Neuroscientific Insights: Attention, Working Memory, and Inhibitory Control

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Summary

In this article, Cybele Raver and Clancy Blair explore a group of cognitive processes called executive function (EF)—including the flexible control of attention, the ability to hold information through working memory, and the ability to maintain inhibitory control

EF processes are crucial for young children's learning. On the one hand, they can help students control their anxiety when they face challenging academic tasks. On the other, these same processes can be undermined when children experience chronically stressful situations—for example, poverty, homelessness, and neighborhood crime. Such adverse early experiences interfere with children's development of EF, hampering their ability to manage challenging situations

Through both behavioral examples and empirical evidence, Raver and Blair illustrate how children's cognitive development is intertwined with EF. They show how children's regulation of higher-order thinking is related to the regulation of emotion—in both top-down and bottom-up fashion—and they review research on early brain development, EF and emotion regulation, and children's academic performance. They also examine the efficacy of educational interventions that target EF and of integrated interventions that target both emotional and cognitive regulation.

What does our understanding of EF imply for policy in pre-K–3 education? First, write Raver and Blair, to help young children learn, school districts need data not only on their academic readiness but also on key dimensions of EF. Second, we already have interventions that can at least partially close the gap in neurocognitive function and academic achievement between children who face multiple types of adversity and those who don't. In the long run, though, they argue, the best way to help these children is to invest in programs that reduce their exposure to chronic severe stress.

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In the past 10 years, formal educational opportunities for children from early childhood to third grade have changed dramatically. Prekindergarten and kindergarten programs have become increasingly available, and standards for learning in the early elementary grades have become more academically rigorous. As a result, young children in the United States are spending more time in formal education and working harder on academically anchored content.[1] For example, the Common Core math standards say that by first grade, children should be able to solve word problems that involve "adding to, taking from, putting together, taking apart, and comparing," with the challenge of solving for unknown values and using "objects, drawings, and equations with a symbol for the unknown number to represent the problem."[2] To be sure, academic challenges such as these require complex, higher-order cognitive skills. Importantly, they also require children to modulate their attention, emotions, and motivation so that they remain focused and persistent when the academic going gets tough. In this article, we discuss recent advances in neuroscience that help reveal the pathways that connect young children's higher-order cognitive skills, their emotional skills, and whether they succeed or struggle in this academically challenging terrain.

We first outline several breakthroughs in how neuroscientists understand children's brain development. These breakthroughs highlight the role that a group of cognitive processes called executive function (EF) play in children's opportunities for learning. What exactly is EF? It encompasses the flexible control of attention, the ability to hold information through working memory, and the ability to maintain inhibitory control. Early in the article we offer a behavioral example and empirical evidence to illustrate what attention control, working memory, and inhibitory control look like and how they work together to support children's early learning. We also consider new findings in neuroscience demonstrating that just as higher-order cognitive processes (including mindsets) can help students modulate anxiety when they face challenging academic tasks, these same processes can be undermined when anxiety and challenge become too great.

Science has recently given us elegant evidence of how these cognitive and emotional domains of children's brain function are wired together in both top-down and bottom-up fashion. We carefully describe how children's regulation of higher-order thinking is related to the regulation of emotion using these top-down and bottom-up models; briefly review research on early brain development, how changes in brain function and related competencies are measured, and how both EF and emotion regulation contribute to children's academic performance; and examine factors that support or constrain children's development of those regulatory competencies, allowing some children to navigate cognitively demanding and emotionally challenging tasks more easily than others. In the remainder of the article, we discuss educational interventions that target EF and integrated interventions that target both emotional and cognitive regulation. We review the efficacy of these approaches, which range from individually administered treatments for clinical levels of EF difficulty to school interventions that can take place in classrooms. We wrap up with implications for policy and prevention in the context of starting early.

Top-Down Executive Function and Academic Success

Imagine a preschooler who wants to join older siblings or peers as they play a blazingly intense card game like Uno. The group's energy is high, and there's laughter all around. But this child doesn't know how to play. To get into the game, she needs to focus her attention, with her brain working at remarkably rapid pace to pick out important details (for example, the numbers and shapes on the cards, or how many cards each player gets). She can sort these key details from irrelevant ones, such as whether players hold the cards in their left or right hands. In short, children must be able to focus their attention flexibly so that they can manage competing and sometimes conflicting chunks of incoming information, in addition to being alert and oriented to cues in their environment. Whether they're learning a card game or managing larger, more academically challenging contexts, children must also handle competing decision rules for how to categorize information and solve problems. This ability to *shift cognitive set* flexibly—that is, to see relationships among things in one way and then shift the mental frame and see them in a different way—is central to executive function. To assess attention shifting, we ask children to sort test items (pictures of objects, shapes, etc.) to reflect similarity in one way, such as color; then we ask them to shift their attention to a second dimension along which the items can be categorized, such as size, and to sort them accordingly. Young children's abilities to focus and flexibly shift their attention play an important role in their capacity to solve problems in the context of play and learning.[3]

To learn the card game, the child in our example also needs to hold a lot of information in mind, such as what patterns or groups of cards may be played and when. In other words, she needs strong working memory skills. We can easily assess working memory orally, for example, by asking children to quickly learn a sequence of numbers or words and then to repeat back or recall them in the reverse order. Developmental research shows that children's working memory changes rapidly during early childhood and plays a key role in goal-directed behavior and higher-order problem solving of many kinds.[4]

Finally, the child who wants not only to play but also to win that card game needs to have some basic capacity to avoid behavioral ruts—that is, she has to inhibit her tendency to respond automatically. For example, she may have to stifle the urge to grab a card she really needs to make a good hand so as not to tip that hand to other players. In psychological terms, this ability to inhibit a more automatic or reactive response in favor of a reflective and flexible one is called *inhibitory control*. Young children increasingly develop this capacity to inhibit knee-jerk responses in favor of more reflective responses that help them meet goals and avoid errors.[5] To assess inhibitory control, we give a child tasks that encourage a pattern of response that the child repeatedly engages in but that must be overcome—that is, inhibited—in response to a specific cue. A game like Simon Says, in which the rules quickly switch, is a good example. Of course, inhibitory control is in many ways linked to attention and memory. Children younger than three, for example, may not only have trouble inhibiting impulsive responses but also following and remembering the rules of the game. Older children master these skills so that in both academically and socially challenging contexts, they can inhibit a previously learned or dominant but incorrect response in favor of a less dominant, correct response.

These three EF skills (flexible shifting and focusing of attention, working memory, and inhibitory control) are the foundations of both children's and adults' abilities to meet goals of all kinds. They serve as air traffic control for a great deal of brain activity.[6] Specifically, EF is associated with neural activity in areas of the prefrontal cortex, located in the anatomically topmost and forward regions of the brain. The signals from the prefrontal cortex extend to cortical and subcortical areas anatomically behind and below the prefrontal cortex (including areas responsible for motor and emotional responses to stimuli, such as the basal ganglia, amygdala, and hippocampus), and to some degree help control activity in those areas. For this reason, EF is described as working in top-down fashion.[7] In combination, EF skills let children organize information in new ways.

Researchers have developed several models of EF (as well as more broad constructs of self-regulation and "approaches to learning") that focus to greater or lesser degrees on how the dimensions of EF work within and across individuals, and within and across educational settings from preschool through K–12 education.[8] In all these models, the consensus is clear: EF gives children increasing cognitive and behavioral control, not only letting them solve more complex academic problems but also allowing them to take other children's perspectives and understand that those perspectives may differ from their own.[9]

The neurobiology of executive function offers insight into its role in children's early learning and how early educational experience and high-quality caregiving support and foster its development. EF, like the prefrontal cortex, matures throughout childhood and isn't fully developed until early adulthood.[10] This leaves ample opportunity for children's experiences to have an extended influence on EF's development and on the development of the prefrontal cortex and its many connections throughout the brain. Although EF and the prefrontal cortex develop over an extended period of time, research suggests that the prefrontal cortex is active in infancy and that early indications of EF-like abilities can be observed in the processing of language and early inhibition of reaching behavior.[11] Not until children are two or three years old, however, can complex EF abilities be directly measured.[12]

A Year of Growth

What skills can preschoolers demonstrate on simple tasks that require attention, memory, and inhibitory control? A recent study in Boston suggests that although most children can understand basic rules of a game in the fall of their prekindergarten year, only about half of them can flexibly remember the different rules of EF tasks and switch the way they use them. By the spring of their preschool year, most students in high-quality prekindergarten gained substantial proficiency in mastering the more complex versions of the tasks. For example, more than three-fourths of students who were assessed could remember and use more complex rules, and the majority of students could use impulse control and memory to perform well on trials that required higher EF skills.

