, but rather, children's overexposure to extreme or to "toxic" stressors in the context of poverty that is damaging (Evans, 2004; Felitti et al., 1998; Repetti, Taylor, & Seeman, 2002; Shonkoff, Boyce, & McEwen, 2009).

Models of chronicity of income poverty exposure (Duncan & Brooks-Gunn, 1997, 2000; McLoyd, 1990) are also helpful in clarifying the relation between poverty and executive function and self-regulation development in children. For instance, chronicity of poverty exposure before the age of four (defined as the number of years since birth that a child has lived in a home that was at or below the United States poverty line) has been negatively associated with executive function at four years of age (Raver, Blair, Willoughby, & The Family Life Project Key Investigators, 2013). In their analysis, Raver et al. (2013) showed that children's executive functions at age four were decreased by a tenth of a standard deviation with each additional year of life lived at or below the U.S. poverty line. Similarly, Evans and colleagues have shown that the proportion of time lived below the U.S. poverty line during childhood is negatively associated with working memory (Evans & Schamberg, 2009) and positively associated with measures of allostatic load (Evans & Kim, 2012) at age seventeen. Thus, evidence is converging to show that living in poverty for longer periods confers more risk to emerging executive functions in children and that this relation is likely mediated, in part, by the effects of poverty-related stress exposure on the physiological systems that modulate executive functions.

Poverty exposure has also been associated with structural and functional characteristics of the brain that support and regulate executive functions. In terms of brain structure, low SES has been shown to be associated with cortical thinning of regions of the frontal lobes including the anterior cingulate cortex (ACC; Lawson, Duda, Avants, Wu, & Farah, 2013), an area of the medial prefrontal cortex involved in error detection and monitoring (Luu & Tucker, 2004). Cortical thinning reflects the relative thickness of gray matter in regions of the cerebral cortex and has been associated with cognitive ability and aging processes. In addition to objective measures of SES (e.g., family income and parental education), Gianaros et al. (2007) showed that a person's subjective perception of their own SES relative to others was associated with the volume of the ACC. That is, individuals who perceived themselves as being of a lower social status relative to others in the USA evidenced reduced gray matter volume in the ACC. Low SES in childhood has also been associated with structural brain architecture of the amygdala and hippocampus in adolescence (Luby et al., 2013; Noble, Houston, Kan, & Sowell, 2012), which has implications for children's neurocognitive development given that the amygdala and hippocampus are key players in the limbic system of the brain—a primary "bottom-up" influence on executive functions.

In terms of brain function, Kim et al. (2013) used functional magnetic resonance imaging (fMRI) to show that poverty exposure in childhood was associated prospectively with reduced prefrontal and increased amygdala activity during an effortful regulation task at age 24 years. Furthermore, exposure to cumulative stress during childhood and adolescence mediated this relation. Increased amygdala activity in young adulthood would suggest a developmental process in which self-regulatory structures and circuits of the brain are being shaped over time to a more *reactive* as opposed to *reflective* phenotype. Others have used methodologies including diffusion tensor imaging and shown that educational attainment is associated with increased white matter integrity in adolescence, which, in turn, mediated the relation between educational attainment and cognitive control abilities (Noble, Korgaonkar, Grieve, & Brickman, 2013). Taken together, evidence is mounting to suggest that poverty-related stress influences the structural and functional development of neural systems involved in error detection and active goal maintenance, memory, threat detection, and general information processing. Consistent with a bi-directional psychobiological model of executive function development, the effects of chronic stress on lower-order or "bottom-up" neural systems undermine the positive development of higher-order reflective cognitions including executive functions.

At this point, it is well established that poverty and low-resource environments are associated with decrements in children's executive functions and cognitive control abilities. That these effects are detectable at both neurophysiological and behavioral levels during early childhood and also prospectively at later ages supports the idea that early life experiences have long-term consequences for self-regulation across the lifespan. What are the critical ingredients of the early life experience that are responsible for this? Parents and other caregivers are the primary socializing agents of young children—and the caregiving environment in general constitutes the child's most proximal environment. As such, one leading hypothesis is that the proximal caregiving environment mediates the effects of more distal contexts on children's self-regulation development. In the context of poverty, for instance, parents and their behaviors are hypothesized to be critical mediators of the relation between adverse environmental conditions and child outcomes. Such a model has considerable theoretical and empirical support (Blair & Raver, 2012; Bradley & Corwyn, 2002; Conger & Donnellan, 2007; Duncan & Brooks-Gunn, 1997; McLoyd, 1998; Repetti, Taylor, & Seeman, 2002; Sastry, 2015; Wadsworth & Ahlkvist, 2015; see also Crnic & Ross, Chap. 11). The idea that poverty-related stress could affect child development *through* intermediary effects on the caregiving environments of children, including caregiver language (Kuhn et al., 2016), is important because it suggests the power of families and other forms of care to buffer or exacerbate the negative effects of poverty on children's executive function development.

