Executive Function: Implications for Education

Authors

Philip David Zelazo

Clancy B. Blair

Michael T. Willoughby

National Center for Education Research (NCER)

Meredith Larson (Project Officer)

Erin Higgins

National Center for Special Education Research (NCSER)

Amy Sussman

NCER 2017-2000

U.S. DEPARTMENT OF EDUCATION

INSTITUTE OF EDUCATION SCIENCES

This paper was prepared for the National Center for Education Research, Institute of Education Sciences under Contract ED-IES-12-D-0015. Meredith Larson was the project officer.

Disclaimer

The Institute of Education Sciences at the U.S. Department of Education contracted with Westat to develop a paper on executive function. The views expressed in this report are those of the authors, and they do not necessarily represent the opinions and positions of the Institute of Education Sciences or the U.S. Department of Education.

Zelazo, P.D., Blair, C.B., and Willoughby, M.T. (2016). Executive Function: Implications for Education (NCER 2017-2000) Washington, DC: National Center for Education Research, Institute of Education Sciences, U.S. Department of Education. This report is available on the Institute website at http://ies.ed.gov/.

Alternate Formats

Upon request, this report is available in alternate formats such as Braille, large print, audiotape, or computer diskette. For more information, please contact the Department's Alternate Format Center at 202-260-0852 or 202-260-0818.

Disclosure of Potential Conflict of Interest

Westat Inc. is the prime contractor for the NCER Analysis and Research Management Support project, under which this paper was developed. Tamara Nimkoff was the project manager. Philip Zelazo, author on this paper, is entitled to royalties from the sale of the Minnesota Executive Function Scale (MEFS) by Reflection Sciences, LLC, along with Stephanie Carlson and the University of Minnesota. The authors of this paper are not aware of any conflicts of interest.

Authors' Note

All authors contributed equally, and author order was determined arbitrarily. While all authors contributed to all chapters, each author was primarily responsible for drafting different chapters or sections within chapters: Zelazo (chapter 1, sections 1.1-1.4 and 1.6; chapter 2), Blair (chapter 1, section 1.5; chapters 5-6), and Willoughby (chapters 3-4). The authors drafted chapter 7 jointly.

Contents

1. Introduction

Executive function (EF) skills are the attention-regulation skills[1] that make it possible to sustain attention, keep goals and information in mind, refrain from responding immediately, resist distraction, tolerate frustration, consider the consequences of different behaviors, reflect on past experiences, and plan for the future. In the past two decades, EF skills have become a major focus of research in psychology, neuroscience, and education, and increasingly both teachers and parents are aware that these skills provide an important foundation for learning in school settings. Indeed, EF is central to school readiness and early school achievement (Blair 2002; Blair and Raver 2015). Research has found that EF measured in childhood predicts a wide range of important outcomes, including readiness for school (e.g., McClelland et al. 2007) and the successful transition to kindergarten (e.g., Blair and Razza 2007); school performance and social competence in adolescence (e.g., Mischel, Shoda, and Rodriguez 1989); better physical health; higher socioeconomic status (SES); and fewer drug-related problems and criminal convictions in adulthood (Moffitt et al. 2011).

This paper provides a selective overview of recent research on EF and explores the implications of this research for educational research and practice. The current widespread interest in EF and its development during childhood is based in large part on the following:

(1) Childhood EF skills provide an important foundation for learning and adaptation across a wide range of contexts, including in school.
(2) Difficulties with EF are associated with learning challenges and a greater likelihood of behavior problems, and they are a prominent feature of many emotional and behavioral disorders (EBDs); neurodevelopmental disorders (e.g., attention deficit hyperactivity disorder (ADHD); autism spectrum disorders (ASD); and specific learning disabilities that interfere with children's education.
(3) EF skills are malleable, meaning they can change and are influenced by both positive and negative experiences. For example, stress, poverty, and disadvantage are associated with worse EF skills. However, supportive caregiving, high quality early education, and even

[1] This and other similarly technical terms are hyperlinked upon their first use in the paper to a definition in the glossary found at the end of this document.

practice can help improve EF skills. A key topic here is the extent to which schooling in childhood shapes the development of EF as well as the extent to which EF is important for doing well in school.

The paper is written to highlight what the authors take to be key findings about EF, focused on the implications of EF research as it relates to educational research and practice, with a particular relevance to early education. It is not a systematic review of all literature related to the field of EF, nor is it intended to be a What Works Clearinghouse review. The primary audience for this paper is researchers and advanced students (e.g., graduate students) in the fields of education, developmental psychology, educational neuroscience, and public policy.

In the remainder of this chapter we provide a definition of EF, describe how it relates to other constructs, and describe the neural basis for EF. In chapter 2, we outline some of the reasons research on EF is relevant to education, and these reasons are explored more fully in subsequent chapters. In chapter 3, we address the assessment of EF, and underscore the importance of selecting measures that are optimized for their intended use. In chapter 4, we consider developmental changes in both the organization and efficiency of EF skills, as well as associated strategy use. Chapter 5 focuses on individual and group differences in EF, including relations between EF and SES, gender, language, culture, parenting, genes, and sleep, among other variables. In chapter 6, we review evidence from interventions designed to promote EF skill development. Finally, chapter 7 summarizes the main findings of this review, outlines future directions for research, and addresses the implications of research on EF for education policy and practice.

1.1 Definition of Executive Function: What It Is and What It Is Not

Historically, EF has been an ill-defined construct, often including broad and diverse processes relevant to many forms of self-regulation, from sustained attention to planning (Zelazo et al. 1997). Over the past two decades, however, research on EF and its development during childhood has increased and led to a sharper, more focused definition. Researchers generally, but not uniformly, characterize EF as a specific set of attention-regulation skills involved in conscious goal-directed problem solving. These skills include cognitive flexibility, working memory, and inhibitory control (e.g., Blair and Diamond 2008; Carlson, Zelazo, and Faja 2013; Diamond 2013; Garon, Bryson, and

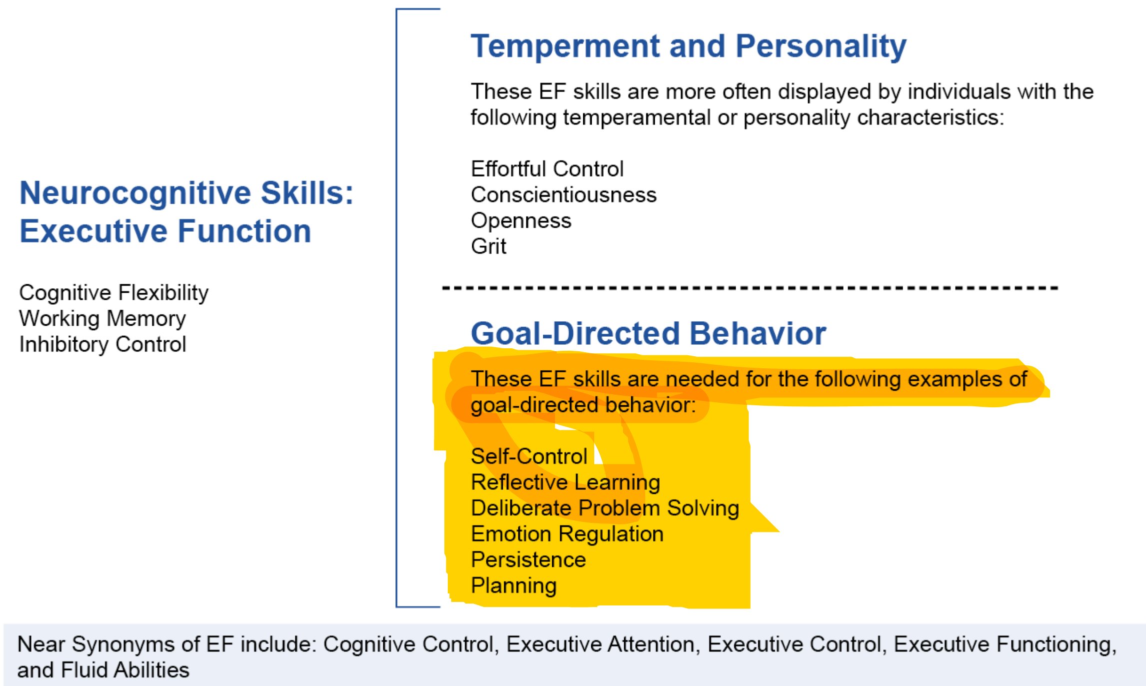
Smith 2008; Hughes 2011; Jacques and Marcovitch 2010; Meuwissen and Zelazo 2014). *Cognitive flexibility* involves thinking about something in multiple ways—for example, considering someone else's perspective on a situation or solving a mathematics problem in multiple ways. *Working memory* involves both keeping information in mind and, usually, manipulating it in some way, such as in passage comprehension when a reader must integrate several pieces of information or ideas into a coherent whole. *Inhibitory control* is the process of deliberately suppressing attention (and subsequent responding) to something, such as ignoring a distraction, stopping an impulsive utterance, or overcoming a highly learned response.

These three skills depend on increasingly well understood neural circuits involving regions in the prefrontal cortex (PFC) and other areas of the brain, and hence may be described as neurocognitive skills. These skills are ways of actively and intentionally controlling attention in order to accomplish a goal, such as keeping a question in mind. In fact, attention can be intentionally shifted, maintained over time, and applied selectively, and so EF is typically measured behaviorally as the three skills of cognitive flexibility, working memory, and inhibitory control (Miyake et al. 2000). Like other skills, EF skills are acquired largely as a function of experience, or practice: the repeated engagement and use of EF skills in problem solving strengthens these skills, increases the efficiency of the corresponding neural circuitry, and increases the likelihood that the skills will be activated in the future (see Zelazo and Lee 2010, for a review).

1.2 Executive Function in Relation to Other Constructs

As shown in Figure 1, EF skills are neurocognitive skills that are required to engage in the goal-directed control of thought, action, and emotion. This goal-directed control in turn is needed for various kinds of *behavior*, including persistence, being able to focus on several things at once, shifting easily between tasks, and reflective learning. These behaviors imply the exercise of EF skills but are not the same as those skills. The behaviors are more commonly displayed by individuals with particular *temperamental or personality characteristics*, such as being high in *effortful control* (e.g., Rothbart 2011), high in *conscientiousness* and *openness to experience* (e.g., Shiner and DeYoung 2013), and high in *self-discipline* (e.g., Duckworth and Seligman 2005).

Figure 1. Semantic map of executive function and related terms



EF can be further differentiated from a number of related, and sometimes partially overlapping constructs, and doing so helps sharpen our characterization of EF skills. For example, EF skills are related to, but different from, what we normally mean by "intelligence," particularly when defined as crystallized intelligence, which is based on facts and knowledge such as vocabulary or knowing the times tables (Blair 2006; Kane and Engle 2002). In general, EF has less to do with possessing intellectual knowledge than it does with being able to reason—to use knowledge purposefully and put it into practice. EF skills are the attentional skills that allow for the adaptive use of one's knowledge in the service of one's goals, for example keeping specific knowledge in mind, or using it to make inferences. These attentional skills allow students not only to learn more effectively, but also to take the content knowledge they have learned in the classroom and to apply it on an exam, or in their daily lives. As such, EF overlaps considerably with reasoning ability or what is referred to as fluid intelligence (Ackerman, Beier, and Boyle 2005; Kane, Hambrick, and Conway 2005). By some accounts, EF is essentially identical with fluid intelligence (Kyllonen and Christal 1990). The reason for this is that EF is essential for making predictions, identifying patterns, and drawing logical conclusions. Dissociations between crystallized knowledge-based aspects of mental ability (e.g., vocabulary, general information) and EF have been shown in several different types of studies, including neuropsychological studies of patients with damage to specific areas of PFC that impairs fluid intelligence but not crystallized intelligence (Duncan, Burgess, and Emslie 1995; Waltz et al. 1999), psychometric studies investigating the structure of cognitive abilities (Ardila et al. 2000), and studies examining academic ability in which predictions from measures of EF and measures of general knowledge are distinct (Espy et al. 2004).

EF skills also overlap with the broader constructs of *self-regulation*, social and emotional learning (SEL), and *noncognitive skills*. As discussed further below, self-regulation is a broad term that refers to the full range of ways in which human beings adjust their behavior, including not only intentional self-regulation, which depends on effortful EF skills, but also involuntary processes, like shivering to increase body temperature (e.g., Blair 2014). EF skills are involved only when self-regulation is conscious and deliberate, i.e., where individuals purposefully modify their behavior in order to achieve a goal.[2] The term *SEL* refers to the process of acquiring social and emotional competence, including emotional self-awareness and a wide range of self-regulatory and pro-social strategies, sometimes including EF skills.[3] The construct of noncognitive skills—poorly named because many of these skills, including EF skills, are in fact cognitive—is especially broad (see Heckman, Stixrud, and Urzua 2006). It refers to whatever skills are not considered academic (e.g., math, reading) or IQ but are nonetheless important for academic success, such as persistence, determination, and SEL.

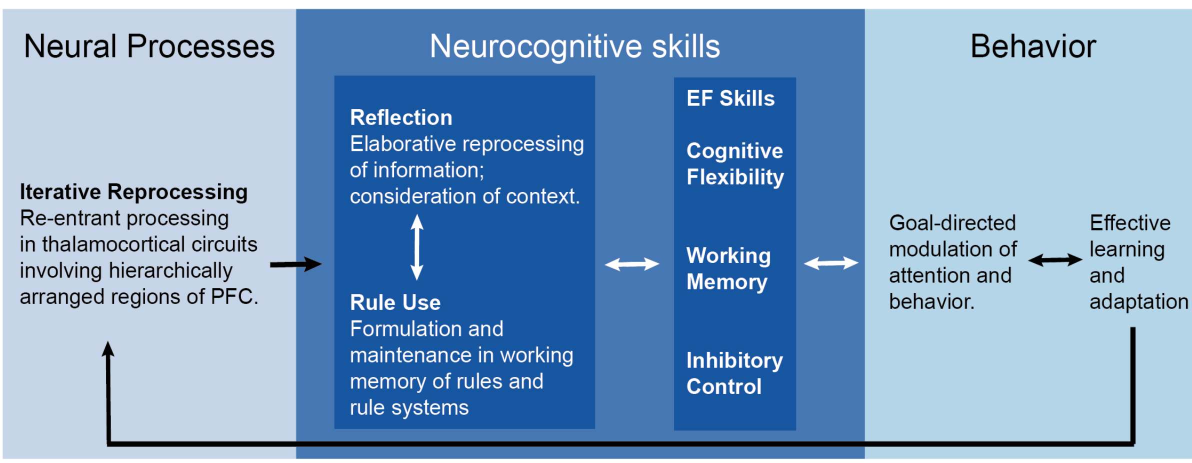
1.3 A Levels of Analysis Approach to Executive Function: Neural, Cognitive, and Behavioral

Research on EF involves multiple levels of analysis (e.g., brain, cognition, behavior), and research in developmental cognitive neuroscience explicitly examines relations among levels. Figure 2 depicts the relations among three levels of analysis, from neural processes (e.g., neural pathways) to the neurocognitive skills that these processes support (e.g., ways of using attention) to the behavioral consequences of attentional control (e.g., goal-directed problem solving). This figure, which is based on one theoretical model, the Iterative Reprocessing model (e.g., Cunningham and Zelazo 2007; Zelazo 2015), illustrates how EF skills modulate attention and consequently control behavior in

[2] For a brief video overview of executive function, see: http://developingchild.harvard.edu/resources/inbrief-executive-function-skills-for-life-and-learning/.
[3] See http://www.casel.org/.

corresponding ways, allowing behavior to be more adaptive, planful, and focused when necessary. According to this model, the goal-directed control of attention is typically verbally mediated and involves the formulation and maintenance in working memory of explicit rules. The development of EF is made possible, in part, by increases in the efficiency of *reflection,* which refers to children's ability to notice challenges, pause, consider their options, and put things into context prior to responding. Having reflected on their situation, children are then in a position to exercise their EF skills (i.e., cognitive flexibility, working memory, and inhibitory control), often using self-directed speech as they do so. When children respond to situations reactively, without much reflection upon what they are doing, they are more likely to show classic EF failures, such as assuming they know what to do, and treating a new situation as if it were an old, familiar one. The model describes both the cognitive and the neural processes associated with reflection and how these lead to specific EF skills and to consciously controlled behavior.