Source: Christina Weiland et al., "Associations between Classroom Quality and Children's Vocabulary and Executive Function Skills in an Urban Public Prekindergarten Program," *Early Childhood Research Quarterly* 28 (2013) 199–209, doi: 10.1016/j.ecresq.2012.12.002.

Given EF's close relation with the prefrontal cortex, its development in children is fostered by types of caregiving and early experiences that facilitate activity in and functioning of this area of the brain in its top-down role. These include parenting behaviors that are grouped together as *sensitive care*, specifically, parenting that's characterized by joint attention, high levels of scaffolding of behavior (where the adult provides appropriate levels of support and challenge), and low levels of intrusiveness and detachment. Failures of executive control are frequent in early childhood (for example, during the terrible twos), and parents and caregivers need to exercise patience and understanding. Three- to four-year-olds don't have the same capacity for executive function that six- to seven-year-olds do, and these differences are reflected in the educational approaches taken in prekindergarten and the early elementary grades. Prekindergarten involves activities through which children acquire information about academic content through purposeful play and exploration. Prekindergarten also often involves shorter periods of teacher-led instruction that take into account preschoolers' more limited attention skills and inhibitory control. Early elementary education requires children to begin putting information to use in more formal math, reading, and writing activities that capitalize on their capacity for longer periods of focused and sustained attention, inhibitory control, and working memory. Early parenting and prekindergarten education that fosters EF prepares children to meet the expectations of the early elementary grades.

We now have strong evidence, including experimental evidence, to show that the development of EF before children enter school consistently predicts early math and early reading skills, even when we control for prior achievement and measures of general mental ability.[13] From the standpoint of cognitive ability, EF is manifestly important for holding information in mind when solving mathematics problems and for learning early literacy skills such as phonemic awareness, where a compound word is understood to be composed of two shorter words (for example, toothbrush.) Accordingly, our research has consistently shown—across multiple samples of children from low-income homes—that individual EF differences in children as young as four or five predict their math and literacy ability from preschool through later elementary school.[14] For example, in two different studies, Clancy Blair (one of the authors of this article) and colleagues found that children's EF predicted their performance in math across the early school years, even after taking into account their general cognitive abilities (or IQ) and other aspects of social-emotional competence.[15]

Other research teams have found that children's EF skills predict academic achievement over the early elementary years and through adolescence.[16] Several studies have taken into account (or statistically controlled for) early measures of children's achievement and found that these self-regulatory skills are related to later achievement net of those early skills.[17] Longitudinal studies—that is, studies that follow children over time—have also shown that just as EF promotes math and reading, learning math and learning to read foster the development of EF.[18]

The more purely cognitive aspects of EF explain part but not all of the self-regulation story when predicting young children's academic achievement in school settings. Specifically, models that emphasize only the top-down cognitive aspects of EF don't fully account for the way that emotions—such as frustration, anxiety, enthusiasm, and motivation—can undercut or energize EF. Children's capacity to manage or modulate emotions (whether they're playing a game with peers or handling the feelings that arise when tackling difficult academic material) is called *emotion regulation*. Prevailing definitions of emotion regulation highlight not only how children's emotions are regulated themselves, but also how emotions regulate cognitive functioning and social interactions.[19] We now turn to those emotional regulatory processes and how they work hand in hand in a bottom-up fashion with top-down EF.

Bottom-Up Emotional Regulation and Learning

Let's return to the preschooler trying to work her way into (and possibly even win) that fast-paced card game. If she gets too excited by the thought of beating her opponents or too frustrated from having lost the most recent hand, she may lose focus and miss her turn; she may momentarily forget the rules; or she may lose behavioral control and jump the gun, playing her hand too soon. In short, her excitement or frustration play a significant role in how well she learns and plays the game. As the neurobiology of EF indicates, and parents and teachers attest, young children's EF skills can be alternately supported or derailed by their emotional state and by the physiological response to the stress that accompanies emotional responses to environmental challenges.[20] In broad-brush terms, this happens because the brain areas associated with reactivity and regulation of emotion and stress—structures in the limbic brain below the cortex, sometimes referred to as the reptilian brain—are reciprocally connected with the prefrontal cortex; consequently, both influence and are influenced by EF. The connectivity between the limbic and cortical areas of the brain makes perfect evolutionary sense—the brain areas associated with emotion and stress need to communicate effectively with the thinking brain (the prefrontal cortex) to direct attention, thinking skills, and planning and problem-solving resources to things that are important for our wellbeing.[21] Emotional arousal sharpens and strengthens attention to the environmental details that are relevant to our goals and interests. At very high levels, however, emotion can disrupt cognitive control, hijacking attention and depleting cognitive resources.[22]

Neurobiologically, the way that the emotional (limbic) brain communicates with the thinking brain is by increasing neurotransmitter levels that at a moderate level cause neurons in the prefrontal cortex to be more active. Those key neurotransmitters (dopamine and norepinephrine) work in concert with the hormone cortisol, the end product of stress-related activity in what's known as the body's hypothalamic-pituitary-adrenal (HPA) axis. Because cortisol is present in children's saliva, it offers scientists a rough proxy for measuring how children's brains and bodies are responding to their environments. When levels of cortisol and other neurotransmitters are too high (indicating that a person is emotionally overwrought and stressed out) or when they are too low (indicating that the person is bored and lethargic), activity in the prefrontal cortex drops; consequently, the valuable thinking skills that this brain area supports aren't as readily available. This bottom-up, top-down relationship between emotions and higher-order cognitive skills is paralleled by children's increasing capacity

Rapid Improvement

How much does children's EF skill grow over time? In one study of young children in rural and semirural communities, growth in EF was about 1.5 standard deviations per year—meaning that a four-year-old child in the lowest end of the distribution for her age group would be at the upper end of the distribution for three-year-olds. This rapid growth means that parents and prekindergarten teachers can expect pronounced improvement in children's abilities to hold information in mind; to flexibly regulate attention, emotion, and behavior in response to changing contexts and contingencies; to show higher levels of sustained attention and engagement; and to disengage from activities when they need to. By kindergarten, evidence from nationally representative data sets suggests, teachers recognize and value these increased competencies; children perform better not only on direct assessments of EF but also on teacher-reported measures of attention, persistence, and behavioral control.

Source: Michael T. Willoughby et al., "The Measurement of Executive Function at Age 3 Years: Psychometric Properties and Criterion Validity of a New Battery of Tasks," *Psychological Assessment* 22 (2010): 306–17, doi: 10.1037/a0018708.

to exert top-down cognitive control over negative emotional states, such as frustration and anxiety, and also to maintain the optimal levels of attention and focus associated with the motivation and engagement that are essential for doing well in school.

As we saw in the card game, a child's acquisition of challenging material can be accompanied by a surge of excitement and pride in her role as a learner. Alternately, children can become increasingly aware of failures, with corresponding negative self-appraisal and rising withdrawal from the process of learning—effectively turning EF off. To explore this process, we must take a step back to map the ways that children's emotional processes are regulating (and dysregulating) and regulated.[23] A good example of the role that the bottom-up, top-down nature of EF plays in education can be seen in a recent study of first- and second-graders. Anxiety about mathematics co-opts the working memory resources that students need for complex problem solving, leaving them vulnerable to choking under pressure.[24] Only a few studies have examined the neurobiological and behavioral mechanisms that link younger children's anxiety levels to their acquisition and recall of academic information in the early elementary grades.[25] This promising area of research is likely to yield new directions for educational intervention.

From early childhood through early elementary school, fortunately, children grow increasingly competent at using voluntary cognitive control to rein in their emotions. Attention, working memory, and inhibitory control each play a key role in that process. This relationship between emotion and EF highlights the complex and interrelated nature of influences on learning, and shows that focusing on the social and emotional aspects of self-regulation is a key part of elementary education.[26]

First, research in both neuroscience and developmental science shows that voluntarily focusing attention (both visually and psychologically) away from sources of distress is a powerful way to manage emotion and maintain behavioral self-control.[27] Landmark research on young children's ability to delay gratification using prohibited but tempting food rewards (such as a marshmallow) is often used to illustrate the power of executive attention. Children who can distract themselves from the source of temptation are able to wait longer and are correspondingly more successful in meeting the task's goal than are children who look at or think about the tempting item.[28] In an innovative experimental twist on the marshmallow delay task, young children have also been found to accrue information about the reliability or predictability of their environments. Children who were randomly assigned to interact with an adult experimenter who was unreliable in coming through with promises (of stickers) waited significantly less time before eating the marshmallow than did children randomized to interact with a more reliable adult.[29] These findings show that young children can mentally focus on the prospect of either a more positive or more negative outcome, demonstrating experimentally induced differences in the power of young children's mindsets for self-control.