Quality of Early Caregiving and Executive Functions

The most striking empirical examples of the importance of families and early rearing environments in self-regulation development come from circumstances in which children are raised in the absence of stable parental caregivers. Studies of institutionalized Romanian orphans have been especially informative in this respect (Carlson & Earls, 1997; Gunnar & Donzella, 2002; Nelson, Bos, Gunnar, & Sonuga-Barke, 2011; Zeanah et al., 2003). Children reared in these settings experience higher amounts of neglect and maternal deprivation (Zeanah et al., 2003), which has effects on the development of children's stress physiology (Carlson & Earls, 1997; for a comprehensive review, see Gunnar & Donzella, 2002). In a large randomized control trial of Romanian orphans (Zeanah et al., 2003), it was shown that institutionalized children displayed blunted HPA axis reactivity and regulation to psychosocial stress compared to children randomly assigned to foster care and to children who were raised at home (McLaughlin et al., 2015). Critically, however, the authors showed that the positive effects of foster care on HPA axis reactivity and regulation were only present for those children who were randomly assigned to foster care before they turned 2 years old. That is, placement into foster care was only effective in mitigating the blunting effects of institutionalization on HPA axis reactivity and regulation if it occurred very early in a child's life. The experimental nature of this study design (i.e., institutionalized orphans were *randomly assigned* to either foster care placement or to remain in institutionalized care as usual) helps researchers draw inferences regarding the true effect of the caregiving environment on self-regulatory systems in contexts of adversity. This type of study design is a notable strength given that nearly all other human work in this area of study is correlational and therefore suffers from some form of selection bias (i.e., in the case of non-random assignment of orphans into foster care, for instance, those orphans placed into foster care may be different in some ways than those not placed into foster care).

Experimental work conducted with non-human animals has also been particularly beneficial in this respect. That early rearing experiences influence the biobehavioral development of offspring has long been shown in non-human animal research. The importance of the primary attachment figure, the mother, for the development of well-regulated psychophysiological development is particularly evident in non-human primate studies of maternal deprivation (for review see Stevens, Leckman, Coplan, & Suomi, 2009; Suomi, 1997). As well, experiments with non-human primates that induced environmental stress by creating situations in which access to food was unpredictable caused significant amounts of stress in parents, which not only disrupted parent-infant interactions, but also had negative consequences for long-term psychophysiological and self-regulatory development of offspring (Coplan et al., 1996; Stevens et al., 2009). Research with rodents has also shown that individual variation in prototypical maternal behaviors (i.e., licking and grooming of pups as well as arched-back nursing) is a primary cause of stress physiological development in rodent offspring and that the effects of the caregiving environment on development persist into adulthood (Meaney, 2001). In a series of cross-fostering experiments, Meaney and colleagues showed that offspring who were reared by mothers expressing high amounts of maternal care displayed more well-regulated behavioral and more efficient physiological stress responses as adults than offspring who were reared by mothers who expressed low amounts of care (Caldji et al., 1998; Francis, Diorio, Liu, & Meaney, 1999; Liu et al., 1997). Recent work has shown that these effects of the early caregiving environment on biobehavioral development are mediated by an organism's epigenome, that part of the genome responsible for gene expression or the dynamic turning "on" and "off" of genes that allows an organism to be highly adaptable to their specific environmental conditions (Provençal et al., 2012; Weaver et al., 2004).