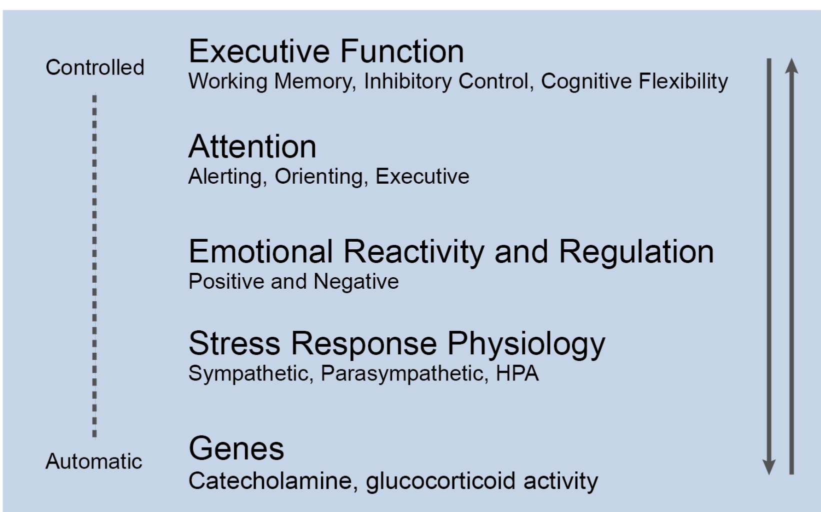
Figure 2. Example of levels of analysis of theoretical characterizations of executive function, from neural processes to behavior



Other theoretical models of EF (e.g., Buss and Spencer 2014; Munakata, Snyder, and Chatham 2012, 2013) vary in what is proposed at one or more of these levels of analysis, but increasingly there is consensus about the relation between EF skills and behavior.

A converging theoretical approach to EF that also spans levels of analysis is Blair's psychobiological model of the broader construct of self-regulation (Blair 2014; Blair and Ursache 2011). This model is based in what is known as dual systems or dual process theory (Shiffrin and Schneider 1977). It addresses how the ability to reflect on information and intentionally direct behavior through "higher level" EF—in an intentional, goal-directed, top-down way—interacts with and depends to some extent on "lower level," more automatic, bottom-up responses to stimulation associated with emotion and the physiological response to stress. The model also addresses variation in EF associated with genes that are related to sensitivity to emotional stimulation and the physiological response to stress and that affect neural activity in PFC (see figure 3 and Sections 1.5 and 5.2). In the psychobiological model, EF is only one component of self-regulation and is facilitated or undercut by emotion and stress. For example, it is difficult to put EF skills into practice when we are stressed out or bored and lethargic. However, just as negative emotion, boredom, and stress interfere with EF, positive emotion and a small amount of stress facilitate EF. Here, the psychobiological model proposes that moderate challenge (eliciting a small amount of stress) increases engagement and learning.

Figure 3. Psychobiological model of self-regulation in which EF is one component of a hierarchy of processes relevant to self-regulation



Another example of a bottom-up influence on EF that is relevant to education is the daily fluctuation of physiological arousal, measured using a variety of biological and behavioral indices (e.g., core body temperature and sleep-wake cycles). There are reliable developmental and individual differences in these *circadian (daily) rhythms of arousal*, and individual differences in circadian timing may be reliably and validly estimated in both adults and children using self-report measures. Such measures ask participants about when during the day they prefer to engage in various intellectual and physical activities (optimal vs. non-optimal times of day). EF performance varies considerably as a function of circadian rhythms of arousal. During the transition to adolescence, most children show a *phase shift* in these daily rhythms, such that arousal peaks later in the day. Children between the ages of 11 and 14 years, tested in the morning or afternoon, have been shown to perform better on measures of EF when tested at their optimal (versus non-optimal) times of day, even when controlling for sleep duration on the previous night (Hahn et al. 2012; see also Goldstein et al. 2007). That is, most older children, for whom arousal is higher later in the day, showed better EF when tested in the afternoon, whereas most younger children, for whom arousal is higher earlier in the day, showed better EF when tested in the morning. The developmental change in rhythms during the transition to adolescence may provide insight into individual differences in educational achievement and behavioral problems, and it may further inform discussions regarding school start times (e.g., Carskadon et al. 1998).

1.4 "Hot" Versus "Cool" Executive Function

The interactions between EF and "lower level" influences such as emotion and stress are relevant to the distinction made between more *"hot" EF* and more *"cool" EF* (Zelazo and Müller 2002; see Peterson and Welsh 2014, for a review). There is now considerable evidence from human and nonhuman animal research, including brain lesion studies, neuroimaging research, and behavioral research that the top-down, neurocognitive processes (i.e., EF skills) needed in the presence vs. absence of high levels of emotion differ somewhat. Hot and cool EF, which typically work together in solving real-world problems, are both forms of deliberate, effortful, top-down, self-regulatory processing that depend on prefrontal brain regions; however, they vary in the extent to which they require managing motivation and emotion, including the goal-directed management of basic approach and avoidance motivations, and different specific neural circuits are involved. Hot EF involves the processes that operate in motivationally and emotionally significant situations, while cool EF involves the processes that operate in more affectively neutral contexts (Zelazo and Carlson 2012).

Most laboratory-based, behavioral measures of EF skills assess cool EF, and do so using abstract, decontextualized tasks that lack a significant affective or motivational component. For example, in the *Dimensional Change Card Sort* (DCCS) task (Zelazo 2006), participants are required to match a stimulus flexibly, such as sorting a red rabbit first with a blue rabbit (by shape) and then with a red car (by color). This task involves using arbitrary rules for responding to arbitrary stimuli (see section 6.3.4 for a more detailed description). In contrast, hot EF refers to those aspects of EF that are needed in situations that are motivationally significant—about which people really care because they stand to win or lose something. Hot EF is typically assessed in tasks that require *the flexible reappraisal of whether to approach or avoid a salient stimulus*. A classic example is delay of gratification as measured by the "marshmallow test" (Mischel, Shoda, and Rodriguez 1989). To the extent that it requires effortfully avoiding a more salient immediate reward and instead approaching a less salient delayed reward, delay of gratification involves hot EF. Another example is the Children's Gambling Task (Kerr and Zelazo 2004), a simplified version of the Iowa Gambling Task (Bechara et al. 1994; Noël, Brevers, and Bechara 2013), in which the options that at first appear advantageous (higher rewards) are revealed gradually to be disadvantageous (higher rewards but even higher losses), and vice versa. Hot EF is also involved in deliberate emotion regulation, as when we down-regulate (i.e., attempt to reduce) anxiety, sadness, or anger, or deliberately up-regulate motivation to accomplish a particular goal (Zelazo and Cunningham 2007).

The distinction between hot and cool EF can be observed in children's behavior by 3 years of age (e.g., Brock et al. 2009; Carlson, Davis, and Leach 2005; Hongwanishkul et al. 2005; Kim et al. 2013; Prencipe and Zelazo 2005; Prencipe et al. 2011; Willoughby et al. 2011), and there is some evidence that this distinction emerges even earlier in childhood (e.g., Bernier, Carlson and Whipple 2010). Whereas poor hot EF in preschoolers is associated with inattentive-overactive problem behaviors, cool EF is associated with academic outcomes, including math and reading (e.g., Brock et al. 2009; Kim et al. 2013; Willoughby et al. 2011). Deficits in hot EF (measured using the Iowa Gambling Task) also distinguish children with antisocial behavior disorders (oppositional defiant disorder or conduct disorder) from those with ADHD in adolescence (Hobson, Scott, and Rubia 2011), and hot and cool EF may be differentially implicated in different forms of ADHD (e.g., Castellanos et al. 2006). Further developmental research on hot vs. cool aspects of EF is needed to refine our conceptualization of this important distinction and explore its implications for learning and classroom behavior, including emotional and behavioral disorders.

1.5. Neural Basis for Executive Function

Understanding the brain systems involved in EF provides insight into the many experiential (e.g., stress) and other (e.g., genetic, physiological) influences on EF and EF development. It also informs efforts to improve EF skills by providing (1) a clearer understanding of the mechanisms whereby EF skills change, (2) various neurophysiological influences on EF skill, and (3) another level of analysis at which to measure the effects of interventions. More generally, research on the neurobiology of EF suggests that it might be productive to examine physiological as well as behavioral indicators of children's responsiveness to and engagement with specific types of learning activities and teaching approaches.

Both hot and cool aspects of EF depend on neural circuits involving PFC. From the study of neurological patients sustaining damage to this area of the brain (e.g., Waltz et al. 1999) to the findings of the latest functional magnetic resonance imaging (fMRI) research (e.g., D'Esposito and Postle 2015), associations of EF skills with well-defined areas of PFC are among the most robust examples of relations between brain and behavior in all of psychology (see Fuster 2015).

Neuroanatomically, the EF skills of cognitive flexibility, working memory, and inhibitory control are associated with distinct and partially overlapping networks involving regions of PFC. These include dorsal (on top) and lateral (on the side) areas of PFC; ventral (underneath) and medial (toward the middle) areas of PFC; and a medial brain structure adjacent to PFC referred to as the anterior cingulate cortex, or ACC for short. Whereas cool EF relies more on dorsal and lateral parts of PFC, hot EF relies more on ventral and medial parts. Regions of PFC have been shown to be active in perhaps hundreds of functional neuroimaging studies with adults when they are completing tasks involving holding information in mind, inhibiting one response in favor of another, and shifting attention from one task set (or approach to a problem) to another (see figures 4 and 5).

Figure 4. Lateral view of select brain regions relevant to executive function

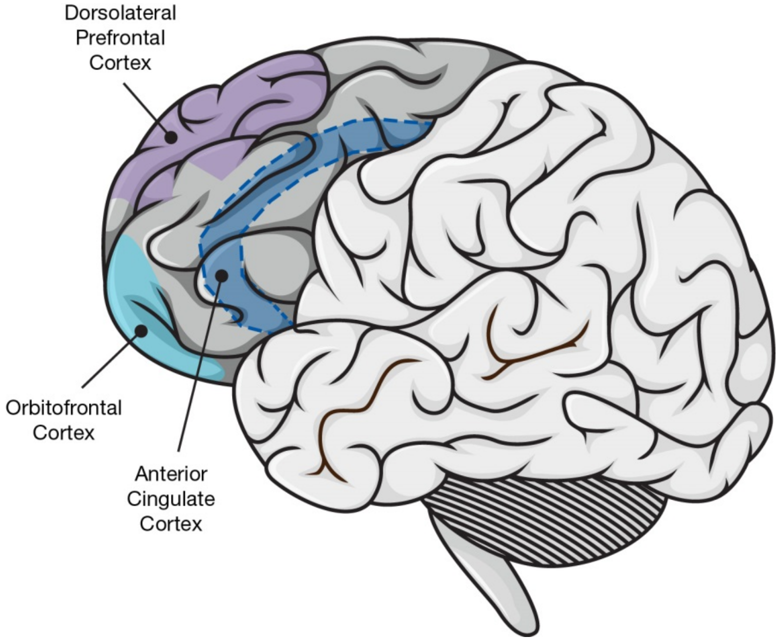
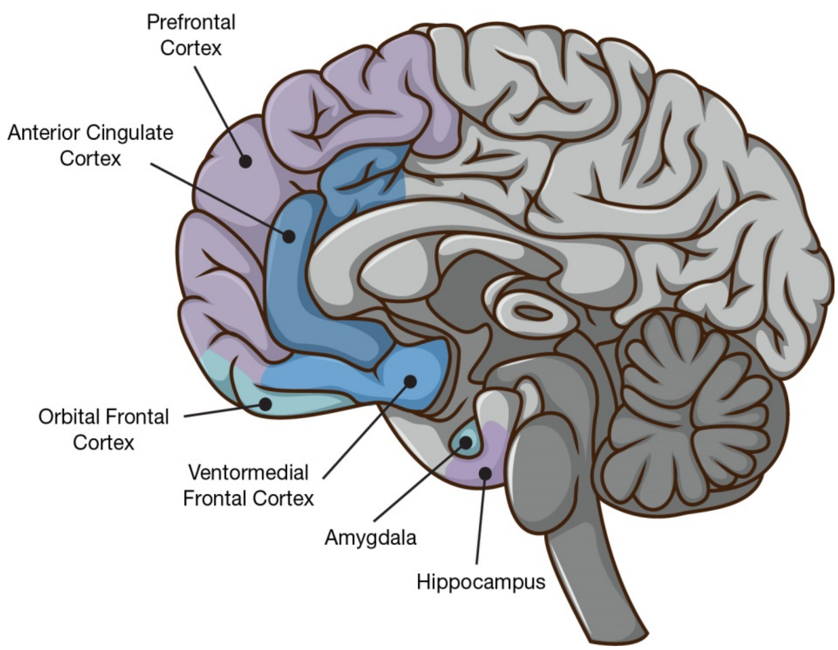


Figure 5. Medial view of select brain regions relevant to executive function



1.5.1 PFC Connectivity

PFC is highly connected with and coordinates activity in many areas throughout the brain. As such, PFC has been likened to the conductor of an orchestra or an air traffic controller (Center on the Developing Child at Harvard University 2011). Connections of PFC with other brain areas occur primarily through white matter tracts,[4] allowing for very rapid goal-directed, "top down" regulation of activity in multiple brain areas, such as those associated with language, memory, attention, and motor responses. PFC is also highly interconnected with subcortical structures such as the basal ganglia, which are important for learning patterns and routines, and the amygdala, which is important for emotion and the stress response. The interconnection of PFC with subcortical brain areas related to emotion regulation and the stress response is a key feature of the neurobiology of EF relevant to understanding the development of EF and its relation to educational outcomes.