In more recent work with older children at risk for anxiety and depression, psychological distraction away from potential negative outcomes, such as performing badly on academic or social tasks, has consistently been associated with a reduction in negative mood, while rumination (or difficulty psychologically disengaging attention from negative mental perceptions) has been associated with increased activity in limbic brain areas and greater feelings of worry and sadness.[30] As we'll discuss below, the recursive top-down, bottom-up nature of executive function and emotion regulation holds substantial promise for educational intervention. Helping children modify their attention biases away from negative stimuli and toward more positive stimuli may reduce negative moods and give them greater emotional and cognitive self-control.[31]

Second, neuroscience research provides strong evidence that children can adapt through *set-shifting*, that is, reorienting how they appraise stimuli that were originally understood to be upsetting.[32] People deploy this form of EF when they take a psychological step back from experiencing a situation or event as painful, frustrating, or upsetting, and instead reappraise it in ways that limit its disruptive power. As a top-down form of emotion regulation, cognitive reappraisal is associated with increased prefrontal cortex activity and decreased activity in emotional areas of brain, such as the amygdala and medial orbitofrontal cortex.[33] The cognitive reappraisal model tells us why some children—and adults—may be more vulnerable than others to interpreting their own errors and difficulties when learning new material as a lack of ability or intelligence, leading them to be less motivated to learn. In an exceptionally powerful set of mindset interventions, researchers have illustrated that cognitive reappraisal can substantially shift older students' emotional responses to learning new, difficult material and their neurocognitive responses to making errors.[34] Those EF-based skills let students exert willpower in ways that have been depicted as cool and logical; students become empowered by reflecting on a given situation or problem, setting and monitoring progress toward goals, and implementing specific strategies to manage behavior and meet those goals.[35]

In sum, neuroscience, developmental science, and education research together give researchers and policymakers new ways to understand the recursive neurocognitive and emotional processes that underlie young children's success and failure when learning. Rapid advances in research also show that adverse early experiences impede the development of EF and their related capacity to manage negative emotions and motivation in challenging situations. Accompanying advances in prevention science point to the ways that children's EF and emotional and behavioral self-regulation can be substantially improved through environmental enrichment from both parents and teachers.

Children's early experiences with their caregivers profoundly influence the processes that undergird their executive functions and emotion regulation later in early childhood.

What Helps and What Hurts

As we've said, children's early experiences with their caregivers profoundly influence the neurobiological and behavioral processes that undergird their executive functions and emotion regulation later in early childhood.[36] Sensitive, contingent parental care not only scaffolds children's attention, EF, and regulation of emotion, but also supports optimal connectivity at the neurobiological level.[37] Conversely, children who experience severely neglectful caregiving are at greater risk of neurobiological and behavioral harm; multiple regions of their brains that are responsible for EF and emotion regulation are at greater risk of both structural and functional compromise.[38] Several studies show that when children are adopted from highly neglectful institutional care settings into homes with more sensitive caregivers, their emotional and higher-order cognitive skills can partially recover, with corresponding partial improvement in brain health and connectivity—especially if they're adopted before they're two years old. Fortunately, few children experience such severe deprivation in infancy. Although studies of children in acutely deprived environments, as well as research on brain and behavioral development among maltreated children and children in foster care, tell us a great deal about the brain's malleability in the face of both environmental insult and intensive support, they don't tell us about how those processes unfold for most children in most families and communities in the United States.[39] Recent evidence from research on both human infants and animals makes abundantly clear that the normative neurobiological and endocrine processes underlying children's attention, EF, and emotion regulation are in large part shaped by whether and how parents provide sensitive, contingent care and organized, stable routines from the early months of life through early childhood.[40] Both caregivers and infants experience positive changes in brain function, brain connectivity, and stress hormones when they are behaviorally in sync; this dynamic, self-reinforcing synchrony supports early attention, emotional control, and EF.[41]

Conversely, studies show that parents who struggle with high levels of anxiety, negative mood, and psychosocial strain also struggle at a neurobiological level to accurately read and tune in to their babies' cues.[42] They chronically miss opportunities to connect with their babies through coordinated attention and positive emotional exchanges involving smiles, laughter, and delight.[43] Moreover, studies of young children's neuroendocrine function have demonstrated that higher-quality care from nonparental caregivers in childcare settings can also contribute to early regulation of both cognition and emotion.[44] The good news is that recent interventions using neuroscientific tools to measure infants' and toddlers' neurocognitive and emotional development clearly show that we can support both parents and children into more positive trajectories of interaction, with positive implications for early EF and emotion regulation.[45]

Forces outside the parent-child dyad can also alternately support or undercut healthy development. Specifically, extensive research over the past two decades has shown that poverty—and the associated exposure to a range of adverse experiences collectively referred to as toxic stress—makes parents more likely to misinterpret their children's cues and to be more irritable, more intrusive, and less patient during routine interactions, leaving parents and children at greater risk of falling out of interactional sync.[46] By disrupting interactions with caregivers, poverty-related stress puts children at greater risk for neuropsychological difficulties with EF, for difficulty modulating fear and anger, and for less optimal patterns of attention.[47] Family socioeconomic disadvantage can have negative, stress inducing, and neurocognitively costly consequences for adults as well as for children.[48]

However, positive caregiving can buffer young children in the face of adverse experiences, and many, many parents provide sensitive, nurturing care while struggling to make ends meet.[49] In our own research with a longitudinal sample known as the Family Life Project, we found that children growing up in rural and semi-urban areas hard-hit by poverty had higher resting levels of the stress hormone cortisol between 7 and 24 months of age compared to somewhat more economically advantaged peers. In our longitudinal analyses, it was clear that positive parenting behavior substantially protected children from these negative consequences of poverty.[50]

In addition to the stress of struggling to make economic ends meet, many US families also experience sufficient disruption and instability both inside and outside the household to place children's EF skills and emotion regulation at risk. In the past five years, we've learned a great deal about several sources of stress, including lack of safety and lack of stability or predictability, which appear to be particularly toxic. For example, evidence from both animal and human studies suggests that chaotic, unpredictable, or unstable conditions may compromise organisms' ability to appropriately regulate their physiological, cognitive, and behavioral responses to stress.[51] Clinical research suggests that high levels of instability, such as when foster children experience multiple changes in households and caregivers, have grave consequences not only for the way they react to stress, but also for their emotion regulation and EF.[52] New research shows that less extreme forms of family turbulence, including adults moving in and out of the household or families changing households frequently, also takes a toll on children's stress physiology, EF, and inhibitory control.[53] High levels of mobility or instability outside the home can also affect children—national Head Start data suggest that switching preschools in early childhood predicts greater academic difficulty in kindergarten and early elementary school.[54]

Another source of toxic stress that can place children's development of EF and their academic achievement at greater risk is exposure to threatening people, places, and situations. Children's risk of exposure to those types of threats increases in conditions of economic hardship, but many children across a range of economic strata must cope with sources of stress like bullying, family violence, or neighborhood crime. For example, regardless of family income, exposure to violent, traumatic events restructures children's attentional, emotional, and cognitive control networks to be on high alert. Adults and children who've been exposed to traumatic threats have consistently been found to pay more attention to negative cues, to have more difficulty switching cognitive gears in the face of negative information, and to experience more negative moods.[55] The behavioral effects of exposure to violence are paralleled by clear evidence of changes in activation and connectivity of brain regions associated with emotion processing, attention, and executive function.[56] Witnessing or overhearing aggression between adults in the household is also associated with significant compromises in children's physiological stress response, their capacity to regulate their attention and emotion, and their effortful control.[57] The negative effects of threatening events and experiences also extend to children's experiences of violence in their neighborhoods and schools. For example, analyses among older children suggest that chronic exposure to the threat of violence from their peers detracts from children's ability to regulate their stress response physiology, attention, emotion, and cognition.[58] Though rates of bullying are lower in elementary school than in middle school, evidence suggests that kindergarten through third grade can be deeply stressful for a small number of students who experience chronic verbal and physical aggression from peers.[59] Similarly, our findings suggest that exposure to violent crimes in the neighborhood has deleterious consequences for children's attention biases in both the preschool and early elementary years.[60] Biased attention to negative social cues and hypervigilant and reactive cognitive response profiles may help children detect early warning signs of conflict in the short run, but they are maladaptive in the long run.

We want to be clear: Many, many children who live settings that can be characterized as turbulent, unsafe, or economically disadvantaged are doing well in school. Exposure to adverse events doesn't destine a child to have trouble regulating cognition, emotion, and attention. Instead, such exposure raises the probability that a given child will face regulatory difficulty, making it harder to navigate demands and expectations at school. A key implication is that many children don't come to school on a level playing field with their counterparts who are exposed to less stress, given the way adverse experiences affect children's ability to remain cognitively reflective, calm, and focused. Just as we must recognize the toll that toxic stress takes on children's potential, we must examine how interventions can support self-regulation and help all children meet their academic potential.