Human studies of more normative early rearing environments have also been informative for exploring the extent to which social environments shape the physiological systems associated with executive functions in children. In the Family Life Project (FLP), a prospective longitudinal sample of children and families in predominantly low-income and rural communities in the USA, instability in the number of caregivers in the home—specifically, more adult exists from the home—was associated with higher resting cortisol levels in children as early as 15 months of age, and this association persisted (and grew in magnitude) over the child's first four years (Blair et al., 2011a). This effect was present even when controlling for ethnicity, SES, parental perceptions of material hardship, and an observed behavioral measure of maternal sensitivity—itself a variable that was uniquely associated with resting levels of cortisol. In another analysis from the FLP, infants and toddlers of mothers who displayed high levels of engagement with their children during parent–child interactions showed more efficient HPA axis regulation in response to an emotion induction procedure than did infants and toddlers of mothers who displayed less engagement with their children (Blair et al., 2008). In terms of relations between SES, parenting, stress physiology, and early executive function development in children, analyses of this sample have also provided evidence that both maternal sensitivity and children's resting levels of cortisol mediate the relation between family SES and children's executive functions at age three (Blair et al., 2011b). Together, the human and animal work provide evidence that early exposure to chronic stress in the caregiving environment shapes the regulation of stress physiology associated with executive function development.

Consistent with theory regarding the development of self-regulation more generally (Kopp, 1982), children's very early control abilities begin by being primarily externally regulated through the actions of parents and other caregivers. As development progresses, experiential input becomes internalized and emotional, attentional, and also executive processes mature and become increasingly *self*-regulated. It has been shown that parental scaffolding, or the process by which parents actively support and organize the problem solving of their children (Wood, Bruner, & Ross, 1976), is associated with children's executive function concurrently at two years of age (Bibok, Carpendale, & Müller, 2009) and longitudinally at four years of age (Hughes & Ensor, 2009). One mechanism through which parental scaffolding may have effects on higher-order cognitions including executive functioning is through children's verbal competencies. Indeed, studies have shown that parental scaffolding at two years of age had positive effects on children's executive function at age four via positive effects on children's verbal ability (Hammond, Müller, Carpendale, Bibok, & Liebermann-Finestone, 2012). Similarly, Landry, Miller-Loncar, Smith and Swank (2002) have shown that verbal scaffolding in parents of 3-year olds was positively associated with children's executive function at six years of age. Again, as implied in the analysis of Kuhn et al. (2016) described previously, this effect was mediated by gains in children's language and nonverbal skills, which were supported by parents' use of scaffolding. Thus, parental verbal scaffolding during problem solving may increase children's capacity for language, which, in turn, may serve to organize their later self-directed problem-solving abilities and executive functions.

In addition to scaffolding, maternal sensitivity (i.e., a concept describing the extent to which a mother is able to interpret meaning and respond appropriately and contingently to her child's cues; Ainsworth, Blehar, Waters, & Wall, 1978) has been associated with children's executive function measured at 18, 26, and 36 months of age (Bernier, Carlson, Deschênes, & Matte-Gagné, 2012; Bernier, Carlson, & Whipple, 2010). Longitudinally, maternal sensitivity assessed at one year of age has been associated with children's executive function two years later (Rochette & Bernier, 2014). Using Family Life Project data, Blair et al. (2011b) found that observed measures of both maternal negativity (intrusiveness and negative regard for child) and maternal sensitivity in the child's first two years made unique contributions to children's executive function at three years of age. Furthermore, each domain of observed parenting behavior statistically mediated the association between parent education and children's executive function, suggesting that the proximal caregiving environment of children acted as an intermediary in the broader relation between families' SES and children's executive function at age three. With respect to educational outcomes in children, it has been shown that maternal sensitivity observed across the first three years of life was associated with preschoolers' delay of gratification abilities, which in turn, partially mediated the relation between maternal sensitivity and school readiness (Razza & Raymond, 2013). Together, these studies provide evidence that the caregiving environment of children is especially important for supporting early self-regulation and success in school.

Research has also begun to address questions regarding the relation between the caregiving environment and growth or change in executive functions across childhood. In a novel approach to modeling change in parenting behaviors and growth in executive functioning from three to five years of age, Blair, Raver, and Berry (2014) employed a cross-lagged latent change score model to explore the potential for bi-directional effects between caregiving and change (i.e., growth) in child executive function across childhood. This analysis showed that higher maternal sensitivity observed at three years of age predicted increased growth in child executive functions from three to five years of age. Furthermore, the authors showed that higher child executive function at three years of age predicted less decline in observed maternal sensitivity from three to five years of child age. This is consistent with a transactional model of early regulation (Sameroff & Fiese, 2000) where both parent and child characteristics are observed to contribute meaningfully to each other's development in a process of co-regulation. Here, it is notable that previously cited studies (Hackman et al., 2014, 2015; Hughes et al., 2009) found no relations between family SES and children's executive function growth across early childhood, which suggests a unique contribution of the early caregiving environment, as opposed to more distal family socioeconomic factors, in predicting longitudinal change and growth in executive functions across childhood.