The coordinating role for PFC in the brain distinguishes EF from other cognitive functions and from crystallized intelligence. This feature of PFC is illustrated by the fact that when neurologists began systematically studying large numbers of patients with damage to PFC, they were at first puzzled by exactly what this brain region does. When scientists administered tests of knowledge or basic information processing to these patients—that is, nonexecutive tasks such as measures of vocabulary or long-term memory—the patients did surprisingly well. It was only when patients were asked to coordinate multiple pieces of information; to plan; to reason, even very simply; or to inhibit seemingly inconsequential automatic responses that deficits were apparent. Neuropsychologists described these difficulties as "goal neglect" (reviewed in Duncan, Burgess, and Emslie 1995), indicating that the individual fails to hold an overarching goal in mind when coordinating two or more even relatively simple relations among distinct pieces of information (Waltz et al. 1999). This set of findings indicates the general distinction between EF and knowledge-based or crystallized abilities described in Section 1.2.

[4] White matter refers to neurons that have developed a fatty, myelin sheath, an experience-dependent process that occurs over the course of development and which greatly speeds communication between neurons.

1.5.2 The Role of Neurotransmitters in PFC Function

Research with nonhuman primates has taught us a great deal about the neuroanatomy and neural basis of EF (e.g., Wilson et al. 2010). This research has shown that activity in individual neurons in PFC is sensitive to variation in levels of neurotransmitters present in the synapse, most specifically the catecholamines, dopamine, and norepinephrine. In humans, levels of dopamine and norepinephrine vary as a function of many things, one of which is the amount of stress a person is experiencing (see Cools and D'Esposito 2011 for review). When levels of these neurotransmitters increase moderately from baseline, indicating that the individual is attentive and engaged and experiencing what might be considered moderate arousal or stress, there is more activity in neurons in regions of PFC that play key roles in networks underlying working memory. This activity maintains information relevant to the task at hand and suppresses extraneous and competing information (Arnsten 2009). Importantly, research relating catecholamine levels to neural activity in PFC has shown that the form of the relation between levels of catecholamines and working memory ability is an inverted U-shape curve. That is, activity in neurons that underlie EF is high when levels of these neurotransmitters increase moderately from baseline. However, as levels of these neurotransmitters rise beyond an intermediate level, reflecting higher levels of stress or arousal, they have an opposite effect; they shut down neural activity in PFC. This research provides evidence of the neuroscientific basis for the well-known Yerkes-Dodson inverted U-shape curve relating stress to performance (Yerkes and Dodson 1908).

1.5.3 PFC and Motivation

The inverted U-shape curve relating neural activity in PFC to EF highlights the interactive or recursive (feed forward-feedback) "top down, bottom up" nature of this neural system. As noted above, some of the neurotransmitters that stimulate activity in PFC, dopamine and norepinephrine, originate in areas of the brain (limbic system and brainstem) that influence attention, emotional responses to stimulation, and the physiological response to stress. Experience can rapidly activate neural activity in these areas, leading to the release of dopamine and norepinephrine, as well as the glucocorticoid hormone cortisol. These chemicals increase neural activity in PFC. PFC then feeds back on the limbic and brainstem areas, so as to maintain stimulation in what can be considered an optimal or effective range depending on the context (Benes 2001; Gunnar and Quevedo 2007).

When stimulation is in a moderate range and controllable, such as well-structured experiences in the classroom, neural activity in this brain network is balanced and EF is readily engaged. When stimulation is uncontrollable and overwhelming, however, as might occur in a highly chaotic and disorganized classroom, activity in the system is weighted toward the subcortical structures as activity in PFC is reduced, and activity in brain areas associated with more reactive and automatic responses to stimulation increases (Arnsten 2009).

1.5.4 PFC Development

Although most research on EF and the brain has been conducted with adults, the burgeoning field of developmental cognitive neuroscience has shown that many findings extend to children (e.g., Bunge et al. 2002; Luna et al. 2013). Certain brain imaging modalities, including *near infrared spectroscopy* (NIRS) and *electroencephalography* (EEG), provide evidence of relations between changes in activity in PFC and changes in child EF (e.g., Espinet et al. 2013; Moriguchi and Hiraki 2009; Rueda et al. 2005). Studies of structural connectivity and white matter tracts using MRI with sleeping infants also indicate relations of early brain connectivity to later EF (Short et al. 2013). In addition, evidence of relations between changes in levels of stress hormones and EF in children (Blair, Granger, and Razza 2005) is similar to that seen in adults (Lupien et al. 2009). Studies including children, however, provide unique information about the developmental relation between brain activity and EF. For example, in neuroimaging studies with children, EF-related brain activity is generally more diffuse, meaning more spread out and less isolated to the specific pathways seen in adults (Durston et al. 2006; Eslinger et al. 2009). With increasing age and experience, there is a shift from more diffuse to more focal activity (albeit with more long-term connections; Fair et al. 2009), which is thought to indicate an increase in the efficiency as well as capacity of the brain as it processes information (Rypma and Prabhakaran 2009), likely due to the development of white matter and synaptic pruning (Klingberg 2006; Sheridan et al. 2014). There is also evidence that brain development is hierarchical, meaning that cortical areas associated with basic processes (e.g., sensory and motor) develop first, and cortical areas associated with more complex processes, such as EF, develop later—literally growing on top and around the primary cortical areas. One influential approach to understanding adolescent development emphasizes the imbalance during adolescence between a relatively well-developed emotional reactivity system and a relatively immature prefrontal cortical system associated with EF skills (e.g., Casey et al. 2008; Crone and Dahl 2012; Ernst 2014; Steinberg 2010).

1.5.5 Neural Plasticity: Experiential Influences on Brain Development

Brain development occurs in large part as a function of experience, and the neural circuitry that supports EF is highly plastic, or modifiable, during development. Research is revealing the ways in which experience shapes the neural circuitry underlying EF, including experience in educational environments. As discussed more fully in chapter 6, behavioral interventions targeting EF have demonstrated the potential to help children at risk for difficulty in school. To some extent, however, PFC never stops developing as both EF skill and connectivity in PFC peak in early to mid-adulthood and then exhibit gradual decline across the lifespan (Zelazo et al. 2013, 2014; see Schaie 1994 for a discussion of adult cognitive development more generally). The protracted course of PFC development and the development of EF allows for an ongoing influence of experience on EF skills.

Given a general principle of brain development, namely, that cells that fire together wire together (also referred to as use- or experience-dependent plasticity), experience more or less shapes the neural connections that underlie EF (Posner and Rothbart 2007). The repeated engagement and use of EF skills in problem solving should strengthen those skills, increase the efficiency of the corresponding neural circuitry, and increase the likelihood that the skills will be activated in the future (see Zelazo and Lee 2010, for a review). This experience-dependent shaping of brain networks is well established (Greenough, Black, and Wallace 1987) and is evident in many cognitive abilities and behaviors, as seen in studies of musicians, jugglers, and taxi drivers (e.g., Bengtsson et al. 2005; Elbert et al. 1995; Maguire et al. 2000). A central research question concerns the ways in which diverse types of educational experiences influence the neural connections that underlie EF.

The protracted malleability of PFC is a double-edged sword. Although EF can be improved by training, for example, it can also be diminished by adverse experience. For example, children growing up in poverty typically perform worse on EF tasks than their more affluent peers (e.g., Noble, Norman, and Farah 2005). Lower EF is also associated with higher levels of stress in childhood, likely because stress impairs EF, and impaired EF in turn leads to more stress (Evans and

Schamberg 2009). There is also evidence, however, that good EF skills can protect against risks associated with poverty and adversity, including the risk of academic failure (Masten et al. 2012).

A number of studies, primarily in animal models, demonstrate that high levels of stress impair brain development and the development of EF (Holmes and Wellman 2009). An example of this phenomenon with an acute stressor in humans is found in a study with students preparing for medical board exams. Stress impaired students' EF performance and reduced their functional activity in PFC relative to a low-stress control group. One month later, after a period of reduced stress, however, EF ability and brain activity returned to normal (Liston et al. 2009). The mechanism whereby stress leads to changes in the brain and changes in EF is through the toxic effects of persistently elevated stress hormone levels on neurons in several brain regions (Holmes and Wellman 2009). Longitudinal developmental studies have demonstrated that chronic stress is associated with elevated stress hormone levels and reduced EF (Blair et al. 2011; Evans and Schamberg 2009; Hostinar, Sullivan, and Gunnar 2014). A growing evidence base indicates that with improvements in conditions, both levels of stress hormones and EF will improve (Fisher et al. 2006).

1.5.6 Sensitive Periods in Brain Development

The human brain is inherently plastic, continually adapting to its environment, but there are periods of relatively high plasticity (so-called "sensitive periods") when particular parts of the brain and their corresponding functions are especially susceptible to environmental influences. These periods typically correspond to times of rapid growth in those regions and functions, when the relevant neural regions are adapting especially rapidly to structure inherent in the environment (Huttenlocher 2002). Because EF skills undergo a particularly rapid transformation during early childhood, from about 2 to 6 years of age (see chapter 3), the preschool period may be a window of opportunity for the cultivation of these skills via well-timed, targeted scaffolding and support.

Although the preschool years may be an especially sensitive period for EF, there is also considerable reorganization of prefrontal systems during the transition to adolescence, when gray matter volume in PFC reaches a peak (Giedd et al. 1999). Prefrontal cortical plasticity is not limited to the preschool period, and training studies have demonstrated the malleability of the neural circuitry that underlies working memory and other aspects of EF in both children and adults (e.g., Klingberg et al. 2005; Olesen, Westerberg, and Klingberg 2003; see Karbach and Unger 2014, for review). Evidence supporting the generalizability of gains in EF skills to academic achievement and other positive life outcomes, however, is mixed at best (Melby-Lervag, Redick, and Hulme 2016).

Such research has implications for educational practice in subject areas that make high demands on EF, such as math, reading comprehension, and any other subjects that require deliberate reasoning (such as science learning; e.g., Gropen, Hoisington, and Ehrlich 2011). Training in academic subjects that makes high demands on reasoning, including the formation of hypotheses and the subsequent revision of those hypotheses based on evidence, would be expected to increase EF, just as EF is important for engagement and achievement with this material. Longitudinal studies looking at the development of academic ability and EF over time provide evidence consistent with the suggestion that academic learning improves EF and vice versa (Fuhs et al. 2014; Welsh et al. 2010).

1.6 Summary

EF can be understood as a set of three neurocognitive skills—cognitive flexibility, inhibitory control, and working memory—that together allow for the conscious control of attention and behavior in order to achieve a goal. These EF skills can be distinguished from relatively stable individual differences in the tendency to display these skills (e.g., effortful control, conscientiousness). Contemporary theoretical models often address EF at multiple levels of analysis, from behavior to brain, and they emphasize bidirectional interactions between deliberate, intentional top-down EF and bottom-up automatic processing of information, such as that associated with emotion and the stress response.

A distinction can also be made between more cool EF, which involves processes that operate in affectively neutral contexts, and more hot EF, which is involved in emotionally significant situations and involves the goal-directed, flexible reappraisal of whether to approach or avoid a salient stimulus. Difficulty with hot EF is associated with social and emotional behavior problems, while difficulty with cool EF is associated with poor academic performance.

Research on the brain networks involved in EF provides insight into the nature and development of EF. For example, there are reasons to believe that the preschool years may be a period of relatively high plasticity in PFC. Although PFC is connected with many regions throughout the brain, the interconnectivity of PFC with brain areas associated with emotion and stress is particularly relevant from an educational standpoint. High levels of stress, particularly early in development, for example, influence brain development in ways that can limit EF. However, PFC and EF are highly malleable and continue to develop across the lifespan. Consequently, high-quality educational experiences as well as direct and indirect training of EF can positively influence brain development and the development of EF.

2. The Role That Executive Function Plays in Learning and Adaptation

In this chapter, we provide a brief overview of the evidence that executive function (EF) provides a foundation for learning and achievement—evidence that is addressed more fully in subsequent chapters. Generally, EF has both *direct* and *indirect* roles in classroom learning. EF skills directly make it possible for students to sit still, pay attention, remember and follow rules, and flexibly adopt new perspectives. Indeed, some researchers assert that skills such as cognitive flexibility, working memory, and inhibitory control contribute to more fully engaged, active, and reflective forms of learning, which are just what is needed in classrooms (Lyons and Zelazo 2011; Marcovitch et al. 2008; Zimmerman 2008). Children who arrive at school with well-practiced EF skills may learn more easily, and this may initiate a positive cascade of indirect effects, such as liking school and being motivated to work hard. More research on these indirect effects is needed, but children with good EF skills who learn more easily may be more likely to enjoy school, feel optimistic about their own learning potential (e.g., adopt a growth mindset; Dweck 2006), and get along with teachers and peers. In contrast, poor EF skills may interfere with children's own (and others') learning and may lead to behavior problems, suspension, expulsion, or being held back (U.S. Department of Education 2014).

A number of sources provide evidence about the roles of EF in learning and adaptation. These sources include *individual differences research* that links EF to school readiness and academic achievement in kindergarten and the early school grades (e.g., Alloway et al. 2005; Blair and Razza 2007; Bull, Espy, and Wiebe 2008). In these studies, the relation of EF to academic achievement is seen over and above effects of intelligence and prior knowledge. Moreover, longitudinal studies have shown that measures of EF and closely related constructs, such as self-control, predict important outcomes, including Scholastic Aptitude Test (SAT) scores in adolescence (Mischel, Shoda, and Peake 1988); the likelihood of graduating from college by age 25 (McClelland et al. 2013); and physical health, substance dependence, socioeconomic status (SES), and the lifetime likelihood of a criminal conviction by age 32 (Moffit et al. 2011). EF predicts these outcomes even after controlling for SES and IQ.