Interventions

In nationally representative surveys, kindergarten teachers consistently name the skills that make up EF and emotion regulation as key components of young students' ability to successfully handle the first few months of formal schooling. Recent efforts to measure kindergarten readiness at the state level reflect this (see box). But how can teachers and schools do their part to support children's EF and emotion regulation, particularly given the substantial

Using EF to Assess School Readiness

EF's association with school readiness and early school achievement is so well established empirically and theoretically that 12 states include it as one aspect of readiness in their initiatives to assess and ensure school readiness for all children. (The initiatives include the Ready for Kindergarten: Early Childhood Comprehensive Assessment System in Maryland and Ohio; the BUILD K–3 Formative Assessment System encompassing nine states; and the Arkansas Early Learning Standards). These readiness assessments and standards describe behavioral and academic competencies that are appropriate for children between the ages of four and six. For executive function, these competencies involve behaviors such as understanding and following multistep instructions; seeking and gathering information; managing the expression of thoughts, feelings, and impulses; and similar behaviors in which EF is understood to be central. Age-appropriate expectations for behavior in these readiness assessments map well to what we know about the development of EF in the preschool period.

Source: Patricia J. Bauer and Philip David Zelazo, "The National Institutes of Health Toolbox for the Assessment of Neurological and Behavioral Function: A Tool for Developmental Science," *Child Development Perspectives* 8 (2014): 119–24, doi: 10.1111/cdep.12080.

disparities in EF and emotion regulation skill across groups of young children? We now turn to several examples of interventions and classroom approaches that hold promise for prekindergarten through early elementary school.

Individualized Interventions Targeting EFs and Related Top-Down Processes

First, a large number of clinical and educational tools have been designed to directly target children's attention, working memory, and inhibitory control.[61] For example, students who are having trouble in key EF domains receive skills-based support over several sessions to learn how to stay more attentive and organized in completing schoolwork.[62] A recent meta-analysis examined whether such programs are effective among elementary-aged students and reported surprisingly large estimates of their benefits: approximately six extra months' worth of learning (or, for readers familiar with statistical analysis, about three-fourths of a standard deviation) across measures of motivation, self-regulated learning, and achievement. These findings suggest that explicit instruction in self-regulated learning strategies may benefit some students who struggle with EF. However, this approach hasn't been well evaluated among children who face high levels of adversity, particularly when they also face higher levels of performance-related anxiety, and it may not be sufficient as the primary or sole technique.

Alternatively, a set of individually targeted *brain training* approaches has recently been developed with clinically referred groups of children who have high levels of difficulty with attention and inhibitory control. These computer-based methods focus on changing children's underlying neurocognitive functioning. For example, to enhance their working memory, young children repeatedly practice increasingly challenging versions of a specific type of working memory task (in about 20 sessions of 30 or more minutes), using an adaptive video game–like format. The repeated practice leads not only to immediate improvement on the task, but also to improvement on similar types of working memory tasks (with effect sizes equal to approximately half of a standard deviation).[63] However, evaluations of this approach have yielded mixed evidence of whether children also improve when it comes to more general skills, such as academic achievement or classroom behavior.[64] Yet this direct training approach continues to hold neuroscientists' and clinicians' interest because trials with adults have yielded intriguing evidence of increased neural activity in the working memory–related circuitry associated with the prefrontal cortex and associated neurotransmitters.[65] Working memory training has also been found to yield significant benefits for children with attention deficit hyperactivity disorder. One problem with those randomized controlled efficacy trials is that they were not balanced for the potentially positive influence of social engagement with the clinician or trainer.[66] This problem suggests that we need a second set of randomized controlled trials using alternate control conditions that vary in the ways children receive social support from adults while completing computer-based training.

Like the self-regulated learning strategies we described above, these training approaches haven't been extensively tested to see how well they work with children who face great adversity. Another problem is that these approaches have been individually delivered in the laboratory. We don't know whether they can be delivered in the classroom, or whether their benefits can be sustained at home and in school—settings that can be disorganized, unpredictable, or chaotic. A third approach, then, has been to target the classroom to support young children's EF more broadly.

Classroom Approaches Targeting Top-Down Processes

In the past decade, a range of classroom activities and approaches to teacher training has been introduced and evaluated using randomized controlled trials. Many of the trials have produced substantial evidence that these methods benefit children's attention, working memory, and impulse control. For example, several trials have targeted children's EF through structured small-group and whole-class activities involving inhibitory control, cognitive flexibility, and working memory that can be delivered at various times of the school day. An initial evaluation of such activities—delivered over 16 brief playgroup sessions of 20 to 30 minutes with a small sample of children—found minimal effects.[67] However, a second evaluation with a larger group of low-income children and classrooms found that those explicitly EF-building activities were associated with small to moderate gains on two measures of EF of approximately one-fifth to one-third of a standard deviation (equivalent to about two to three months' worth of expected growth and development).[68]

In contrast to using EF-targeted classroom activities limited to specific times of the day, a program called Tools of the Mind takes a comprehensive approach, meaning that all classroom learning is structured to foster EF (and other aspects of children's development, particularly oral language).[69] Tools of the Mind aims to reorient teachers' instructional style to emphasize scaffolding of children's planning, self-regulation, and learning, and to reorient classroom activities to make them more child-centered and child-directed. One of the program's major learning activities is structured sociodramatic play, in which children plan and then act out pretend scenarios such as "grocery store" in a designated area of the classroom with props like a cash register and grocery items. In carrying out this type of purposeful play, children practice switching between their pretend and stage-directing roles while using language to regulate their own and their peers' attention and actions. Children also collaborate in pairs to complete activity center–based learning activities, such as breaking down words into sounds, placing objects into categories, and jointly solving early math problems. Throughout the day and school year, the program also offers opportunities for children to reflect on and discuss their progress on learning and on planning and problem solving with their teachers.[70] The theory behind Tools of the Mind is that children who experience a classroom environment conducive to EF will improve not only on measures of EF and emotion regulation, but also on measures of academic ability.

Evaluations of Tools of the Mind have produced mixed results. An early evaluation of the program's preschool version was promising, but a later, larger trial found that Tools of the Mind had no effect on any aspect of preschool children's school readiness.[71] A third evaluation with children who were English language learners from low-income homes found that the program produced effects at one site but not another.[72] But an evaluation of the kindergarten version of Tools of the Mind, using a randomized controlled trial spanning several school districts in Massachusetts, demonstrated that the approach clearly benefited both middle-income and low-income children, with gains in both self-regulation and early academics.[73] Moreover, compared with the control group, kindergartners in schools with a high proportion of low-income students showed the largest benefits in the areas of working memory, executive attention, inhibitory control, reasoning ability, and vocabulary.[74] In contrast to many interventions whose benefits appear to fade out after one or more years, children who were initially enrolled in Tools of the Mind kindergarten classrooms continued to demonstrate greater gains in reading and vocabulary into the first grade than their control group counterparts. In short, Tools of the Mind has demonstrated academic benefit for young children in some but not all studies. Though mixed, this evidence has been persuasive enough to educational leaders that many school districts have adopted classroom EF approaches in both prekindergarten and kindergarten.

Classroom Approaches Targeting Both Bottom-Up and Top-Down Processes

As we said above, the neurobiological model of bottom-up, top-down relationships between EF and emotion regulation suggests that we should widen our intervention approaches to help children not only increase their attention and inhibitory control, but also manage anger, sadness, and fear.[75] In efficacy trials among low-income preschoolers, several classroom approaches to simultaneously support stronger EFs and emotional and behavioral self-regulation have yielded impressive short-term benefits, and smaller but significant impacts when taken to scale. This type of intervention approach has also come up against the problem of fade-out: That is, it has yielded mixed (rather than overwhelmingly strong) evidence of sustained improvement in children's academic performance through the transition to kindergarten.[76]

What does this type of intervention look like in real-world classrooms? One model for kindergarten through fifth grade, called SECURe, explicitly targets multiple domains of self-regulation, including EF, emotional regulation, and interpersonal skills. To do so, it uses a number of mechanisms: helping teachers manage their classrooms, restructuring daily routines, and directly supporting the curriculum through brain games and lessons.[77] Preliminary results indicate that this multipronged approach has impressive benefits, particularly given that the early efficacy trials have been conducted among a large number of schools that vary in their capacity to successfully implement new curricular and instructional approaches.[78]