Parenting and Child Development in Context

Parenting behaviors and caregiving environments are embedded within families and socioeconomic contexts, and the early caregiving environment may be one mechanism through which the broader context of poverty confers risk to children's emerging executive functions. Parents living in poverty experience higher amounts of psychological distress, depression, more marital discord and increased risk of intimate partner violence, and more negative life events compared to non-poor parents (McLoyd, 1990). These factors can increase parenting stress and reduce parents' capacity for warm and sensitive caregiving with their children—rendering their interactions with children harsher than those observed in families experiencing far less daily stress (Cassells & Evans, Chap. 2; Duncan & Brooks-Gunn, 2000). These realities have the potential to disrupt family functioning and to negatively affect children's development (Conger & Conger, 2002; Conger & Donnellan, 2007; Conger & Elder, 1994). Poverty also limits the extent to which parents are able to invest in the social capital of their children (i.e., to provide a rich home learning environment by buying books or cognitively stimulating toys, paying for tutoring, and visiting museums; Becker & Tomes, 1994; Conger & Donnellan, 2007; Haveman & Wolfe, 1994). In the context of deep poverty, parents' investments are often necessarily directed more toward survival goals (Conger & Donnellan, 2007). Such conditions can undermine the development of executive functions. For instance, having fewer learning resources in the home has been shown to be associated with slower growth in inhibitory control and cognitive flexibility during the preschool years (Clark et al., 2013) and both the home learning environment and parental responsiveness have been shown to mediate relations between family SES and inhibitory control and working memory at nine years of age (Sarsour et al., 2011). One recent study showed that aspects of the home learning environment mediated the effects of family SES on children's executive function and planning ability (i.e., a skill highly associated with executive function) and that maternal sensitivity mediated the relation between family SES and children's planning ability (Hackman et al., 2015). Findings from these studies suggest that the home caregiving environment—characterized by both the provision of learning materials/experiences as well as the parenting behaviors that a child is exposed to—may be seen as both a consequence of parent stress processes in the context of poverty as well as an antecedent of neurocognitive outcomes in children including executive functions.

It is important to acknowledge that family processes and the proximal caregiving environment are embedded within larger socioecological contexts that influence stress processes in parents. For instance, the communities and neighborhoods that poor families reside in tend to be inferior to those of wealthier families in terms of infrastructure and services and disadvantaged neighborhoods often have higher instances of violence than do more advantaged neighborhoods (Brooks-Gunn, Duncan, & Aber, 1997; Duncan & Brooks-Gunn, 2000; Evans, 2004; Foster & Brooks-Gunn, 2009), and there is evidence that residential segregation by family income is increasing (Bischoff & Reardon, 2014). How does neighborhood stress permeate the family unit? Parents' perceptions of high neighborhood stress, that is, of poor services available in their community, of high unemployment and drug use, of low social cohesion, and of economic disadvantage, have been associated with increased psychological distress in parents as well as with negative interactions with adolescents (Gutman, McLoyd, & Tokoyawa, 2005). Mothers' perceptions of neighborhood danger are also associated with less maternal warmth toward adolescent children (Gonzales et al., 2011), and a study using public crime report data showed that residential proximity to recent homicides in Chicago communities was associated with higher distress in parents—a potential mechanism through which community violence may be transmitted indirectly to children (Sharkey, Tirado-Strayer, Papachristos, & Raver, 2012).