2.1 Executive Function and Learning in School

The links between EF and academic functioning in early childhood are robust (see Allan et al. 2014, for a meta-analysis showing a mean effect size of r =.27 across studies, indicating a moderate and statistically significant association). EF assessed in early childhood (either directly or indirectly via related measures, such as teacher ratings of effortful control) has been found to predict school readiness for both math and reading (Espy et al. 2004; McClelland et al. 2007; Morrison, Ponitz, and McClelland 2010; St. Clair-Thompson and Gathercole 2006); overall school achievement (e.g., Bull and Scerif 2001; Bull, Espy, and Wiebe 2008; Clark, Pritchard, and Woodward 2010; Mazzocco and Kover 2007); grades (Duckworth and Seligman 2005); high school completion (Vitaro et al. 2005), and even college graduation (McClelland et al. 2013). In many cases, EF predicted outcomes better than IQ. Kindergarteners with poorer EF skills and poorer social competence had more difficulty in reading and math, with growth curves indicating that this gap in performance widened until second grade and then persisted from third through sixth grade (McClelland, Acock, and Morrison 2006). There is also evidence that children with better EF skills actually learn more (i.e., retain more information) from a given amount of instruction and practice than do their peers with worse EF skills (Benson et al. 2013). For example, children with better EF skills showed a larger gain in math achievement between kindergarten and first grade, especially on applied problems (Hassinger-Das et al. 2014), and children with better EF skills were more likely to learn new concepts when trained in biology (Zaitchik, Iqbal, and Carey 2014).

In order to accurately describe the specific relations of EF to school readiness, achievement, and learning, it is important to consider EF as one aspect of self-regulation. As noted in chapter 1, self-regulation is a broader construct that includes not only effortful EF skills but also involuntary, automatic processes of self-regulation (e.g., Blair 2014). For example, in contrast to the meta-analysis by Allan et al. (2014), referred to above, a separate meta-analysis by Jacob and Parkinson (2015) used a broader definition of EF with a broader age range. While Allen and colleagues (2014) focused only on the inhibitory control dimension of EF in children between 2.5 and 7 years of age, Jacob and Parkinson (2015) included all three aspects of EF as well as measures of sustained, focused attention (e.g., a continuous performance task involving pressing a button as fast as possible only when a target picture appears onscreen) and motor response inhibition (e.g., the walk-a-line task involving walking a six foot line as slowly as possible) in children ages 2 to 18 years. Across 67 studies and across EF skills, this meta-analysis found EF to be positively related to reading achievement (average $r = .30$) and math ($r = .31$), for both concurrent and predictive correlations. Correlations were highest for attention shifting (i.e., cognitive flexibility), with an average $r = .42$ for reading and average $r = .34$ for math. Correlations were lowest for response inhibition, with an average $r = .25$ for reading and average $r = .31$ for math. As reviewed more comprehensively in chapter 6, there is some evidence from controlled experiments that a focus on improving EF skills can lead to improved reading and math outcomes (e.g., Raver et al. 2011). In addition, there is evidence that improving math and language skills can lead to improved EF outcomes (#Weiland and Yoshikawa 2013).[5]

Issues of construct differentiation are highlighted in research on EF and self-regulation. EF is occasionally used as an umbrella term encompassing all aspects of self-regulation. It is clear, however, that aspects of self-regulation other than EF per se—such as being compliant and cooperative, being prosocial and considerate of others, and having a growth mindset (i.e., believing that one can improve one's own cognitive skills)—are also important for school readiness and school achievement (Blair 2002; Dweck 2006; Yeager and Walton 2011). These other aspects of self-regulation have been shown in a number of studies to uniquely influence early progress in school (Bierman et al. 2008; Duncan et al. 2007; McClelland et al. 2007).

Nonetheless, numerous studies have found EF to be a unique predictor of academic learning and achievement in kindergarten and during the school-age years (Fuchs et al. 2003, 2006; Siegler and Pyke 2013; Vukovic et al. 2014). Although this is clearly established for mathematics (e.g., Bull and Lee 2014; Monette, Bigras, and Guay 2011), it is also found for reading (e.g., Kieffer, Vukovic, and Berry 2013; St. Clair-Thompson and Gathercole 2006) and for science (Nayfield, Fuccillo, and Greenfield 2013).

The role of EF in mathematics learning has been particularly well studied, perhaps because of the obvious need for working memory and cognitive flexibility when solving math problems. Longitudinal studies have typically attempted to isolate the added value of EF skills to math learning

[5] Citations with an # reflect publications reporting findings from experimental studies that were examined by the What Works Clearinghouse (http://ies.ed.gov/ncee/wwc/) and that, as of May 2016, did not met What Works Clearinghouse's group design standards.

by controlling for baseline math skills (e.g., Bull et al. 2011). Studies of EF and math learning have also controlled for relevant cognitive covariates such as verbal ability and general processing speed (although both of these are positively correlated with EF skills), as well as child and family background characteristics that might be associated with both higher levels of EF and higher levels of achievement (e.g., Blair et al. 2014). In some studies (Fuhs et. al 2014; Welsh et al. 2010), relations between EF and math from pre-kindergarten (pre-K) to kindergarten have been shown to be reciprocal. That is, initial pre-K EF skills predicted change in math over the pre-K year (controlling for initial pre-K math skills), and initial pre-K math skills predicted change in EF over the pre-K year (controlling for initial pre-K EF skills). To the extent that math involves EF skills, and given that both math and EF skills improve with practice, this type of reciprocal ratcheting-up of both skills is to be expected.

Teacher-report measures of attention, in which stable individual differences in EF are perhaps implied but not measured directly, are robustly associated with multiple aspects of math competence, including word problem solving, algorithmic computation, and arithmetic (Fuchs et al. 2006). These correlations are obtained over and above associations with other cognitive characteristics such as language, processing speed, and conceptual ability. Notably, teacher report measures of attention problems have been shown to differentiate students with math disability from students with reading disability (Cirino et al. 2007).

The prominent role of EF in math learning is further highlighted by research on the phenomenon of math anxiety. In keeping with the inverted U-shape relation between stress and EF, math anxiety refers to a heightened negative emotional arousal in response to math challenges that interferes with and overwhelms EF (Ashcraft and Krause 2007; Beilock and Carr 2005). Math anxiety, therefore, illustrates the bidirectional relation between stress and EF. When the experience of emotion and stress is high, EF is compromised (as described in section 1.5 above and section 5.2 below). Compromised EF then interferes with math competence, further increasing anxiety and leading to even larger deficits in EF and in math. This back and forth, or reciprocal relation between EF and ability, in this instance math ability, is central to the relation between EF and educational achievement generally and suggests that EF is maximized when task difficulty and, hence, stress is in a moderate range. In addition, the EF requirements of math learning may be greater in the context of math anxiety and may include a greater need for hot EF to down-regulate negative emotion.

Although a good deal of recent research on EF and academic achievement has focused on math, the relation of EF to reading ability is also well established. This is particularly the case for working memory (e.g., Alloway and Alloway 2010; Daneman and Carpenter 1980; Karbach, Strobach, and Schubert 2014; Loosli et al. 2012). In part, associations between EF and reading are attributable to strong associations between EF and language development (Daneman and Merikle 1996; Gathercole and Baddeley 1989). Specific effects of EF on reading are seen most consistently for reading comprehension and fluency, however, rather than for more basic, knowledge-based aspects of reading, such as knowledge of letters and words (Cutting et al. 2009; Fuchs et al. 2015; Kieffer, Vukovic, and Berry 2013; Sesma et al. 2009). By kindergarten, knowledge of letters and words often represents acquired, *crystallized* aspects of mental ability rather than *fluid*, reasoning-based aspects of mental ability associated with EF. As such, by the school age years, some aspects of reading ability are primarily accounted for by measures of vocabulary and speed of information processing rather than measures of EF (reviewed in Blair, Protzko, and Ursache 2011; Evans et al. 2002). There is some evidence, however, that EF is important when children are first acquiring knowledge of letters and words. For example, analysis of a large middle-income sample assessed longitudinally indicated that EF skills were associated with letter and word knowledge during pre-K but not kindergarten (Fuhs et al. 2014). Relations between EF and oral language comprehension, however, were present both in pre-K and kindergarten and were reciprocal. There are also relations between EF and *phonemic awareness* (Blair and Razza 2007; Welsh et al. 2010). Children demonstrating phonemic awareness recognize smaller units of meaning and sound (e.g., smaller words embedded within larger words, such as the word *tooth* in *toothbrush*). This requires cognitive flexibility, such as seeing the word *toothbrush* in two distinct ways, both as a complete word and as composed of two smaller words. Similarly, learning to spell in English requires working memory to hold multiple representations of letter-sound correspondence in mind. It also requires inhibitory control to inhibit one representation over the other, such as when learning the letters C and K, and learning letter combinations such as "kn" and "ph." These are only two of many examples of the EF demand of early literacy acquisition.

The association of EF with academic learning more generally is also seen in research on *self-regulated learning* (Zimmerman 2008). Self-regulated learning refers to an active form of learning, in which the learner is metacognitively, motivationally, and behaviorally engaged in the learning process. Although the specific relation of EF to self-regulated learning remains to be explored, EF is surely a key contributor to self-regulated learning, with its emphasis on goal setting, self-monitoring, and strategy use. Experimental research on self-regulated learning strategies, therefore, provides some indirect causal evidence linking EF (or EF as applied to self-regulated learning) to academic achievement. A meta-analysis of the effectiveness of self-regulated learning strategies revealed relatively large effects on math, with an average effect size of 1.0 standard deviation (*SD*), compared to an average effect size of .44 *SD* for reading and writing (Dignath, Buettner, and Langfeldt 2008). For example, in one experiment (Fuchs et al. 2003), third grade students were randomly assigned to one of three conditions. Children who received activities designed to promote goal-setting and self-assessment in math learning, as well as assistance with the transfer of problem solutions (all of which are heavily dependent on EF skills), outperformed children assigned to control or transfer-training-only conditions. It will be of considerable interest in the future to examine the roles of EF in self-regulated learning, the efficacy of self-regulated learning interventions, and the transfer of what is learned.

Research focusing on EF for classroom learning and academic function shows that EF skills may play a key role in the *achievement gap* between children from lower vs. higher SES backgrounds. It is now well established that lower SES is associated with lower EF skills, even when controlling for general cognitive ability (e.g., Farah et al. 2006; Farah et al. 2008; Masten et al. 2012; Mezzacappa 2004; Noble, Norman, and Farah 2005; Obradović 2010). Lower EF skills, in turn, place children from lower SES families at a further disadvantage in a classroom context, potentially setting up a cascade of events leading to negative self-perceptions and undermining motivation. There is also evidence, however, that having strong EF skills serves as a *protective factor* against the academic risks associated with extreme poverty (Masten et al. 2012; Obradović 2010). Masten and colleagues found that children who are (or have been) homeless and highly mobile are, on average, much more likely than other children to perform poorly in school but that this did not apply to children with good EF skills. These children tended to succeed in school despite being homeless, showing evidence of *resilience*. Two studies have shown that EF partially accounts for the association between SES and early learning in school, and these studies also suggest that EF accounts for more of the variance related to SES than do measures of IQ or language ability (Fitzpatrick, McKinnon, and Blair 2014; Nesbitt, Baker-Ward, and Willoughby 2013). Further research is needed to understand why lower SES is associated with lower EF, including which aspects of lower SES environments (e.g., nutrition, parenting, unpredictability) contribute to lower EF and why.

As will be reviewed more fully in chapter 6, recent studies using randomized controlled designs suggest that improving EF through classroom-based activities improves academic achievement. For example, in a study with 5-year-olds in foster care, a short-term, classroom-based intervention focusing on self-regulation (e.g., how to focus attention, sit still, and wait for one's turn) and school readiness led to improved inhibitory control and to higher literacy scores (Pears et al. 2013). In another study, kindergarteners receiving a commercially-available curriculum named Tools of the Mind[6] showed gains in EF skills that were associated with gains in achievement (e.g., reading) that carried over into first grade ([#]Blair and Raver 2014). Finally, research on the impact of a self-regulation intervention that took place with 4-year-olds in Head Start classrooms over the course of 8 weeks (two 20–30 minutes playgroups per week) found that, compared to children who did not receive the intervention, trained children showed better EF skills, even controlling for baseline self-regulation, child age, and English language learner (ELL) status (Schmitt et al. 2015). Furthermore, ELL students receiving the self-regulation intervention showed higher math scores at the end of the year than ELL students who did not.

2.2 Difficulties With Executive Function Are a Prominent Feature of Many Disabilities and Disorders that Interfere With Learning

Given the important role that EF plays in learning and the robust association between EF and academic achievement, it is perhaps not surprising that difficulties with EF, particularly in working memory, are associated with learning difficulties and specific learning disabilities (Geary 2011; McLean and Hitch 1999; Swanson, Howard, and Saez 2006; Toll et al. 2011). Difficulties with EF are also associated with autism spectrum disorder (ASD) (e.g., O'Hearn et al. 2008), conduct disorder (e.g., Séguin 2004; Séguin and Zelazo 2005), obsessive-compulsive disorder (e.g., Pietrefesa and Evans 2007), and attention deficit hyperactivity disorder (ADHD) (e.g., Castellanos et al. 2006; Willcutt et al. 2005). Different aspects of EF may be implicated in each disorder, but there are also reasons to believe that the same EF difficulties may result from many different forms of atypical cognitive development.

---

[6] The Tools of the Mind program blends teacher-led scaffolding of a comprehensive curriculum of early literacy, mathematics, and science activities with child-directed activities and structured sociodramatic play, as well as the use of specific tactics to support EF and learning in young children (Bodrova and Leong 2007).

EF difficulty may then be expected to interfere with learning, both directly through the ability to process complex information and indirectly through behaviors that are related to learning. Several studies have found EF is also implicated in specific learning disabilities such as reading disability (Alloway et al. 2009; Booth, Boyle, and Kelly 2010). Working memory, in particular, has been found to be related to specific language impairment (Archibald and Gathercole 2006; Briscoe and Rankin 2009).

Difficulties with different aspects of EF may be implicated in different forms of a single disorder. Because of the multiple influences on and pathways that interact with EF, researchers are working to identify the heterogeneity in disorders characterized by EF difficulty. They are also exploring the heterogeneity of psychological functioning in typically developing populations so that they can better understand the etiology, diagnosis, and treatment of disorders (e.g., Fair et al. 2012). For example, although models of ADHD have focused on EF deficits as a core feature of the disorder (e.g., Barkley 1997; Nigg 2001), there is evidence that ADHD is a heterogeneous disorder, with different subtypes, and that several pathways can lead to ADHD (Castellanos and Tannock 2002; Nigg et al. 2005; Willcutt et al. 2005), including an increased sensitivity to rewards, particularly in adolescence (Nigg and Casey 2005). Castellanos and colleagues (2006) have proposed that while inattention symptoms are due to cool EF deficits, hyperactivity/impulsivity symptoms depend on more difficulties with hot EF. Empirical studies suggest that measures of hot EF (e.g., delay aversion, or the motivation to escape or avoid delay) and measures of cool EF (e.g., the Stop-Signal task which measures inhibitory control) are independent predictors of ADHD status (e.g., Solanto et al. 2001). Further, even after controlling for working memory, hot EF is associated with symptoms of hyperactivity/impulsivity but not with symptoms of inattention (Toplak, Jain, and Tannock 2005; but see Geurts, van der Oord, and Crone 2006).