Given that children's emotional difficulties can also be tied to parents' lack of responsiveness and unpredictability (and to lack of safety in the home and neighborhood), some prevention scientists have also found innovative ways to include parents as well as teachers in early intervention. Trials that incorporate parents and teachers have yielded substantial benefits for young children, improving both their emotion regulation and their academic readiness.[79] Some interventions work through parent groups that meet in schools, successfully bolstering self-regulatory and early literacy skills for students who are at higher risk for emotional and EF difficulty. One example of a program targeting children at greater risk is the KITS intervention, where the group intervention to parents is delivered over a relatively short period during the two months before children transition to kindergarten.[80] Additionally, a few prevention models have tackled the behavioral and neurocognitive consequences of children's exposure to trauma in both the community and the home. Although these models haven't yet been extensively tested through experimental design to see whether they lead to EF benefits and academic gains, they hold substantial promise from both theoretical and practitioner perspectives.[81] Similar approaches that target the school climate more generally in elementary and middle schools, such as School-Wide Positive Behavioral Interventions and Supports, have yielded clear benefits.[82] These programs not only reduce aggression and bullying among children, but they may also help adults to reinterpret children's poor emotion regulation, effectively changing teachers' mindsets regarding whether economically vulnerable students in their classrooms have the capacity to change, grow, and learn.[83] School leaders who have implemented programs that focus on trauma report that students express greater trust of adults and a stronger sense of emotional attachment and belonging, and that they're better at focusing their attention and maintaining a more reflective cognitive orientation to learning.[84]

These approaches are guided by models of bottom-up regulation, which propose that if we help children develop greater emotional self-control through intervention, environmental stress will be less likely to hijack their higher-order cognitive processes. But what about targeting top-down EF processes to help young learners manage negative emotions like frustration and anxiety? A burgeoning model that falls loosely into the category of mindset interventions has demonstrated impressive positive impacts on helping children to shift their ideas about their own capacity to learn and to hold up under academic pressure.[85] Interventions that follow this model are based on evidence that older students' encounters with situational cues that highlight expectations of failure not only capture their attention but also trigger greater demands on EF and emotional regulation.[86] In field experiments among students in middle school, high school, and college, mindset interventions have been found to reduce feelings of anxiety, improve motivation, and improve academic achievement.[87] But we know less about whether younger children will experience the same benefits. Nor do we know whether the academic gains from such interventions result from changes in children's EF and corresponding regulation of emotion. Children's ability (and encouragement through intervention) to shift set may be a key mechanism for helping them adopt new, more flexible perspectives on their own and others' minds, intentions, and feelings.[88] Children's stronger versus weaker self-regulation skills may also be a key factor that influences their vulnerability to situational triggers and either amplifies or attenuates the effect of mindset interventions on their academic performance. For example, during a tough math test students with stronger EFs may be more likely to shift their attention from errors in their performance and focus instead on larger goals.[89] Other students with less skill in flexibly deploying their attention may get more easily snagged by early but transient indicators of test-taking difficulty, and they may have a harder time tamping down rising feelings of anxiety. Whether or not mindset approaches are found to directly involve EFs, studies of these interventions demonstrate that students' higher-order cognition can forcefully shape beliefs, mood, effort, and outcomes in ways that are empowering and liberating. This represents an exceptionally innovative and exciting area for research.

Policy Implications

Recent analyses of longitudinal data suggest that children's self-regulation plays a powerful role in predicting the long-term likelihood that they'll experience "health, wealth, and public safety."[90] For example, one analysis found that four-year-olds' attention and persistence predicts not only their academic achievement in high school, but also their odds of finishing college by age 21, even after accounting for their achievement levels and other characteristics, such as their mothers' educational level.[91] Given their powerful role in predicting later academic and behavioral success, we're gravely concerned by mounting evidence that adversity places young children's EF and emotional regulation in jeopardy.

School districts need data not only on the academic readiness of young children entering preschool and early elementary school, but also on key dimensions of EF.

One key policy implication is that school districts need data not only on the academic readiness of young children entering preschool and early elementary school, but also on key dimensions of EF such as attention, working memory and inhibitory control. Given both direct and indirect linkages among EF, emotion regulation, children's ability to handle increasingly challenging academic demands, districts would be also be wise to have information on so-called soft skills, for example, children's capacity to modulate negative emotions. Fortunately, low-cost tools for directly assessing children's cognitive control and emotion regulation are increasingly available and show promise that they can be taken to scale. We have expanded the assessment toolkit used to assess young children's EF in the lab to include large numbers of children in kindergarten and universal prekindergarten in large, urban school districts like New York City. Wider use of such tools would help us estimate how many children have trouble with EFs—information that would have strong public health significance. For example, if data on children's EFs were collected citywide, they could be geocoded and mapped to help policy leaders clearly see where scarce educational resources could be deployed to make the most difference for children's early learning.

A second policy implication is that interventions targeting EF and related self-regulatory skills in preschool through the early elementary grades can and do alter young children's early academic trajectories. In this article, we've highlighted the value of targeting not one but many possible mechanisms at both the neuropsychological and behavioral level, using interventions designed to work both with individual children and with classrooms as a whole. When those different mechanisms are activated, we have strong evidence that we can at least partially, if not fully, close the gap in neurocognitive function and academic achievement between children who face multiple types of adversity and their better-off counterparts in early childhood and the early elementary years.

Third, though we may make progress in supporting young children with interventions that represent more oars in the water, we are rowing against the tide of children's continued exposure to high levels of adversity as they grow older. We must now find the political will to invest in programs that reduce children's exposure to stresses like family financial hardship, household instability, and neighborhood crime, turning the tide for young children's neurocognitive development, academic achievement, and behavioral health in the years ahead.

ENDNOTES

1. Daphna Bassok, Scott Latham, and Anna Rorem, "Is Kindergarten the New First Grade?" *AERA Open* 1, no. 4 (2016), doi: 10.1177/2332858415616358; Kristie Kauerz, "State Kindergarten Policies: Straddling Early Learning and Early Elementary School," *Beyond the Journal: Young Children on the Web* (March 2005), https://www.naeyc.org/files/yc/file/200503/01kauerz.pdf; National Conference of State Legislatures, "2014 Legislative Summit," Minneapolis, MN, August 19–22, 2014.
2. Common Core State Standards Initiative, "Read the Standards," http://www.corestandards.org/read-the-standards.
3. Clancy Blair and Rachel Peters Razza, "Relating Effortful Control, Executive Function, and False Belief Understanding to Emerging Math and Literacy Ability in Kindergarten," *Child Development* 78 (2007): 647–63, doi: 10.1111/j.1467-8624.2007.01019.x; Megan M. McClelland et al., "Links between Behavioral Regulation and Preschoolers' Literacy, Vocabulary, and Math Skills," *Developmental Psychology* 43 (2007): 947–59, doi: 10.1037/0012-1649.43.4.947.
4. Monica Luciana and Charles A. Nelson, "The Functional Emergence of Prefrontally-Guided Working Memory Systems in Four- to Eight-Year-Old Children," *Neuropsychologia* 36 (1998): 273–93, doi: 10.1016/S0028-3932(97)00109-7.
5. Natasha Z. Kirkham, Loren Cruess, and Adele Diamond, "Helping Children Apply Their Knowledge to Their Behavior on a Dimension-Switching Task," *Developmental Science* 6 (2003): 449–76, doi: 10.1111/1467-7687.00300.
6. Rebecca Bull and Gaia Scerif, "Executive Functioning as a Predictor of Children's Mathematics Ability: Inhibition, Switching, and Working Memory," *Developmental Neuropsychology* 19 (2001): 273–93, doi: 10.1207/S15326942DN1903_3.
7. Joaquin M. Fuster, *The Prefrontal Cortex*, 5th ed. (London: Academic Press/Elsevier, 2015).
8. Clancy Blair and C. Cybele Raver, "School Readiness and Self-Regulation: A Developmental Psychobiological Approach," *Annual Review of Psychology* 66 (2015): 711–31, doi: 10.1146/annurev-psych-010814-015221; Nancy Eisenberg et al., "Prediction of Elementary School Children's Externalizing Problem Behaviors from Attentional and Behavioral Regulation and Negative Emotionality," *Child Development* 71 (2000): 1367–82, doi: 10.1111/1467-8624.00233.
9. Philip David Zelazo, Stephanie M. Carlson, and Amanda Kesek, "Development of Executive Function in Childhood," in *Handbook of Developmental Cognitive Neuroscience*, ed. Charles A. Nelson and Monica Luciana, 2nd ed. (Cambridge, MA: MIT Press, 2008), 553–74.
10. Nitin Gogtay et al., "Dynamic Mapping of Human Cortical Development during Childhood through Early Adulthood," *Proceedings of the National Academy of Sciences* 101 (2004): 8174–79, doi: 10.1073/pnas.0402680101.
11. Ágnes Melinda Kovács and Jacques Mehler, "Cognitive Gains in 7-Month-Old Bilingual Infants," *Proceedings of the National Academy of Sciences* 106 (2009): 6556–60, doi: 10.1073/pnas.0811323106.
12. Stephanie M. Carlson, "Developmentally Sensitive Measures of Executive Function in Preschool Children," *Developmental Neuropsychology* 28 (2005): 595–616, doi: 10.1207/s15326942dn2802_3.
13. Rebecca Bull and Kerry Lee, "Executive Functioning and Mathematics Achievement," *Child Development Perspectives* 8 (2014): 36–41, doi: 10.1111/cdep.12059; Michael J. Kieffer, Rose K. Vukovic, and Daniel Berry, "Roles of Attention Shifting and Inhibitory Control in Fourth-Grade Reading Comprehension," *Reading Research Quarterly* 48 (2013): 333–48, doi: 10.1002/rrq.54.