There are also recent findings suggesting that the neighborhood context may be associated with the development of stress response physiology at the individual level. For instance, high neighborhood stress measured both objectively (e.g., using U.S. Census data) and subjectively (e.g., perceptions of neighborhood disorder and safety) have been associated with flatter diurnal HPA activity in adults—indicating dysregulation of stress systems involved in self-regulation within neighborhood contexts of high stress (Karb, Elliott, Dowd, & Morenoff, 2012). Concentrated neighborhood disadvantage has also been associated with heightened resting cortisol levels (Rudolph et al., 2014) and with increased HPA reactivity to psychosocial stress in adolescents (Hackman, Betancourt, Brodsky, Hurt, & Farah, 2012). Others have found lower neighborhood SES to be associated with lower cortisol levels in children (Dulin-Keita, Casazza, Fernandez, Goran, & Gower, 2012) and adolescents (Chen & Paterson, 2006). One study found no association between neighborhood SES and HPA activity (Kapuku, Treiber, & Davis, 2002). These studies provide preliminary evidence that the broader neighborhood context may be associated with developing stress physiology over and above the proximal family-level environment. The small number of studies and the inconsistencies in the findings (i.e., neighborhood-level stress and disadvantage have been associated with both over- and under-activation of HPA axis), however, suggests that the exact relation between the neighborhood context and this stress response system is not yet fully understood and suggests an area for future research. Discrepant findings are likely due to inconsistencies in the measurement of neighborhood-level stress and disadvantage across studies, differences in the extent of stress that children face in their home environments and if and how the home environment is measured across studies, differences in the developmental ages of participants in previous studies, and differences in the exact measure of HPA activity across studies. Clarifying these terms will aid in understanding the true relation, if any, between the neighborhood context and the development of this stress response system. In terms of relations between neighborhood characteristics and children's executive function development, one recent study found no relation between concentrated neighborhood disadvantage and children's working memory at age ten, nor between concentrated neighborhood disadvantage and children's growth in working memory through age fourteen, controlling for family socioeconomic status (Hackman et al., 2014).

Families living in poor neighborhoods are also exposed to more violence than those living in non-poor neighborhoods (Brooks-Gunn et al., 1997). Results from a recent study suggest that aspects of preschoolers' self-regulation may be compromised when exposed to local violence in their community. Specifically, Sharkey, Tirado-Strayer, Papachristos, and Raver (2012) matched data on preschoolers' self-regulation with Chicago Police homicide records and found that children who were recently exposed to community violence (operationalized as residing within 2500 feet of a homicide that occurred within seven days of testing) displayed worse impulse control and attention and scored worse on pre-academic skills measures including early vocabulary and math than children who were not recently exposed to violence. There were no significant effects of exposure to community violence on executive function or effortful control. These effects may have consequences for children's success in school. As evidence of this, in a study of a different sample, Sharkey (2010) found that living in the proximity of a homicide taking place within seven days prior to testing was associated with lower reading and vocabulary scores in African–American students. Although the very limited number of studies that have assessed relations between the neighborhood context and children's executive functions have found no evidence of such a relation, findings from these studies do suggest that aspects of the neighborhood context may be associated with more "bottom-up" aspects of self-regulation in children including their stress response physiology and attentional processes.

In addition to the effects of environmental stress on family processes and self-regulatory outcomes in children, poverty-related stress may also be associated with the neurophysiological and cognitive regulation of parents themselves (Barrett & Fleming, 2011; see also Mileva-Seitz & Fleming, Chap. 10). Consistent with findings indicating the early and long-lasting social regulation of the developing HPA axis, research has shown that adult mothers who reported having experienced early life adversity show heightened and dysregulated patterns of diurnal HPA axis activity compared to mothers who reported no early life adversity (Gonzalez, Jenkins, Steiner, & Fleming, 2009). The relation between stress exposure and parents' HPA axis regulation is important given that regulation of the maternal HPA axis has been associated with variation in maternal caregiving behaviors in humans. For instance, increased cortisol levels in mothers have been associated with more fatigue and negative mood (Krpan, Coombs, Zinga, Steiner, & Fleming, 2005) and with less observed maternal sensitivity and more intrusive behaviors in the first six months of the postpartum period (Mills-Koonce et al., 2009; Thompson & Trevathan, 2008). Higher maternal cortisol levels have also been associated with lower levels of maternal sensitivity observed across the first two postpartum years (Finegood et al., 2016). Using functional magnetic resonance imaging (fMRI) to assess regional brain activity associated with aspects of the parent experience, new research has shown that mothers' neural response to baby-cry stimuli in key regulatory areas of the brain are correlated with measures of observed maternal sensitivity (Kim et al., 2011; Musser, Kaiser-Laurent, & Ablow, 2012; Swain, 2011), suggesting that parenting behaviors are organized by psychobiological processes operating at multiple levels. Retrospective reports of the quality of parental care that one received during childhood have also been shown to predict adult mothers' grey matter density in several key self-regulatory regions of the brain and, as well, are predictive of mothers' functional neural responses to baby cries (Kim et al., 2009), suggesting a potential neural mechanism through which early experiences with caregivers shape the development of the parental brain and indirectly affect parenting behaviors and child outcomes—a potential means through which stress may be transmitted across generations (see Mileva-Seitz & Fleming, Chap. 10).