It is currently unclear to what extent difficulties with EF contribute to the broad category of emotional and behavioral disorders (EBDs) (Individuals with Disabilities Education Act (IDEA) Regulations, Sect. 300.8 c 4). However, several studies have found EF to be associated with conduct problems in preschool-aged children (e.g., Hughes et al. 2000; Speltz et al. 1999). Others have found EF to relate to parent reports of social competence and social skills in elementary school (Hughes and Ensor 2011; Riggs, Blair, and Greenberg 2003). This is an area for future research, and it will be of interest to examine the role of hot vs. cool EF in EBDs, as well as the role of bottom-up influences such as stress and arousal.

2.3 Summary

The evidence briefly summarized in this chapter highlights only a few of the reasons research on EF is relevant to learning and to education more generally. First, EF skills predict both math and reading comprehension in kindergarten and during the elementary grades. There is also evidence that children with better EF skills learn more from a given amount of instruction, although other aspects of self-regulation, such as having a growth mindset, are also important. EF difficulty may be caused by many forms of atypical cognitive development. Difficulties with EF are prominent in numerous disorders with childhood onset, moreover, including specific learning disabilities and ADHD, although there is increasing awareness of the heterogeneity of these disorders and associated EF deficits. However, good EF skills have been found to serve as a protective factor against the risk of low academic achievement in disadvantaged children. Research has shown clearly that EF skills can be improved by relatively brief interventions that provide children with opportunities to practice their developing EF skills at increasing levels of challenge. The preschool years may be an especially sensitive period for the acquisition of EF skills, but the transition to adolescence is another promising target for interventions. Ongoing research is directed at finding optimal strategies for cultivating EF skills at different ages and for tailoring these strategies to individual children's needs.

3. Assessment of Executive Function

This chapter considers issues related to the assessment of EF in children. We begin with a brief account of historical changes in the assessment of EF. Next, exemplar measures are introduced. Finally, key challenges in the assessment of EF are summarized and decision rules for the selection of measures are proposed. A unifying idea of this chapter is that there are variety of different reasons EF might be assessed, each of which benefits from specific measurement approaches (questionnaires, performance-based tasks) and the selection of instruments or tasks that have specific psychometric properties.

3.1 Historical Context for Assessing Executive Function in Children

For most of the 20th century, neuropsychological assessments of so-called frontal lobe functions, which were the predecessors of current conceptualizations of EF, were limited to adults. This was due to an early belief that frontal lobe development in childhood was limited (Golden 1981). However, improvements in our understanding of normative brain development established that the frontal lobes undergo a prolonged period of development that spans infancy through early adulthood. This shift in understanding was pivotal in initiating modern research on EF in children (reivewed by Hughes 2011; Teeter et al. 2009).

In the 1980s and 1990s, a number of studies demonstrated age-graded changes in performance on “frontal lobe” tasks that were evident for children as young as 5 years old into early adulthood (Becker, Isaac, and Hynd 1987; Levin et al. 1991; Passler, Isaac, and Hynd 1985; Welsh and Pennington 1988; Welsh, Pennington, and Groisser 1991). This work was complemented by efforts to develop performance-based assessments of EF that were appropriate for preschool-aged children (Archibald and Kerns 1999; Espy 1997; Espy et al. 1999; Zelazo, Frye, and Rapus 1996). By the end of the 20th century, vague notions of “frontal lobe functions” were replaced by more well-defined notions of specific EF skills, and the construct of EF was increasingly understood to be a life-course construct in which developmental changes were evident from early childhood into old age (Anderson, Sleeper, et al. 2008; Anderson, Jacobs, and Anderson 2008; Zelazo, Craik, and Booth 2004).

In addition to expanding ages in which EF was assessed, there has been a broadening of the intended uses of EF assessments. Like the adult studies that preceded them, many of the early studies of EF in children focused on discrete clinical populations or events, including prematurity (Luciana et al. 1999); prenatal drug exposure (Espy, Kaufmann, and Glisky 1999); early brain disease (Taylor et al. 1996); suspected or known genetic, clinical, or neurological disorders (Diamond, Prevor, Callendar, and Druin 1997; Fletcher et al. 1996; Hughes, Russell, and Robbins 1994; Temple, Carney, and Mullarkey 1996); or specific learning disabilities often with comorbid attention deficit hyperactivity disorder (ADHD) (Denckla, 1996; Pennington, Groisser, and Welsh 1993; Swanson and Alexander 1997; Swanson and Berninger 1995). Although EF assessments continue to be used with children who have known clinical conditions or who have been defined by singular risk events (e.g., preterm birth; Mulder et al. 2009), EF has increasingly transitioned from a construct primarily relevant in clinical populations to a key aspect of cognitive development and a source of individual differences in self-regulation that contributes to social and academic success (Blair 2002; Heckman, Stixrud, and Urzua 2006; Moffitt et al. 2011), thus making it a developmental and individual differences variable. This expanded characterization of EF has resulted in both increases in the use of questionnaires to assess EF and in the use of performance-based assessments in ways that diverge from their original uses.

3.2 Approaches to Assessment

The shift from conceptualizing EF as an indirect proxy of presumed neurological dysfunction involving the frontal lobes to a core aspect of cognitive development and an individual differences variable has raised important questions about how EF is best assessed. Performance-based tasks have long been the dominant approach for measuring EF, and they continue to be considered the gold standard method of assessment. A comprehensive summary of performance-based EF tasks is beyond the scope of this chapter (but see Carlson 2005; Chan, et al. 2008). Instead, we describe exemplar measures in order to provide a shared understanding of how EF skills are often assessed. Exemplar measures were chosen based on their wide use and are not intended to convey any endorsement.

The National Institutes of Health (NIH) Toolbox for the Assessment of Neurological and Behavioral Function includes free, validated, reliable, norm-referenced measures of EF that can used with children and adults ages 2.5-85 years.[7] These brief (~5 minute) tablet-based measures are designed so that they can be administered repeatedly to the same individuals, making them suitable for clinical trials and large-scale epidemiological and longitudinal studies. Three measures of EF are available. The *Dimensional Change Card Sort* (Zelazo 2006) requires children to match a series of bivalent test pictures (e.g., yellow balls and blue trucks) to target pictures, first according to one dimension (e.g., color) and subsequently to a second dimension (e.g., shape). The ability to successfully switch the sorting rules is an indicator of cognitive flexibility. In the *Flanker* task (Eriksen and Eriksen 1974; Rueda et al. 2005), individuals are asked to identify the direction of a centrally presented stimulus while inhibiting attention to stimuli (fish for ages 3-7 or arrows for ages 8-85) that are flanking it. Sometimes the central stimulus is pointed in the same direction as the "flankers" (congruent) and sometimes in the opposite direction (incongruent). Responses to the incongruent items are an indicator of inhibitory control. In the *Toolbox List Sorting Working Memory Test*, pictures of different foods and animals are displayed with accompanying audio recording and written text (e.g., "elephant"). Individuals are instructed to repeat the items back in size order from smallest to largest, first within a single dimension (either animals or foods, called 1-List) and then on two dimensions (foods, then animals, called 2-List). The proportion of correctly recalled items is an indicator of working memory. The NIH Toolbox also includes brief measures of processing speed (90 seconds) and vocabulary (~ 4 minutes), which can be useful for examining EF in relation to other cognitive processes.

The CANTAB is a commercially available (through Cambridge Cognition) computerized assessment of a broad set of cognitive processes, of which EF skills are only a subset.[8] The EF battery consists of seven tasks that are appropriate for use in childhood through adulthood (age 4-90 years of age). The CANTAB EF tasks correspond to well-known tasks in the literature. For example, the *One Touch Stockings of Cambridge* test, which measures spatial planning and working memory, is based on the Tower of Hanoi test. Participants are shown two displays of three colored balls. Participants are instructed to reconfigure one set to resemble a display set, while following a set of rules about

---

[7] See http://www.healthmeasures.net/explore-measurement-systems/nih-toolbox.
[8] See http://www.cambridgecognition.com/.

permitted moves. Items differ with respect to the number of moves that are required to replicate the display set. The *Spatial Working Memory* task, which measures working memory, is a self-ordered task that involves locating a blue token that is hidden under one of a number of colored boxes. Participants have to recall which boxes have been previously touched in an effort to locate the token. Items become more difficult as the number of colored boxes that require searching is increased. The *Stop-Signal* test, which measures inhibitory control, closely approximately Logan's task by the same name (Verbruggen, Logan, and Stevens 2008). Participants are instructed to touch either a left or right button according to the direction that an arrow is pointing unless that arrow is preceded by an audible tone. Items become more difficult as the time interval between the presentation of the arrow and the audible sound vary. Two unique feature of the CANTAB battery are (1) the reliance on touch-screen technology and (2) its extensive use in research studies (see maintained bibliography at www.cambridgecognition.com).

The Delis-Kaplan Executive Function System (D-KEFS; Delis, Kaplan, and Kramer 2001) is another commercially available, norm-referenced battery of nine verbal and nonverbal EF tasks that are appropriate for use in childhood through adulthood (age 8-89 years). The tasks include both adaptations of existing EF tasks, as well as newly developed tasks. For example, whereas the *Color-Word Interference* task closely approximates the classic Stroop task, which is a well-established measure of inhibitory control, the *Word Context* test is a new task that measures deductive reasoning, hypothesis testing, and flexibility in thinking. Notably, the D-KEFS tasks focus less on the three core domains of EF that we have emphasized throughout (i.e., inhibitory control, working memory, and cognitive flexibility) and more on measures fluency and fluid intelligence. This represents a more expansive characterization of the construct of EF than comparison batteries, and assesses behaviors that depend on more specific EF skills.

In addition to dedicated EF task batteries, the Wechsler Preschool and Primary Scale of Intelligence Fourth Edition (WPPSI-IV; Wechsler 2012), the Wechsler Intelligence Scale for Children Fifth Edition (WISC-V; Wechsler 2014), and the Stanford-Binet Intelligence Scale, Fifth Edition (SB5; Roid 2003) all have multiple subtests that are combined to yield working memory and fluid intelligence composite scores. Whereas working memory is a core domain of EF, fluid intelligence is a broader but closely related construct that involves reasoning or novel problem-solving efforts that make use of EF skills. School psychologists routinely make use of the WISC-V and SB5 in the context of psychoeducational assessments; hence, the working memory and fluid intelligence subtest are frequently used in educational contexts. For example, school psychologists often consider children's differential performance on nonverbal versus verbal working memory and fluid intelligence tasks in order to make educational recommendations (e.g., children who have poor verbal, but not nonverbal, working memory may benefit from the use of visual reminders, pre-printed notes, or other written materials that serve as accommodations).

Over the last decade, there has been a burgeoning interest in developing questionnaire measures of EF for use with children, adolescents, and adults (Buchanan et al 2010; Geurten et al. 2016; Gioia 2000; Naglieri and Goldstein 2004-2015; Nilsen et al. 2016; Shaw, Oei, and Sawang 2015; Thorell and Nyberg 2008; Vallat-Azouvi, Pradat-Diehl, and Azouvi 2012). Whereas performance-based tasks are understood to measure a child's cognitive skills directly in a standardized way, EF questionnaires have been described as measuring the behavioral enactment of EF skills in "everyday" contexts (Gioia et al 2000). Questionnaires that are used with children are typically, though not exclusively, completed by parents and teachers (older children and adolescents may provide self-reports). Questionnaires are presumed to benefit from parent and teachers' opportunities to observe children's behaviors in multiple contexts and are understood to index behaviors over longer spans of time than performance-based tasks are able to assess. EF questionnaires are also appealing because they often require less effort to administer relative to performance-based measures.

The family of Behavioral Rating Inventory of Executive Functions (BRIEF) scales are the most widely used and researched questionnaire measures of EF (Gioia, Espy, and Isquith 2003; Gioia et al. 2002; Isquith et al. 2005; Rabin et al. 2006; Roth et al. 2013). The scales now include preschool, child, and adult versions. The childhood version of the BRIEF, which is commercially available through PAR, includes 86 items that are combined to form eight individual (inhibit, shift, emotional control, initiate, working memory, plan/organize, organization of materials, and monitor) and two higher-order (behavioral regulation and metacognition) scales. Notably, these scales are all norm-referenced which facilitates clinical inferences. Interested readers are referred to two recent narrative reviews that described the ways in which the BRIEF scales have been used to facilitate clinical assessment, as well as to inform treatment planning and evaluation (Isquith, Roth, and Gioia 2013; Isquith et al. 2014).

The Childhood Executive Functioning Inventory (CHEXI) is another example of a questionnaire measure of EF that can be used with children (Thorell et al. 2010; Thorell and Nyberg, 2008).

Although not as widely used or researched as the BRIEF, the CHEXI is relatively short (26 items), has been translated into multiple languages (i.e., English, Swedish, French, Spanish, Galician and Persian), and most importantly is freely available for wide scale use (see www.chexi.se). Although the CHEXI was designed to measure four dimensions of EF (inhibition, regulation, working memory and planning), empirically two factors (inhibition/regulation and working memory/planning) provide a more parsimonious representations of the items (Catale, Meulemans, and Thorell 2013). Exemplar items for working memory include "has difficulty remembering length instructions" and "when asked to do several things, s/he only remembers the first or the last." Exemplar items for the inhibition scale include "has difficulty holding back his/her activity despite being told to do so" and "has a tendency to do things without first thinking about what could happen."

3.3 Assessment Challenges

3.3.1 Measurement Impurity

One of the most frequently cited challenges of assessing EF is what is known as the measurement impurity problem (Miyake, Emerson, and Friedman 2000). Measurement impurity refers to the idea that there are multiple processes that contribute to individual differences in performance on any EF task. Measurement impurity refers to at least three interrelated ideas.

First, many EF tasks require a combination of so-called executive and non-executive cognitive processes in order to be completed. For example, in the flanker task, which is featured in the NIH Toolbox as a measure of inhibitory control (Bauer and Zelazo 2014), children respond to stimuli that include a central arrow that points to either the left or the right and that is flanked by arrows that point in either the same (congruent) or opposite (incongruent) direction as the central arrow. Children are instructed to touch the button to which the central arrow points. Task performance is based on both the accuracy and speed of children's responses. Children's scores on the flanker task (and others like it) likely reflect a combination of inhibitory control and processing speed (i.e., executive and non-executive processes). To the extent that the resulting scores conflate these two sources of variation, however, they become "impure" measures of inhibitory control.