14. Blair and Razza, "Emerging Math and Literacy"; Clancy Blair et al., "Multiple Aspects of Self-Regulation Uniquely Predict Mathematics but Not Letter-Word Knowledge in the Early Elementary Grades," *Developmental Psychology* 51 (2015): 459–72, doi: 10.1037/a0038813; Allison H. Friedman-Krauss and C. Cybele Raver, "Does School Mobility Place Elementary School Children at Risk for Lower Math Achievement? The Mediating Role of Cognitive Dysregulation," *Developmental Psychology* 51 (2015): 1725–39, doi: 10.1037/a0039795.

15. Blair and Razza, "Emerging Math and Literacy"; Blair et al, "Aspects of Self-Regulation"

16. See, for example, Christine P. Li-Grining et al., "Children's Early Approaches to Learning and Academic Trajectories through Fifth Grade," *Developmental Psychology* 46 (2010): 1062–77, doi: 10.1037/a0020066.

17. Caron A. C. Clark, Verena E. Pritchard, and Lianne J. Woodward, "Preschool Executive Functioning Abilities Predict Early Mathematics Achievement," *Developmental Psychology* 56, (2010): 1176–91, doi: 10.1037/a0019672.

18. Christina Weiland and Hirokazu Yoshikawa, "Impacts of a Prekindergarten Program on Children's Mathematics, Language, Literacy, Executive Function, and Emotional Skills," *Child Development* 84 (2013): 2112–30, doi: 10.1111/cdev.12099.

19. Pamela M. Cole, Sarah E. Martin, and Tracy A. Dennis, "Emotion Regulation as a Scientific Construct: Methodological Challenges and Directions for Child Development Research," *Child Development* 75 (2004): 317–33, doi: 10.1111/j.1467-8624.2004.00673.x.

20. Clancy C. Blair et al., "Allostasis and Allostatic Load in the Context of Poverty in Early Childhood, " *Development and Psychopathology* 23 (2011): 845–57, doi: 10.1017/S0954579411000344; Gary W. Evans and Michelle A. Schamberg, "Childhood Poverty, Chronic Stress, and Adult Working Memory," *Proceedings of the National Academy of Science* 106 (2009): 6545–49, doi: 10.1073/pnas.0811910106

21. Kevin N. Ochsner et al., "For Better or for Worse: Neural Systems Supporting the Cognitive Down- and Up-Regulation of Negative Emotion," *NeuroImage* 23 (2004): 483–99, doi: 10.1016/j.neuroimage.2004.06.030.

22. Marc D. Lewis, Rebecca M. Todd, and Michael J. M. Honsberger, "Event-Related Potential Measures of Emotion Regulation in Early Childhood," *Neuroreport* 18 (2007): 61–65, doi: 10.1097/WNR.0b013e328010a216.

23. Cole, Martin, and Dennis, "Directions for Child Development."

24. Mark H. Ashcraft and Jeremy A. Krause, "Working Memory, Math Performance, and Math Anxiety," *Psychonomic Bulletin & Review* 14 (2007): 243–48, doi: 10.3758/BF03194059; Gerardo Ramirez et al., "On the Relationship between Math Anxiety and Math Achievement in Early Elementary School: The Role of Problem Solving Strategies," *Journal of Experimental Child Psychology* 141 (2016): 83–100, doi: 10.1016/j.jecp.2015.07.014.

25. Sian L. Beilock et al., "Female Teachers' Math Anxiety Affects Girls' Math Achievement," *Proceedings of the National Academy of Sciences* 107 (2010): 1860–63, doi: 10.1073/pnas.0910967107.

26. J. Lawrence Aber, Stephanie M. Jones, and C. Cybele Raver, "Poverty and Child Development: New Perspectives on a Defining Issue," in *Child Development and Social Policy: Knowledge for Action*, ed. J. Lawrence Aber et al. (Washington, DC: American Psychological Association, 2006), 149–66.

27. Kateri McRae et al., "The Neural Bases of Distraction and Reappraisal," *Journal of Cognitive Neuroscience* 22 (2010): 248–62, doi: 10.1162/jocn.2009.21243; Philip K. Peake, Michelle Hebl, and Walter Mischel, "Strategic Attention Deployment for Delay of Gratification in Working and Waiting Situations," *Developmental Psychology* 38 (2002): 313–26, 10.1037/0012-1649.38.2.313.

28. Walter Mischel, Yuichi Shoda, and Monica L. Rodriguez, "Delay of Gratification in Children," *Science* 244, no. 4907 (1989): 933–38, doi: 10.1126/science.2658056.

29. Celeste Kidd, Holly Palmeri, and Richard N. Aslin, "Rational Snacking: Young Children's Decision-Making on the Marshmallow Task is Moderated by Beliefs about Environmental Reliability," *Cognition* 126 (2013): 109–14, doi: 10.1016/j.cognition.2012.08.004.

30. Lori M. Hilt and Seth D. Pollak, "Characterizing the Ruminative Process in Young Adolescents," *Journal of Clinical Child and Adolescent Psychology* 42 (2013): 519–30, doi: 10.1080/15374416.2013.764825.

31. Laura O'Toole and Tracy A. Dennis, "Attention Training and the Threat Bias: An ERP Study," *Brain and Cognition* 78 (2012): 63–73, doi: 10.1016/j.bandc.2011.10.007.

32. Kateri McRae, Bethany Ciesielski, and James J. Gross, "Unpacking Cognitive Reappraisal: Goals, Tactics and Outcomes," *Emotion* 12 (2012): 250–55, doi: 10.1037/a0026351.

33. Mizhi Hua, Zhuo Rachel Han, and Renlai Zhou, "Cognitive Reappraisal in Preschoolers: Neuropsychological Evidence of Emotion Regulation from an ERP Study," *Developmental Neuropsychology* 40 (2015): 279–90, doi: 10.1080/87565641.2015.1069827; Jennifer A. Silvers et al., "Concurrent and Lasting Effects of Emotion Regulation on Amygdala Response in Adolescence and Young Adulthood," *Developmental Science* 15 (2015): 771–84, doi: 10.1111/desc.12260.

34. Carol S. Dweck and Allison Master, "Self-Theories Motivate Self-Regulated Learning," in *Motivation and Self-Regulated Learning: Theory, Research, and Applications*, ed. Dale H. Schunk and Barry J. Zimmerman (Mahwah, NJ: Lawrence Erlbaum, 2008), 31–51; Erin A. Maloney, Marjorie W. Schaeffer, and Sian L. Beilock, "Mathematics Anxiety and Stereotype Threat: Shared Mechanisms, Negative Consequences and Promising Interventions," *Research in Mathematics Education* 15 (2013): 115–28, 10.1080/14794802.2013.797744.

35. Walter Mischel, Nancy Cantor, and Scott Feldman, "Principles of Adolescent Self-Regulation: The Nature of Willpower and Self-Control," in *Social Psychology: Handbook of Basic Principles*, ed. Arie W. Kruglanski and E. Tory Higgins (New York: Guilford Press, 1996), 329–60.

36. Clancy Blair and C. Cybele Raver, "Child Development in the Context of Adversity: Experimental Canalization of Brain and Behavior," *American Psychologist* 67 (2012): 309-18, doi: 10.1037/a0027493.

37. Nim Tottenham, "The Importance of Early Experiences for Neuro-Affective Development," in *The Neurobiology of Childhood*, Current Topics in Behavioral Neurosciences, vol. 16, ed. Susan L. Anderson and Daniel S. Pine (2014), 109–29.