Consistent with the observed effects of environmental stress on adult stress physiology as well as on the structure and function of brain areas involved in self-regulation, a number of recent studies have noted relations between maternal executive function and maternal behaviors with children (Chico, Gonzalez, Ali, Steiner, & Fleming, 2014; Cuevas et al., 2014; Deater-Deckard, Sewell, Petrill, & Thompson, 2010; Deater-Deckard, Wang, Chen, & Bell, 2012). Indeed, one study has shown that both maternal HPA axis activity and maternal executive function fully mediate the relation between mothers' exposure to early life adversity and maternal sensitivity in adulthood (Gonzalez, Jenkins, Steiner, & Fleming, 2012). The evidence suggests that parent stress associated with the strains of poverty and early life adversity is associated with alterations to the neurophysiological systems that underlie the parental brain, which supports parents' own cognitive self-regulation as well as the organization of their interactions with children.

Conclusions and Future Directions

In this chapter, we have overviewed some of the neurobiological foundations of executive functions and the developmental trajectory of these skills across the childhood years. We outlined what is known regarding the relation between poverty and executive function development in children and some of the specific neurobiological mechanisms of this relation—specifically emphasizing research suggesting that the caregiving environment is a primary mediator of the relation between the socioeconomic conditions of families and children's neurocognitive development. In doing so, we considered several aspects of the caregiving environment that may be affected by the context of poverty (e.g., parents' behaviors with children, the home learning environment, and parents' own cognitive and biobehavioral regulation) that are presumed to shape children's neurocognitive growth.

The relation between stress exposure in early life and children's executive function development is moderate and robust across a large number of studies. The specific mechanisms of this relation remain somewhat unclear, however, even after the large amount of studies conducted on this topic. This is because almost all of the findings from the human research discussed herein are derived from non-experimental correlational studies, which suffer from selection bias, limiting the extent of inference that may be drawn with respect to casual mechanisms. Descriptive correlational studies preclude the ability to conclusively say, for instance, that poverty *causes* changes in the caregiving environments of children, which, in turn, shape the trajectories of children's neurocognitive development. With this in mind, more non-human experimental work is needed to understand the causal links between low-resource environments, specific caregiving environments, and neurophysiological and behavioral outcomes in offspring. Non-human animal models are extremely useful from a causal inference perspective because they allow for the experimental manipulation of environmental stress, for instance, which helps to clarify the role that low-resources play in shaping parenting behaviors (Raineki, Moriceau, & Sullivan, 2010). Furthermore, experimental manipulation of the caregiving environment itself in animal models, through either induction of environmental stress (Raineki et al., 2010) or through cross-fostering procedures (Meaney, 2001) and the observation of subsequent changes to neural, physiological, and behavioral outcomes in offspring are necessary steps in estimating the true and potentially multifaceted role that the caregiving environment plays in early self-regulation development of offspring.

Of course, non-human animal studies are limited in their translation to human ecology and development. Particularly, when these studies are used to model cognitive abilities such as executive functions. As such, it is important to note that there have been a small number of randomized controlled trials conducted with humans in low-income settings that have directly targeted the caregiving environment (e.g., by focusing on enhancing parents' competencies and supporting parent–child relationships) and shown positive effects in terms of boosting maternal responsiveness and cognitive, socioemotional, and language development in infants (Landry, Smith, & Swank, 2006; Landry, Smith, Swank, & Guttentag, 2008). Other parenting programs have been successful in reducing attention deficit hyperactivity disorder symptoms in preschoolers at risk for conduct problems (Bor, Sanders, & Markie-Dadds, 2002; Jones, Daley, Hutchings, Bywater, & Eames, 2007) and in improving the functioning of neural systems involved in early attention processes in children (Neville et al., 2013). Parenting interventions have also had positive effects on HPA axis regulation in preschoolers at high risk of conduct problems (Brotman et al., 2007) and enhanced foster care interventions have had positive effects on HPA axis regulation in children in foster care (Dozier, Peloso, Lewis, Laurenceau, & Levine, 2008; Fisher, Gunnar, Dozier, Bruce, & Pears, 2006; Fisher, Stoolmiller, Gunnar, & Burraston, 2007). These studies are promising and provide necessary experimental evidence for the role of the caregiving environment in shaping infants and preschoolers' early self-regulation. Experimental studies that test intervention effects on direct assessments of children's early executive functions as well as on related aspects of stress physiology, neural functioning, and behavior are needed to more firmly establish the causal mechanisms and the multifaceted nature of children's early self-regulation development in the context of adversity.