Second, many EF tasks require multiple executive processes in order to be completed. For example, the hearts and flowers (formerly dots) task has been used to demonstrate developmental differences in both the structure and level of proficiency of EF skills across time, as well as the dependence of EF skills on genetic and neurochemical factors (Davidson et al. 2006; Diamond et al. 2004; Shing et al. 2010). In this task, individuals see pictures of heart or flowers, one at a time, on either the left or right side of the screen. When pictures of hearts appear, individuals are to press a designated key on the keyboard that is on the same side as the stimulus (e.g., heart on left side requires pressing the left key). When pictures of flowers appear, individuals are instructed to press a designated key on the keyboard that is on the opposite side as the stimulus (e.g., flower on right side requires pressing the left key). The task involves three conditions—hearts only, flowers only, and mixed hearts and flower stimuli. Task developers have emphasized that while all three conditions make demands on working memory, the flowers only condition makes unique demands on inhibitory control, while the mixed condition makes unique demands on cognitive flexibility (Brocki and Tillman 2014; Diamond and Wright 2014). This is consistent with the suggestion that there are no "pure" measures of any specific EF skill.

Third, virtually all performance-based EF tasks require some degree of attention, engagement, and willingness on the part of the child to participate. For example, children's observable behaviors during the completion of EF tasks is correlated with their performance on those tasks (Bassett et al. 2012). Moreover, even modest disruptions in children's sleep are associated with poorer performance on EF tasks (Molfese et al. 2013; Vartanian et al. 2014). Individual differences in children's behavior, as well as idiosyncratic factors including mood or fatigue, contribute to their performance on EF assessments and serve as additional sources of measurement impurity.

Thus far, researchers have relied on the use of latent variable models as their primary strategy for addressing concerns about measurement impurity. Although a detailed account of these approaches and their rationale is beyond the scope of this chapter, the basic idea is to administer to multiple EF tasks to children and to use latent variable models to isolate that variation in each task that is shared with other EF tasks (see e.g., Huizinga, Dolan, and van der Molen 2006; Miyake et al. 2000; Wiebe, Espy, and Charak 2008). More recent efforts have begun fitting models that further partition the variation that is shared across EF tasks into that which represents a combination of general (e.g., processes that are shared across inhibitory control, working memory, and cognitive flexibility tasks) and domain specific (i.e., variation that is specific to inhibitory control, working memory, or cognitive flexibility tasks) EF skills (Miyake and Friedman 2012; Schmiedek, Lövdén, and Lindenberger 2014). It is worth noting that all of these approaches implicitly assume that the variation that is shared across a set of EF tasks is indicative of "true" EF competence, whereas the variation that is unique or specific to each task represents multiple sources of variation that jointly contribute to measurement impurity. It is not yet clear whether these are reasonable assumptions and consideration of alternative statistical approaches for attending to measurement impurity remains an active area of research (see Willoughby et al. 2014). It is noteworthy that issues related to measurement impurity have only been considered with respect to performance-based assessments of EF. Although questionnaire based assessments of EF likely suffer from similar problems (i.e., scores reflect individual differences in more than EF abilities), this has not been an area of much empirical study to date.

3.3.2 Ecological Validity

Despite the long history and widespread use of performance-based assessments of EF, researchers have frequently raised concerns about their ecological validity (Anderson 2002; Barkley and Murphy 2010, 2011; Burgess et al. 1998; Chaytor, Schmitter-Edgecombe, and Burr 2006; Kenworthy et al. 2008; Sbordone 2001; Sbordone and Purisch 1996). The essential concern is that performance-based measures (i.e., highly structured EF tasks, completed during a single testing session in a quiet and emotionally neutral setting) do not adequately characterize the actual manifestation of EF skills in "everyday" life. For example, many of the school-based situations in which children presumably engage their EF skills (e.g., competitive interactions with peers at recess or high-stakes test-taking) are characterized by strong emotional or motivational influences. It has been suggested that children's performance on traditional "cool" performance-based measures may bear little resemblance to their EF performance in "hot" contexts (see the hot vs cool distinction, chapter 1, section 1.4). Although questionnaire-based assessments of EF have frequently been described as measuring EF behaviors in "everyday contexts" (e.g., Isquith, Gioia, and Espy 2004), their consistently weak associations with performance-based assessments have raised questions about what they actually measure (see section 3.3.3, below).

Ten years ago, Burgess et al. (2006) highlighted the limitations of using traditional performance-based assessments of EF for clinical purposes and emphasized the value of developing a new class of EF assessments that better approximated real world contexts. The *Multiple Errands Task* (MET) was highlighted as an exemplar measure. The MET required individuals to complete a hypothetical set of shopping tasks following rules that were consistent with real-world context (Shallice and

Burgess 1991). Over the last two decades, the MET has been iteratively developed, including being migrated to virtual reality environments, and has demonstrated acceptable reliability, as well as concurrent and predictive validity (Alderman et al. 2003; Cuberos-Urbano et al. 2013; Dawson et al. 2009; Maeir, Krauss, and Katz 2011; Morrison et al. 2013; Raspelli et al. 2010). More recent tasks that were inspired by the MET include the *Virtual Errands Task* (Law, Logie, and Pearson 2006; Logie, Trawley, and Law 2011; McGeorge et al. 2001), the *Virtual Coffee Task* (Allain et al. 2014), the *Virtual Library Task* (Renison et al. 2012), and the *Kitchen Task* (Berg, Edwards, and King 2012; Rocke et al. 2008). Notably, the *Kitchen Task* was the only one of these functionally-based tasks that was specifically developed for use with children. All of these efforts reflect a broader interest in understanding how technological developments might modernize the assessment of EF in ways that have clear benefits for clinical and educational practice (Lalonde et al. 2013; Parsons et al. 2015). An important direction for future research involves clarifying whether and how the conceptualization of EF skills might change through the use of functionally-based assessments. For example, the children's Kitchen task was described as evaluating "the level of cognitive assistance that children require to complete a challenging functional activity" (Rocke et al. 2008). It is not yet clear to what extent tasks of this sort necessarily measure EF versus correlated processes (i.e., functionally-based assessments may still suffer from measurement impurity problems).

3.3.3 Poor Convergence between Questionnaire and Performance-Based Tasks

The widespread interest in using questionnaires to assess EF was described above. However, the validity of EF questionnaires is predicated on a strong assumption—the items on questionnaires are assumed to represent behavioral manifestations of children's underlying cognitive (EF) skills. Currently, there is limited empirical support for this assumption. In a review of 20 studies that included child and adult samples, Toplak and colleagues reported a median correlation of $r = .19$ between questionnaire and performance-based assessments of EF (Toplak, West, and Stanovich 2013). Moreover, EF questionnaires are often more strongly associated with ratings of other aspects of children's behaviors than they are with performance-based measures of EF (e.g., Catale, Meulemans, and Thorell 2013; Mahone et al. 2002; Mahone and Hoffman 2007), raising the possibility that ratings reflect relatively non-specific evaluations of children, such as how likeable they are. This would be broadly consistent with evidence that adult self-reports of their own EF problems are more strongly correlated with aspects of their personality than performance-based indicators of EF skill (Buchanan 2016).

Despite their poor correspondence with performance-based tasks, questionnaires continue to be advocated as part of a comprehensive assessment of EF because they provide information that complements performance-based measures and that can be useful for treatment planning and evaluation (Isquith, Roth, and Gioia 2013; Isquith et al. 2014). However, at the level of individual children, questionnaire and performance-based assessments of EF often result in discrepant results that are difficult to reconcile (Silver 2014). At the present time, it seems best to conclude that questionnaires and performance-based measures of EF measure different phenomena. Although these methods of assessment may yield complementary data, they certainly do not yield interchangeable data. EF questionnaires index parental and teacher impressions of children's behaviors in every day contexts. It is not clear whether these behaviors necessarily represent manifestations of underlying cognitive skills (behaviors are multiply determined). In contrast, performance-based EF tasks index a child's EF skills under optimal testing conditions and may not be indicative of a child's typical use of those skills in every day contexts.

3.4 Decision Rules for Assessing Executive Functions in Educational Settings

In this final section, we introduce three instances in which educators might be interested in the assessment of EF in children. In each instance, we highlight the motivating question, consider which method of assessment may be most appropriate, and emphasize psychometric issues that should inform the selection of specific instruments. We emphasize that the selection of specific measures of EF should be informed by the broader objectives of the assessment.

3.4.1 Academic Impairments

There are a variety of ways in which EF may contribute to children's academic impairments. Some children's academic difficulties may result from behaviors that are considered "executive" in nature, including poor planning and time management (Langberg, Dvorsky, and Evans 2013). Other students may have a specific impairment in working memory that may undermine their ability to comprehend or apply specific strategies involved in academic instruction (Gathercole and Alloway 2008). Still other children may experience subject-matter (e.g., math-related) or general performance anxiety that undermines their use of specific EF skills and, thereby, impedes their academic progress (Ashcraft and Krause 2007).

If the primary presenting problem involves a child's poor planning or organizational skills in general, questionnaires may be the preferred approach. In contrast, if the primary presenting problem is impairments in working memory or other specific EF skills, performance-based assessments may be the preferred approach. In both cases, instruments that have norm-referenced scores should be prioritized. Norm-referenced scores facilitate inferences about how a child's behavior or cognitive function compares to other children of similar ages. In addition, the selection of specific instruments should prioritize those that have excellent precision of measurement (i.e., test information) in the low ability range. That is, measures that were demonstrated to maximally distinguish between children of low versus average executive function ability should be prioritized. Although it has been relatively rare for EF assessments to be evaluated from this perspective (i.e., delineating differences in measurement prediction as a function of underlying ability), this is the type of information that end-users require for purposes of measure selection (Willoughby, Wirth and Blair 2011).

3.4.2 Differentiated Instruction

Differentiated instruction involves matching instruction to a particular child's needs or level of understanding. It may also include modifying the process of instruction or other aspects of the learning environment. Students who receive differentiated instruction show greater rates of academic improvement (e.g., Connor et al. 2011; Connor et al. 2010).

Although not yet routinely done, differentiated instruction might benefit from considering individual differences in EF skills and/or other cognitive processes. In terms of behavioral indicators of EF, children who are characterized by poor regulation (e.g., easily bored, difficulty persisting in things that are not interesting) may benefit from the receipt of more frequent but shortened periods of instruction or instruction that involves manipulatives. Alternatively, children who are characterized by strong overall EF skills may benefit from more independent learning opportunities or more deductive instructional input.

The key psychometric issue that informs measure selection for differentiated instruction again involves measurement precision. However, in this case, the best measures would have excellent measurement precision along the full spectrum of children's ability. This differs from the original intent of many measures, which were designed to identify impairment in function. Given the focus on differentiating among all children in a classroom (e.g., in the case where different groups receive different types of instruction), norm referenced scoring is less important for assessments that are used to facilitate differentiated instruction.

3.4.3. Intervention and Individual Progress Monitoring

As reviewed in chapter 2, there is mounting evidence that children's earlier EF skills predict their future academic performance, above and beyond earlier levels of academic performance (e.g., McClelland et al. 2014; Ursache, Blair, and Raver 2012). This suggests that schools may benefit from systematic efforts to improve children's EF skills. Doing so requires regular assessments of EF that can be used to evaluate intervention effects or monitor student progress. Given that most of the evidence linking earlier EF to later academics comes from studies that have used performance-based assessments, we focus our attention on this assessment method.

Prepost designs are routinely used to evaluate intervention effects (this is true for both open trials and randomized controlled trials). In prepost designs, children are assessed immediately prior to and following the delivery of an intervention. Prepost designs (and repeated measures designs more generally) make unique demands of EF assessments. First, in order for any observed changes in EF scores to be interpretable, the assessment measure must exhibit longitudinal measurement invariance. This ensures that any differences in scores across time are attributable to true changes in ability and not an artifact of changing measurement. Second, the test-retest reliability of the measure has a direct impact on the extent to which any observed score changes can be attributable to the intervention versus situational variability or measurement error. In situations where individual EF tasks exhibit poor to modest test-retest reliability, educators might consider aggregating children's performance across a battery of tasks in order to obtain a composite score that exhibits improved test-retest reliability (Willoughby, Blair, and Family Life Project 2015). Estimates of test-retest reliability are also useful for constructing indices of minimally detectable change (MDC). MDC values can be used by school personnel as a benchmark that defines the minimal amount of change in EF scores that are not attributable to measurement error. This becomes a minimum amount of change that can be interpreted as meaningful improvement. Third, program evaluation efforts benefit from the selection of assessment tools that have strong precision of measurement across the full range of child ability. This differs from many performance-based measures of EF in early childhood, which typically only measure a relatively narrow range of ability and often demonstrate floor and ceiling effects (Carlson 2005). It is imperative that newer measures that do not suffer from these limitations be used for program evaluation efforts.

While prepost designs are commonly used for the evaluation of small-group and classroom-based interventions, more frequent assessments may be used when evaluating individualized programs. Although progress monitoring tools (including curriculum based assessments) are widely used to evaluate children's ongoing improvements in core academic areas (Hintze, Christ, and Methe 2006), they have not yet been developed for EF. This is an important direction for future research.

3.5 Summary

Over the last 30 years, substantial changes have occurred in the assessment of EF. For example, while EF assessments were initially exclusively conducted with adults, they are now routinely conducted with children; while EF assessments were initially exclusively used in clinical contexts as a cognitive proxy of potential neurological dysfunction involving the frontal lobes, more recently they have been used with typically developing children as an index of healthy neurocognitive development and as a predictor of social and academic success. The expanded conceptualization of EF has resulted in a proliferation of performance-based assessments of EF, as well as the development of questionnaire-based assessments.

Despite their shared intent, questionnaires and performance-based assessments of EF measure different phenomena. While performance-based tasks measure optimal cognitive ability in highly structured testing environments, questionnaires measure behavior in everyday contexts. It is not yet clear that the behaviors that are measured by EF questionnaires are functionally related to underlying EF skills. In light of their differences, the decision about whether to use questionnaire or performance-based assessments should be based on the objectives of the assessment (i.e., whether the presenting problem or area of interest is believed to be primarily behavioral or cognitive in nature). In light of the expanded number of uses of EF assessments, it is also important for test-developers and end-users to consider the specific psychometric properties that are most appropriate for the intended use. Many traditional performance-based measures of EF were designed to detect EF impairments in the low ability level. These tasks are not optimal for differentiating among children across a full range of ability or for monitoring developmental changes in EF skills.

4. Developmental Change in Executive Function

This chapter summarizes developmental changes in executive function (EF) from early childhood through adolescence, with an emphasis on pre-kindergarten (pre-K)–12th grade (for recent reviews of EF development that include infancy and the toddler years, see Carlson et al. 2013; Müller and Kerns 2015). We consider developmental changes in the dimensionality (structure) of EF and in the level or efficiency of EF. A unifying idea is that, although EF undergoes rapid developmental change from pre-K–12th grades, this change likely reflects a combination of quantitative improvements in skill and efficiency as well as qualitative shifts in the ways that EF tasks are solved and/or the ways that EF skills are used.