38. Michael D. De Bellis and Lisa A. Thomas, "Biologic Findings of Post-Traumatic Stress Disorder and Child Maltreatment," *Current Psychiatry Reports* 5 (2003): 108–17, doi: 10.1007/s11920-003-0027-z; Charles A. Nelson, Nathan A. Fox, and Charles H. Zeanah, "Tragedy Leads to Study of Severe Child Neglect: The Plight of Orphaned Romanian Children Reveals the Psychic and Physical Scars from First Years Spent without a Loving, Responsive Caregiver," *Scientific American* 308, no. 4 (2013): 62–67.

39. Seth D. Pollak, "Mechanisms Linking Early Experience and the Emergence of Emotions: Illustrations from the Study of Maltreated Children," *Current Directions in Psychological Science* 17 (2008): 370–75, doi: 10.1111/j.1467-8721.2008.00608.x.

40. Kimberly Cuevas et al., "What's Mom Got to Do with It? Contributions of Maternal Executive Function and Caregiving to the Development of Executive Function across Early Childhood," D*evelopmental Science* 17 (2014): 224–38, doi: 10.1111/desc.12073; Ruth Feldman, "Sensitive Periods in Human Social Development: New Insights from Research on Oxytocin, Synchrony, and High-Risk Parenting," *Developmental Psychopathology* 27 (2015): 369–95, doi: 10.1017/S0954579415000048.

41. Johanna Bick et al., "Foster Mother-Infant Bonding: Associations between Foster Mothers' Oxytocin Production, Electrophysiological Brain Activity, Feelings of Commitment, and Caregiving Quality," *Child Development* 84 (2013): 826–40, doi: 10.1111/cdev.12008; Leah C. Hibel at al., "Maternal-Child Adrenocortical Attunement in Early Childhood," *Developmental Psychobiology* 57 (2015): 83–95, doi: 10.1002/dev.21266.

42. Jennifer Barrett and Alison S. Fleming, "Annual Research Review: All Mothers Are Not Created Equal: Neural and Psychobiological Perspectives on Mothering and the Importance of Individual Differences," *Journal of Child Psychology and Psychiatry* 52 (2011): 368–97, doi: 10.1111/j.1469-7610.2010.02306.x.

43. Pilyoung Kim, Lane Strathearn, and James E. Swain, "The Maternal Brain and Its Plasticity in Humans," *Hormones and Behavior* 77 (2016): 113–23, doi: 10.1016/j.yhbeh.2015.08.001.

44. Sarah E. Watamura et al., "Morning-to-Afternoon Increases in Cortisol Concentrations for Infants and Toddlers at Child Care: Age Differences and Behavioral Correlates," *Child Development* 74 (2003): 1006–20, doi: 10.1111/1467-8624.00583.

45. Kristin Bernard, Robert Simons, and Mary Dozier, "Effects of an Attachment-Based Intervention on Child Protective Services-Referred Mothers' Event-Related Potentials to Children's Emotions," *Child Development* 86 (2015): 1673–84, doi: 10.1111/cdev.12418; Helen J. Neville et al., "Family-Based Training Program Improves Brain Function, Cognition, and Behavior in Lower Socioeconomic Status Preschoolers," *Proceedings of the National Academy of Science* 110 (2013): 12138–43, doi: 10.1073/pnas.1304437110.

46. Jeanne Brooks-Gunn, William Schneider, and Jane Waldfogel, "The Great Recession and the Risk for Child Maltreatment," *Child Abuse & Neglect* 37 (2013): 721–79, doi: 10.1016/j.chiabu.2013.08.004; Melissa L. Sturge-Apple, Jennifer H. Suor, and Michael A. Skibo, "Maternal Child-Centered Attributions and Harsh Discipline: The Moderating Role of Maternal Working Memory Across Socioeconomic Contexts," *Journal of Family Psychology* 28 (2014): 645–54, doi: 10.1037/fam0000023.

47. Kimberly G. Noble, Nim Tottenham, and B. J. Casey, "Neuroscience Perspectives on Disparities in School Readiness and Cognitive Achievement," *Future of Children* 15, no. 1 (2005): 71–89.

48. Kirby Deater-Deckard, "Family Matters: Intergenerational and Interpersonal Processes of Executive Function and Attentive Behavior," *Current Directions in Psychological Science* 23 (2014): 230–36, doi: 10.1177/0963721414531597; Richard L. Bryck and Philip A. Fisher, "Training the Brain: Practical Applications of Neural Plasticity from the Intersection of Cognitive Neuroscience, Developmental Psychology, and Prevention Science," *American Psychologist* 67 (2012): 87–100, doi: 10.1037/a0024657.

49. Allison Sidle Fuligni et al., "Patterns of Supportive Mothering with 1-, 2-, and 3-Year-Olds by Ethnicity in Early Head Start," *Parenting* 13 (2013): 44–57, doi: 10.1080/15295192.2013.732434.

50. Clancy Blair et al., "Maternal and Child Contributions to Cortisol Response to Emotional Arousal in Young Children from Low-Income Rural Communities," *Developmental Psychology* 44 (2008): 1095–1109, doi: 10.1037/0012-1649.44.4.1095; Blair et al., "Allostatic Load."

51. Gary W. Evans and Theodore D. Wachs, eds., *Chaos and Its Influence on Children's Development: An Ecological Perspective* (Washington, DC: American Psychological Association, 2010); M. Mar Sanchez, Charlotte O. Ladd, and Paul M. Plotsky, "Early Adverse Experience as a Developmental Risk Factor for Later Psychopathology: Evidence from Rodent and Primate Models," *Development and Psychopathology* 13 (2001): 419–49.

52. Katherine Pears and Philip A. Fisher, "Developmental, Cognitive, and Neuropsychological Functioning in Preschool-Aged Foster Children," *Journal of Developmental and Behavioral Pediatrics* 26 (2005): 112–22.

53. Terry-Ann L. Craigie, Jeanne Brooks-Gunn, and Jane Waldfogel, "Family Structure, Family Stability and Outcomes of Five-Year-Old Children," *Families, Relationships and Societies* 1 (2012): 43–61, doi: 10.1332/204674312X633153; Blair et al., "Allostatic Load"; Dana Charles McCoy and C. Cybele Raver, "Household Instability and Self-Regulation among Poor Children," *Journal of Children and Poverty* 20 (2014): 131–52, doi: 10.1080/10796126.2014.976185.

54. Fuhua Zhai, Jane Waldfogel, and Jeanne Brooks-Gunn, "Head Start, Prekindergarten, and Academic School Readiness: A Comparison among Regions in the United States," *Journal of Social Service Research* 39 (2013): 345–64, doi: 10.1080/01488376.2013.770814.

55. Tracy A. Dennis, David Amodio, and Laura J. O'Toole, "Associations between Parental Ideology and Neural Sensitivity to Cognitive Conflict in Children," *Social Neuroscience* 10 (2014): 206–17, doi: 10.1080/17470919.2014.968290.

56. Kathleen Thomaes et al., "Increased Anterior Cingulate Cortex and Hippocampus Activation in Complex PTSD during Encoding of Negative Words," *Social Cognitive and Affective Neuroscience* 8 (2013): 190–200, doi: 10.1093/scan/nsr084.

57. Melissa L. Sturge-Apple et al., "The Impact of Allostatic Load on Maternal Sympathovagal Functioning in Stressful Child Contexts: Implications for Problematic Parenting," *Development and Psychopathology* 23 (2011): 831–44, doi: 10.1017/S0954579411000332; Hanna C. Gustafsson, Martha J. Cox, and Clancy Blair, "Maternal Parenting as a Mediator of the Relationship between Intimate Partner Violence and Effortful Control," *Journal of Family Psychology* 26 (2012): 115–23, doi: 10.1037/a0026283.

58. Isabelle Ouellet-Morin et al., "Blunted Cortisol Responses to Stress Signal Social and Behavioral Problems among Maltreated/Bullied 12-Year-Old Children," *Biological Psychiatry* 70 (2011): 1016–23, doi: 10.1016/j.biopsych.2011.06.017.

59. Jaana Juvonen and Sandra Graham, "Bullying in Schools: The Power of Bullies and the Plight of Victims," *Annual Review of Psychology* 65 (2014): 159–85, doi: 10.1146/annurev-psych-010213-115030.

60. Dana Charles McCoy, C. Cybele Raver, and Patrick Sharkey, "Children's Cognitive Performance and Selective Attention following Recent Community Violence," *Journal of Health and Social Behavior* 56 (2015): 19–36, doi: 10.1177/0022146514567576.

61. Tulio M. Otero, Lauren A. Barker, and Jack A. Naglieri, "Executive Function Treatment and Intervention in Schools," *Applied Neuropsychology: Child* 3 (2014): 205–14, doi: 10.1080/21622965.2014.897903.

62. Howard Abikoff et al., "Remediating Organizational Functioning in Children with ADHD: Immediate and Long-Term Effects from a Randomized Controlled Trial," *Journal of Consulting and Clinical Psychology* 81 (2012): 113–28, doi: 10.1037/a0029648.