The field would also benefit from more studies that measure and model multiple component stress processes in low-income parents. In particular, it would be beneficial to test which forms of stress are most responsible for the relation between poverty and parenting behaviors. Is it, for instance, parenting stress (i.e., stress having to do with the parenting role in particular) that is most responsible for the relation between the context of poverty and reductions in maternal sensitivity (see Crnic & Ross, Chap. 11)? Is the relation more strongly accounted for by other stress processes in these contexts (e.g., perceptions of material hardship, marital conflict, violence exposure, or psychopathology)? What about aspects of parents' cognitive and neurophysiological regulation that have been shown to be associated not only with stress exposure in early life but also with parenting behaviors? How do the unique or interactive effects of multiple coordinated stress processes come to organize parental executive functions and HPA axis activity, as well as the functional and structural components of the parental brain? The answers to these questions would benefit policy and early intervention immensely.

Given that children and families are embedded within sociocultural contexts, future research that aims to understand the influence of context on family functioning and child development would benefit from widening the concept of disadvantage to consider people's individual subjective and/or relative experiences of hardship rather than focusing on absolute levels of disadvantage (e.g., income and education) alone. For instance, one recent study (Ursache, Noble, & Blair, 2015) showed that both objective family SES and parents' subjective perceptions of relative social status were uniquely associated with children's executive functions measured at age nine. Children who were from poorer families or whose parents rated themselves as being of lower social status performed worse on executive function tasks. Additionally, the authors noted a significant negative association between parents' perceptions of stress and their children's cortisol levels, although neither objective family SES nor parents' subjective social status was associated with children's cortisol levels. Little is currently known about the mechanisms through which these effects on children's executive function might occur, but it is likely that perceptions of low status increase stress in parents which may influence their interactions with their children. No studies to date have directly tested these questions, although the field would benefit greatly from such approaches. Additionally, given the interconnectedness of social class and race, perceptions of discrimination may be another factor relevant to understanding stress processes in parents and family functioning in the context of adversity. For instance, one recent study found relations between mothers' perceptions of daily racial discrimination and their children's birthweight (Earnshaw et al., 2013).

A similarly beneficial approach may be to examine macrocontextual factors—aligned with a social epidemiological perspective on relations between social class and health—as they relate to family functioning, proximal family stress processes and to child self-regulation development in particular. Incorporating measures of regional income inequality or of social stratification of families using U.S. Census data, in addition to family-level measures of SES, may be particularly beneficial to understanding the etiology of family stress processes in the context of adversity given recent evidence suggesting that the link between SES and health is stronger in geographic contexts characterized by higher income inequality (Wilkinson & Pickett, 2006), that individual health is worse when relative income deprivation is high (Kondo, Kawachi, Subramanian, Takeda, & Yamagata, 2008), and that psychosocial comparative processes are associated with alterations to individual-level stress systems that partially explain mortality and morbidity in human and non-human primates (Sapolsky, 2005). It may be that proximal family stress processes and children's emerging self-regulation abilities evidence similar etiologic and developmental patterns to those found for physical health outcomes, and/or that family stress processes and children's emerging self-regulation abilities are mechanisms of the association between SES and physical health.

Further examination of the specific mechanisms that explain the association between the socioeconomic conditions of families and children's emerging self-regulation and executive functions is warranted. An abundance of descriptive, correlational research and theory suggests that aspects of the caregiving environment of children may be partially responsible for this association, but we note the need for more experimental studies that not only test the malleability of parenting behaviors and caregiving environments in the context of poverty, but also that test the extent to which children's early self-regulation including their executive functions and supporting attentional and neurophysiological processes are amenable to family-based intervention and concomitant changes to the caregiving environment.

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