4.1 Changes in the Structure of EF

We have defined EF narrowly as consisting of cognitive flexibility, working memory, and inhibitory control. These three neurocognitive skills have been understood to reflect partially dissociable constructs that rely on overlapping but distinct neural circuitry and that collectively contribute to goal-directed behaviors. Researchers have relied heavily on factor analytic techniques to inform questions about whether cognitive flexibility, working memory, and inhibitory control represent distinct cognitive processes.

We begin by briefly reviewing three high impact studies that have helped to frame current thinking about the factor structure (i.e., dimensionality) of EF. In a seminal study by Miyake and colleagues (2000), 137 undergraduate students completed 9 performance-based EF tasks, which were intended to represent 3 distinct aspects of EF—shifting (cognitive flexibility), updating (working memory), and inhibition (inhibitory control)—for a total of 3 tasks per construct. A three-factor confirmatory factor analysis (CFA) model provided excellent fit to the observed data, which provided empirical evidence in support of the hypothesis that shifting, updating, and inhibitory control represented correlated but separate cognitive processes. Lehto and colleagues (2003) subsequently administered eight different performance-based tasks to 108 children who were age 8 to 13 years. A three-factor CFA that resembled that used by Miyake and colleagues (2000) again provided excellent fit to the data. The authors interpreted this as evidence that the structure of EF in middle childhood was comparable to that in adulthood. Finally, Wiebe and colleagues (2008) administered 10 performance-based tasks to 243 children who were on average 3.9 years old. A series of CFA models indicated that a one-factor model provided excellent fit to the data; two- and three-factor models did not provide an improvement in model fit. The results of this study gave rise to the idea that EF may be better construed as an undifferentiated set of cognitive skills in early childhood, which subsequently differentiate during the transition to middle childhood. Although this conclusion differed from conventional wisdom at the time, the results of three additional studies, which used a similar analytic approach, that were published soon after Wiebe et al. (2008) came to the same conclusion (Hughes et al. 2010; Wiebe et al. 2011; Willoughby, Blair et al. 2010). Collectively, these studies suggested that the cognitive processes implicated in the completion of performance-based EF tasks might undergo developmental reorganization during the transition from early childhood into middle childhood and adolescence.

The studies that were used to infer developmental changes in the structure of EF skills were limited by the use of cross-sectional designs (which could not inform questions about changes in the structure of EF at the level of individual children) and the use of different assessment tools for participants of differing ages. A study by Shing and colleagues was important because it included a common set of assessments that were administered to a sample of children who varied in age (Shing et al. 2010). Shing and colleagues reported that inhibitory control and working memory were not separable factors among children who were 4 to 7 years or 7 to 9.5 years old but were separable among children who were 9.5 to 14.5 years old. Notably, the correlations between inhibitory control and working memory (memory maintenance) factors were reported to be .98, .81, and .32 for the three age groups, respectively. These results provided evidence in support of a differentiation hypothesis. A later analysis of the NIH Toolbox Cognition Battery[9] by Mungas and colleagues (2013) came to similar conclusions regarding the differentiation of cognitive functions for children and adolescents who ranged from age 3 to 15 years. These studies provided additional evidence in support of the suggestion that the structure of EF skills may shift during the transition from early to middle childhood. These empirical results were also in alignment with models of neural development that emphasize experience-dependent neural specialization (e.g., Johnson 2011).

[9] See http://www.healthmeasures.net/explore-measurement-systems/nih-toolbox/intro-to-nih-toolbox/cognition.

Despite the consistency in results across these early studies and their conceptual appeal (changes in the structure of EF skills conforming to models of neural development), a number of more recent studies have reported contradictory results. For example, at least five recent studies that involved preschool-aged children concluded that EF was best characterized by two-factor models in which inhibitory control and working memory were distinguished (Gandolfi et al. 2014; Lerner and Lonigan 2014; Miller et al. 2012; Schoemaker et al. 2012; Usai et al. 2014). Conversely, at least two other recent studies that involved elementary school-aged children concluded that EF was best characterized by a single undifferentiated factor (Brydges et al. 2012; Xu et al. 2013). Finally, in one of the few studies that used a prospective longitudinal design, Lee and colleagues reported that while a two-factor model, which distinguished working memory (updating) from inhibitory control and cognitive flexibility, provided the best fit to data for children 5- to 13-years old, a three-factor model, which distinguished working memory, inhibitory control, and cognitive flexibility, provided the best fit to the data among 15-year-olds (Lee, Bull, and Ho 2013).

These results are difficult to reconcile because individual studies differed along a number of important dimensions including sample characteristics (ascertainment method, sample size, clinical condition, and age distribution); research designs (cross sectional, longitudinal); and measurement characteristics (number of indicators per factor, score distributions, correlations among task scores). The preponderance of studies has lent support to the idea that cognitive flexibility, working memory, and inhibitory control represent separable (but correlated) dimensions of cognitive function in school aged children, adolescents, and adults. What is less clear is whether EF is best conceptualized as an undifferentiated set of skills in early childhood and, if so, when it begins to "fractionate" into dissociable dimensions.

Practically speaking, questions about developmental changes in the structure of EF are likely of more interest to researchers than to educators. If the structure of EF changes over time, this complicates the ability to make clear inferences about developmental changes in the efficiency (improvements) in EF skills (i.e., the interpretation of changes in scores is ambiguous, as it may reflect either changes in ability level or in the structure of tasks). If cognitive flexibility, working memory, and inhibitory control are not differentiated in early childhood, this may have implications for intervention development efforts. For example, rather than focusing on the improvement of specific aspects of EF (e.g., computerized training programs that specifically target improvements in working memory), interventions may be better focused on improving broader aspects of EF (e.g., professional development activities that encourage teachers to use scaffolded instructional strategies).

4.2 Changes in the Level or Efficiency of EF Skills

As noted earlier, the prefrontal cortex (PFC) exhibits a protracted period of change across the first two decades of life, which is correlated with improvements in EF skills (Giedd et al. 1999; Miller and Cohen 2001; Ordaz et al. 2013; Sheridan, et al. 2014; Zhong et al. 2014). Two general approaches have been used to investigate quantitative developmental changes in EF skills across childhood and adolescence. The first, most common approach has involved the use of cross-sectional designs in which a standard set of EF tasks is administered to participants who were recruited into specific age groups. Subsequent between-group (i.e., inter-individual) comparisons provided an indirect means of understanding developmental changes in EF skills across the range of ages considered. The second, less common approach has involved the use of prospective longitudinal designs in which a standard set of EF task(s) is repeatedly administered to the sample participants across multiple assessments. These data facilitate tests of individual differences in developmental change (i.e., inter-individual differences in intra-individual change) and provide a more compelling characterization of changes in EF skills across time.

4.2.1 Evidence from Cross-Sectional Studies

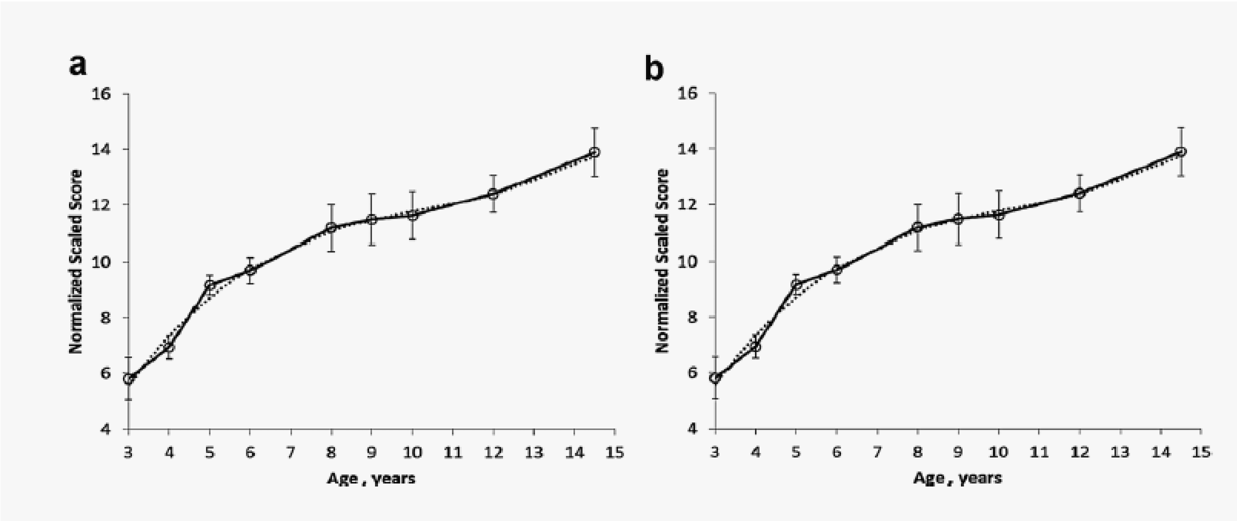
An initial set of cross-sectional studies focused on young children who were generally between 2 and 5 years old. These studies typically recruited children in relatively narrow age bands (e.g., 3.0-3.5 years, 3.5-4.0 years) and would have them all complete the same task. Of interest was the age at which children, on average, transitioned from being unable to being able to successfully complete the task (e.g., Gerardi 2000; Gerstadt, Hong, and Diamond 1994; Jones, Rothbart, and Posner 2003; Kloo et al. 2008). These studies did not emphasize individual differences in EF. Instead, they demonstrated that age-graded changes in EF were evident across early childhood.

Studies that have investigated developmental changes in EF skills in early childhood have typically characterized children's task performance with respect to the accuracy of their responses. In contrast, studies that have investigated developmental changes in EF among school-aged and adolescent-aged participants have often relied on tasks that include accuracy and reaction time metrics. The use of reaction time has facilitated the use of the same tasks over wider ranges of time. A recurring conclusion across many of these studies was that EF skills typically exhibit continued improvement throughout middle childhood and into adolescence (e.g., Becker et al. 1987; Davidson et al. 2006; Gur et al. 2012; Huizinga, Dolan, and van der Molen 2006; Levin et al., 1991; Luciana and Nelson 2002; Luna, et al. 2004; Magar, Phillips, and Hosie 2010; Rebok et al. 1996; Williams, et al. 1999; Zelazo et al. 2013).

An example of the data that result from these sorts of studies is shown in figure 6, which depicts mean level changes in performance as indicated by youth who ranged from 3- to 15-years-old for two EF tasks that are part of the NIH Toolbox Cognition Battery. One of the notable features of the NIH Toolbox Cognition Battery is that it provides scores that combine information about participants' item accuracy and reaction time. This combined scoring approach permits age-based comparisons that span early childhood (minimum age 3 years) through adulthood.

Relatively few studies have formally tested differences in the functional form (i.e., the shape) of change in EF skills across time (see Luna et al. 2004 for an exception). However, doing so has the potential to reveal developmental periods in which improvements in EF skills are either more or less pronounced. For example, the NIH Toolbox Cognition Battery data that are depicted in figure 6 suggest that improvements in EF skills may be more likely to occur in early childhood and adolescence than in middle childhood.

Figure 6. Pediatric data from a cross-sectional validation study on two measures of executive function



Note: Normalized scaled scores from (a) the NIH Toolbox Dimensional Change Card Sort (measure of cognitive flexibility) and (b) the NIH Toolbox Flanker (measure of inhibitory control). The best fitting polynomial model (cubic, $R^2 = .76$) indicates two periods of relatively rapid growth (preschool and early adolescence). Error bars are +/- 2 standard errors.

Source: Adapted with permission from Zelazo et al. (2013). II. NIH Toolbox Cognition Battery (CB): Measuring Executive Function and Attention. *Monographs of the Society for Research in Child Development*, *78*(4). doi: 10.1111/Mono.12039.

4.2.2 Evidence from Longitudinal Studies

A small number of studies have examined correlations of children's performance across two assessments. For example, a recent study demonstrated that EF measures that were collected in middle childhood (age 8) were significantly correlated with the same measures that were administered in early adolescence (age 12), with the resulting implication that the rank-order stability of EF was preserved across an important developmental transition period (Harms et al. 2014). Other researchers have adopted a similar approach and established the continuity of EF skills (or deficits in EF) during the transitions from childhood to adolescence and adolescence into early adulthood (Biederman et al. 2008; Biederman et al. 2007; Boelema et al. 2014; Rebok et al. 1996). Studies that investigate the short-term stability of EF skills implicitly characterize EF as an individual differences variable and demonstrate that individual differences in EF ability are preserved across time. This provides a counterpoint to the historically older practice of identifying the age at which an ability "came online." However, a limitation of short-term correlation studies is that they inform questions only about the rank order stability of EF skills across time. Even studies that report strong associations are uninformative with respect to the amount of actual change that occurred across time (this is further compounded when different measures are used at different ages).

Prospective longitudinal designs in which participants are measured at three or more times using the same measure(s) provide the most compelling approach to characterizing developmental changes in EF across time. To date, relatively few studies have used prospective longitudinal designs to characterize developmental changes in EF, and most of these studies have focused exclusively on relatively short intervals of time across the early childhood period (Clark et al. 2013; Hughes et al. 2010; Wiebe, Sheffield, and Espy 2012; Willoughby et al. 2012). These studies have provided consistent evidence for linear improvements in EF between ages 3 to 6 years, with some evidence that changes may be more pronounced for 3 to 4 versus 4 to 6 years of age.

As has been noted elsewhere (Best, Miller, and Jones 2009), a disproportional amount of research on EF has focused on the early childhood period, despite the fact that much EF development occurs throughout middle childhood and adolescence. We are aware of only one study that used a prospective longitudinal design to evaluate changes in EF across adolescence. In the context of a large Dutch cohort study of preadolescents, Boelema and colleagues (2014) reported developmental changes in multiple aspects of EF over an approximately 8-year period (i.e., performance was measured on assessments that occurred when study participants were approximately 11 and 19 years of age). Although they were able to identify tasks for which developmental changes were least pronounced (i.e., inhibition) and most pronounced (i.e., working memory, focused attention), they were unable to address questions about the functional forms of change given only two repeated assessments.

4.2.3 Integrating Evidence Across Cross-Sectional and Longitudinal Studies and Implications for Educators

A number of authors have attempted to integrate the results of individual studies to provide an aggregate characterization of developmental improvements in EF skills from early childhood into adulthood. For example, Garon and colleagues proposed that a specific *sequence* of changes in basic attention, response inhibition, working memory, and shifting occurred across the first 5 years of life (Garon, Bryson, and Smith 2008; Garon, Smith, and Bryson 2014). Their proposal emphasized a long held view that more rudimentary EF skills, which lay the foundation for the development of more complex skills, emerge early in life. Romine and Reynolds (2005) used a meta-analytic approach to quantitatively characterize the degree of age-related improvements in EF tasks from 5 to 22 years of age. Medium- to large-sized differences were evident from age 5 to 22 years, with some evidence that changes were more pronounced between 5 to 11 than 11 to 22 years (the aggregate Cohen *d* effect sizes were 1.2, 0.9, 0.5, .03, and 0.6 for participants in the 5- to 8- , 8- to 11-, 11- to 14-, 14- to 17-, and 17- to 22-year-old age groups, respectively). Finally, adopting a more qualitative approach, De Luca and Leventer (2008) proposed a set of age-typical trajectories of multiple aspects of EF from 4 to 72 years of age. Their summary also emphasized the differential time course of specific EF skills with some reaching "mature function" as early as middle childhood (cognitive flexibility), others in adolescence (inhibitory control and affective decision making), and others in early adulthood (goal-setting and problem solving).