63. Torkel Klingberg, "Training and Plasticity of Working Memory," *Trends in Cognitive Sciences* 14 (2010): 317–24, doi: 10.1016/j.tics.2010.05.002.

64. Sissela Bergman-Nutley and Torkel Klingberg, "Effect of Working Memory Training on Working Memory, Arithmetic and Following Instructions," *Psychological Research* 78 (2014): 869–77, doi: 10.1007/s00426-014-0614-0; Darren L. Dunning, Joni Holmes, and Susan E. Gathercole, "Does Working Memory Training Lead to Generalized Improvements in Children with Low Working Memory? A Randomized Controlled Trial," *Developmental Science* 16 (2013): 915–25, doi: 10.1111/desc.12068.

65. Pernille J. Olesen, Helena Westerberg, and Torkel Klingberg, "Increased Prefrontal and Parietal Activity After Training of Working Memory," *Nature Neuroscience* 7 (2004): 75–79, doi: 10.1038/nn1165.

66. Zach Shipstead, Thomas S. Redick, and Randall W. Engle, "Is Working Memory Training Effective?" *Psychological Bulletin* 138 (2012): 628–54, doi: 10.1037/a0027473.

67. Shauna L. Tominey and Megan M. McClelland, "Red Light, Purple Light: Findings from a Randomized Trial using Circle Time Games to Improve Behavioral Self-Regulation in Preschool," *Early Education and Development* 22 (2011): 489–519, doi: 10.1080/10409289.2011.574258.

68. Megan M. McClelland et al., "Predictors of Early Growth in Academic Achievement: The Head-Toes-Knees-Shoulders Task," *Frontiers in Psychology* 5 (2014): 1–14, doi: 10.3389/fpsyg.2014.00599; Phillip David Zelazo, "The Dimensional Change Card Sort (DCCS): A Method of Assessing Executive Function in Children," *Nature Protocols* 1 (2006): 297–301, doi: 10.1038/nprot.2006.46.

69. Elena Bodrova and Deborah Leong, "The Development of Self-Regulation in Young Children: Implications for Teacher Training," in *Future Directions in Teacher Training*, ed. Martha Zaslow and Ivelisse M. Martinez-Beck (New York: Brooks-Cole, 2006), 203–24.

70. Ibid.

71. W. Steven Barnett et al., "Educational Effects of the Tools of the Mind Curriculum: A Randomized Trial," *Early Childhood Research Quarterly* 23 (2008): 299–313, doi: 10.1016/j.ecresq.2008.03.001; Adele Diamond et al., "Preschool Program Improves Cognitive Control," *Science* 318, no. 5855 (2007): 1387–88, doi: 10.1126/science.1151148; Sandra Jo Wilson and Dale C. Farran, "Experimental Evaluation of the Tools of the Mind Preschool Curriculum," paper presented at the Society for Research on Educational Effectiveness Spring Conference, Washington, DC, March 8–10, 2012.

72. Clancy Blair, Paula Daneri, and the Tools ELL Investigators, "Effects of the Tools of the Mind Program on the School Readiness of English Language Learners from Low-Income Homes," New York University, Steinhardt School of Education, 2012; Carol Hammer et al., "Tools of the Mind: Promoting the School Readiness of Dual Language Learners," paper presented at Head Start's Eleventh National Research Conference, Washington, DC, June 18–20, 2012.

73. Clancy Blair and C. Cybele Raver, "Closing the Achievement Gap through Modification of Neurocognitive and Neuroendocrine Function: Results from a Cluster Randomized Controlled Trial of an Innovative Approach to the Education of Children in Kindergarten," *PLoS One* 9, no. 11 (2014): e112393, doi: 10.1371/journal.pone.0112393.

74. Ibid.

75. Stephanie M. Jones and Suzanne M. Bouffard, "Social and Emotional Learning in Schools: From Programs to Strategies," *Social Policy Report* 26 (2012): 1–32; Ursache, Blair, and Raver, "School Readiness."

76. C. Cybele Raver et al., "CSRP's Impact on Low-Income Preschoolers' Pre-Academic Skills: Self-Regulation and Teacher-Student Relationships as Two Mediating Mechanisms," *Child Development* 82 (2011): 362–78, doi: 10.1111/j.1467-8624.2010.01561.x; Karen L. Bierman et al., "The Effects of a Multiyear Universal Social-Emotional Learning Program: The Role of Student and School Characteristics," *Journal of Consulting and Clinical Psychology* 78 (2010): 156–68, 10.1037/a0018607; Carolyn Webster-Stratton, M. Jamila Reid, and Ted Beauchaine, "Combining Parent and Child Training for Young Children with ADHD," *Journal of Clinical Child and Adolescent Psychology* 40 (2011): 191–203, doi: 10.1080/15374416.2011.546044; Judy Hutchings et al., "A Randomized Controlled Trial of the Impact of a Teacher Classroom Management Program on the Classroom Behavior of Children with and without Behavior Problems," *Journal of School Psychology* 51 (2013): 571–85, doi: 10.1016/j.jsp.2013.08.001; Pamela Morris et al., "Does a Preschool Social and Emotional Learning Intervention Pay Off for Classroom Instruction and Children's Behavior and Academic Skills? Evidence from the Foundations of Learning Project," *Early Education and Development* 24 (2013): 1020–42, doi: 10.1080/10409289.2013.825187; Robert L. Nix et al., "Promoting Children's Social-Emotional Skills in Preschool Can Enhance Academic and Behavioral Functioning in Kindergarten: Findings from Head Start REDI," *Early Education and Development* 24 (2013): 1000–19, doi: 10.1080/10409289.2013.825565; Fuhua Zhai, C. Cybele Raver, and Stephanie Jones, "Academic Performance of Subsequent Schools and Impacts of Early Interventions: Evidence from a Randomized Controlled Trial in Head Start Settings," *Children and Youth Services Review* 34 (2012): 946–54, doi: 10.1016/j.childyouth.2012.01.026.

77. Rebecca Bailey et al., *Social, Emotional, and Cognitive Understanding and Regulation in Education (SECURe): Preschool Program Manual and Curricula* (Cambridge, MA: Harvard University, 2012).

78. Stephanie M. Jones, Rebecca Bailey, and Robin Jacob, "Social-Emotional Learning is Essential to Classroom Management," *Phi Delta Kappan* 96, no. 2 (2014): 19–24.

79. Laurie Miller Brotman et al., "Cluster (School) RCT of ParentCorps: Impact on Kindergarten Academic Achievement," *Pediatrics* 131 (2013): e1521–29, doi: 10.1542/peds.2012–2632.

80. Katherine C. Pears et al., "Immediate Effects of a School Readiness Intervention for Children in Foster Care," *Early Education and Development* 24 (2013): 771–91, doi: 10.1080/10409289.2013.736037.

81. Stacy Overstreet and Tara Mathews, "Challenges Associated with Exposure to Chronic Trauma: Using a Public Health Framework to Foster Resilient Outcomes among Youth," *Psychology in the Schools* 48 (2011): 738–54, doi: 10.1002/pits.20584.

82. Catherine P. Bradshaw et al., "The Integration of Positive Behavioral Interventions and Supports and Social and Emotional Learning," in *Handbook of School Mental Health: Research, Training, Practice, and Policy*, ed. Mark D. Weist et al., 2nd ed. (New York: Springer, 2014.), 101–18.

83. Ibid.

84. Pamela Cantor, "Schools Can Overcome the Challenges of Poverty—with the Right Interventions," *Hechinger Report* (April 8, 2014), http://hechingerreport.org/schools-can-overcome-challenges-poverty-right-interventions/.

85. David S. Yeager and Greg M. Walton, "Social-Psychological Interventions in Education: They're Not Magic," *Review of Educational Research* 81 (2011): 267–301.

86. Toni Schmader, Michael Johns, and Chad Forbes, "An Integrated Process Model of Stereotype Threat Effects on Performance," *Psychological Review* 115, no. 2 (2008): 336–56.

87. Yeager and Walton, "Not Magic."

88. Dweck and Master, "Self-Regulated Learning."

89. Mangels et al., "Stereotype Threat."

90. Terrie E. Moffitt et al., "A Gradient of Childhood Self-Control Predicts Health, Wealth, and Public Safety," *Proceedings of the National Academy of Sciences* 108 (2011): 2693–98, doi: 10.1073/pnas.1010076108.

91. Megan M. McClelland et al., "Relations between Preschool Attention Span-Persistence and Age 25 Educational Outcomes," *Early Childhood Research Quarterly* 28 (2013): 314–24, doi: 10.1016/j.ecresq.2012.07.008.