Over the last 30 years, we have accumulated substantial and irrefutable evidence that children and adolescents exhibit nearly continuous improvements in their EF skills prior to and throughout their educational careers. Given evidence that EF skills uniquely contribute to learning-related outcomes and academic achievement, an important question for educators is how best to facilitate the progression of EF skills in individual children, as well as how to best structure school experiences in ways that leverage these ongoing improvements in EF skills. For example, it may be valuable to consider ways in which the existing academic curricula could be modified to explicitly promote EF-related improvements. Similarly, efforts to tailor instructional approaches to a child's individual need have the potential to improve their EF skills (e.g., Connor et al. 2010).

More generally, the existence of developmental periods during which normative improvements in EF skills are more typical or more rapid (e.g., during early childhood and adolescence), may have implications for intervention. One line of reasoning suggests that developmental periods in which change is most evident represent a particularly appropriate time for EF-related interventions (e.g., the neural substrates that support the development of EF may be especially malleable during these time periods). An alternative line of reasoning suggests that interventions should occur during those periods in which normative changes are less evident. This may recast these periods of less pronounced change as opportunities to facilitate "catch up" among children who did not make earlier expected EF gains.

Despite the consistency in evidence that EF skills continue to improve from early childhood through adolescence, what is less clear is how best to interpret these improvements. Although the tendency has been to characterize quantitative improvements in EF performance as reflecting increased efficiencies in the neural networks that support EF skills, these improvements likely also reflect qualitative changes in the strategies that children use to solve EF tasks. For example, Chevalier and colleagues have published a series of studies in which they manipulated traditional EF tasks in ways that revealed shifts in children's strategy use from reactive to proactive control (Chevalier, Huber et al. 2013; Chevalier, Wiebe et al. 2011). Reactive control strategies involve the engagement of EF on an "as-needed" basis, whereas proactive control strategies involve the engagement of EF on the basis of their anticipated need. Chevalier and colleagues' research suggests that an initial shift from reactive to proactive control occurs somewhere between the ages of 5 and 10 years.

Consideration of stage-like transitions in the use of EF can have implications for educators. For example, the transition from using EF skills on an 'as needed', reactive basis towards using them for an anticipated need may indicate a period of time in which children begin to benefit from efforts to improve their meta-cognitive skills. Moreover, the period of time in which children shift from using EF skills to solve externally to internally initiated goals may correspond to the transition in which children become more self-regulated learners. Consideration of stage-like transitions in the use or function of EF skills may signify periods in which specific interventions (e.g., metacognitive reading strategies) are differentially efficacious. Of course, there will be individual differences in the rates at which these stage-like transitions occur.

4.3 Summary

Developmental changes in EF can be understood in terms of changes in the structure or organization of EF skills as well as changes in the level or efficiency of EF skills. In terms of their structure, there is consistent evidence that cognitive flexibility, working memory, and inhibitory control represent dissociable but correlated processes. What is unclear is how early in development these processes are distinct.

With respect to level or efficiency, EF skills undergo large and continuous improvements from early childhood through adolescence. However, much of what is known is derived from studies that used cross-sectional designs and relied on single tasks (not constructs) as outcomes. Future studies will benefit from a greater reliance on prospective longitudinal designs and the use of assessment tools that are appropriate for a wide age range to provide stronger tests of these questions. A recurring idea is that EF develops in a hierarchical manner, such that the more complex forms of behavior that depend on EF skills (e.g., planning, self-monitoring) and are characteristic of adolescence are preceded by, and depend upon, more rudimentary skills that develop in early childhood. There are some indications that EF skills may develop more rapidly during some developmental periods (i.e., early childhood and adolescence) than others (i.e., middle childhood, early adulthood). This raises questions about whether interventions are differentially effective depending on when in development they are delivered, which is an important area for future research. Most studies that have focused on the development of EF skills have characterized these changes as relatively smooth and continuous improvements across a period of time. Although useful, this characterization risks obscuring more stage-like shifts in the ways in which EF tasks are solved, as well as the ways in which EF skills facilitate goal directed behaviors. Attending to both quantitative and qualitative aspects of change in EF may inform thinking about the design and evaluation of interventions.

5. Individual Differences in Executive Function Development

Because executive function (EF) and associated neural circuitry develop gradually, individuals can differ substantially in the rate at which these cognitive skills grow and change throughout childhood. Individual differences in EF are associated with temperament, with the presence or absence of other cognitive abilities that are related to EF, and to a small extent with genetic background. Individual differences in EF, however, are primarily attributable to aspects of experience in childhood, especially the socioeconomic conditions in which children are reared and differences in parental and out-of-home care that children receive, as well as differences in cultural beliefs and practices in families and communities. The purpose of this chapter is to review some of the evidence on individual differences in EF and consider implications of this research for understanding variation in EF, particularly in early childhood as children are approaching school age and getting ready to enter kindergarten.

5.1 Temperament and Executive Function

EF can be assessed directly in late infancy using what is known as a delayed-response paradigm, such as the A-not-B task, in which the infant must keep the location of a hidden object in mind and respond flexibly (Marcovitch and Zelazo 2009; see Müller and Kerns 2015, for review). However, tasks explicitly designed to assess complex EF skills often rely on verbal instructions and cannot be administered until age 2 or 3 years (Carlson 2005; see Gandolfi et al. 2014 and Mulder et al. 2014 for comprehensive discussion of the age at which conventional measures of EF can be administered).

Research on temperament, however, provides a useful framework for describing the early development of individual differences in self-regulation and EF-like behaviors. Research on temperament has shown that the construct is best described by three general dimensions of behavior (Derryberry and Rothbart 1988; Rothbart and Ahadi 1994): namely, activity level and approach, referred to as surgency/extraversion; fear and withdrawal, referred to as negative affectivity; and the emerging ability to control the focus of attention and inhibit automatic responses to stimulation, referred to as *effortful control* (EC). In research on temperament, EC is often treated as analogous to

EF. As noted earlier, however, EC is differentiated from EF in that it refers to a relatively stable temperamental predisposition to use EF to control attention, emotion, and approach/withdrawal tendencies. EF, in contrast, specifically refers to a set of neurocognitive information processing skills that are active in response to specific situational cues and goals (Liew 2012; Sulik et al. in 2015; Zhou et al. 2012).

Although clearly differentiated, EF and EC are united in their relation to what can be considered a central element of both, in particular the ability to control attention and behavior in the face of interfering or competing information, referred to as executive attention (Posner and Rothbart 2000). Executive attention is distinct from more automatic alerting and orienting responses to stimulation (Petersen and Posner 2012). Executive attention is the aspect of attention that is sensitive to conflicting information, such as when something unexpected occurs, or when something that is expected does not occur. Executive attention is understood to rapidly signal the need for increased intentional control of behavior through EF. As such, executive attention can be considered an indicator of the tendency to engage EF as well as an indicator of the temperamental predisposition to EC.

5.2 Individual Differences in Executive Function Associated With Cognitive Ability, Sex, and Genes

Individual differences in EF are also associated with aspects of cognition such as theory of mind (Carlson, Mandell, and Williams 2004) and language comprehension (Just and Carpenter 1992). In research on theory of mind, as well as social development more generally, developmental psychologists have examined whether advances in EF precede the ability to take the perspective of another person or whether increases in social perspective taking precede and set the stage for advances in EF. At least two longitudinal studies (Carlson et al. 2004; Hughes and Ensor 2007) have addressed this question with children between the ages of 2 and 4. Both found evidence that EF predicts later social perspective taking but not vice versa. Associations between EF, particularly working memory, and language comprehension, are well documented, primarily in adults (Daneman and Merikle 1996) as well as in early childhood. In two longitudinal studies, oral language comprehension was reciprocally related to EF (Fuhs and Day 2011; Fuhs et al. 2014). Associations between language development and EF are also seen in research on bilingualism. In several studies, children growing up in homes in which they are exposed to two languages have been shown to have better EF, particularly the inhibitory control dimension (e.g., Bialystok 2010; Bialystok and Martin 2004; Carlson and Meltzoff 2008).

Research on sex differences in EF indicates few differences in direct assessments, but when differences are found, they are small and usually favor females (e.g., Bjorklund and Kipp 1996; Carlson and Moses 2001; Isquith, Gioia, and Espy 2004; Kalkut et al. 2009; Kochanska et al. 1996; Wiebe, Espy, and Charak 2008; Zelazo et al. 2013).

Research on individual differences in EF associated with genes has focused most specifically on working memory and on genes associated with the activity of dopamine in the brain (Barnes et al. 2011; Tunbridge, Harrison, and Weinberger 2006). As noted in chapter 1, dopamine is important for neural activity throughout the brain, including the prefrontal cortex (PFC), and there are numerous genes that influence how sensitive one is to the amount of dopamine in the brain (Frank and Fossella 2011). Examinations of genes related to the activity of dopamine and the catecholamine norepinephrine have tended to demonstrate that higher levels of these neurotransmitters (through less efficient breakdown or reuptake) are associated with increased neural activity in PFC in response to EF tasks (Mier, Kirsch, and Meyer-Lindenberg 2010). Genes associated with greater availability of these neurotransmitters are also associated with better EF skills—at least up to a point. Given that neural activity in PFC is sensitive to levels of dopamine and norepinephrine in an inverted U-shaped curve (described in detail in section 1.5), one should take into account context when examining genes affecting sensitivity to dopamine and norepinephrine (Cools and D'Esposito 2011; Dickinson and Elvevag 2009). Specifically, studies demonstrate that versions of genes associated with increased sensitivity to catecholamines are beneficial for EF when resting levels are low (indicating that the individual is in a relaxed, calm state) but detrimental to EF when resting levels are high (Mattay et al. 2003; Qin et al. 2012). Furthermore, most of the research on genes and EF has been conducted with adults. Findings can likely be generalized to children, but this remains to be clearly demonstrated.

The above example highlights a central point in the literature on genes and EF, i.e., the need to take into account context, particularly educational context, when examining relations of genes to EF. The theories of differential susceptibility (Belsky and Pluess 2009), biological embedding of experience (Boyce and Ellis 2005), and experiential canalization (Blair and Raver 2012) all clearly specify that the relations of specific genes to many aspects of behavior, including EF, are likely to vary by context (Blair 2010). Implications for education from this research are that children who are the most deleteriously affected by low quality classroom and educational experiences may be the ones who show the most benefit from and responsiveness to high-quality classroom environments and instruction. The phenomenon of differential susceptibility is well established (Belsky and Pluess 2009). There have, however, been relatively few applications to educational topics. Those that are currently available relate to aspects of early care experience, namely parenting quality and childcare quality, to later educational outcomes. In one analysis (Pluess and Belsky 2010), negative emotionality as reported by the mother at child age 6 months—an indicator for genes associated with increased sensitivity to stress, among other things—interacted with the quality of parenting that the child received from birth through school entry (assessed at 6, 15, 24, 36, and 54 months). For children with high levels of negative emotionality and low-quality early parental care, math, reading, and vocabulary skills were much lower than they were in children with low negative emotionality but also receiving low-quality care. Among children receiving high-quality parental care, however, children with high negative emotionality were no different from children with low negative emotionality. And in fact, children with high negative emotionality in infancy receiving high-quality care had the lowest levels of behavior problems and conflict with teachers.

Clear expectations for the relation of specific genes to EF are particularly important given that behavior genetic analyses using samples of monozygotic and dizygotic twins, in which genetic contributions to behavior are implied rather than measured directly, indicate that EF in school age children and young adults is highly heritable (Engelhardt et al. 2015; Friedman et al. 2008). Heritability is sometimes misinterpreted as meaning that a given characteristic or behavior is fixed and not influenced by the environment. However, a characteristic can be highly heritable and still be strongly influenced by experience (Tucker-Drob et al. 2011).

5.3 Individual Differences in Executive Function Associated With Experience

As with many aspects of children's development, individual differences in EF are also associated with the quality of early caregiving (Bernier et al. 2012; Geoffroy et al. 2010). Early care and the initial relationship with the primary caregiver are essential for the development of basic skills to regulate attention and emotion that form the foundation for learning and school readiness. Combined, these skills provide the foundation for the development of more mature and more intentional forms of self-regulation such as EF that children require when starting school (Kopp 1989).

Parenting is a complex construct composed of distinct aspects, including support for autonomy, positive regard, animation, detachment, and intrusiveness, among other characteristics. These characteristics can be grouped into general positive and negative factors, and these general positive and negative aspects of parenting are related to variation in EF in early childhood (Blair et al. 2011) and adolescence (Evans et al. 2007). Studies have also examined specific aspects of parenting behavior and have shown that support for autonomy is associated with individual differences in EF in young children over and above more general dimensions of positivity (Bernier, Carlson, and Whipple 2010).

The neurobiology of EF highlights the importance of early caregiving. Early caregiving has been shown in human and animal models to influence the development of the central and autonomic nervous systems and the stress response (Hostinar, Sullivan, and Gunnar 2013) in ways that are expected to directly influence the development of EF. This influence is understood to predispose the developing child either toward a tendency to engage EF or toward more reactive, less intentional responses to stimulation, such as a high level of emotional reactivity (Blair and Raver 2012). This hypothesized developmental process is highly relevant to the experience of children in poverty and may help to explain individual differences in EF and in school readiness and early educational outcomes associated with poverty status. The context of poverty is frequently characterized by household chaos, stress, and instability in parental care. High levels of psychosocial and physical disadvantage in the home are understood to increase stress to what can be considered "toxic" levels, meaning that physiological stress response systems adapt by maintaining high resting levels and, thereby, altering brain development and behavior in ways that are conducive to functioning in such high stress contexts, but at the expense of functioning in lower stress contexts. This process is relevant to both children and their caregivers. A growing number of studies with children and families in poverty have shown that levels of stress in the home are associated with lower levels of parenting quality and increases in resting stress response physiology in children (Evans 2003) and, through parenting and stress, with lower levels of EF in childhood (Blair et al. 2011; Evans and

Schamberg 2009). Importantly, this understanding of the relation of stress to the development of EF does not indicate that a stressful beginning invariably leads to later problems with EF, nor does it indicate that stress is uniformly bad for development (Parker and Maestripieri 2011).

Finally, given the role of early parenting and care in the development of self-regulation and EF, researchers have recently turned their attention to the study of EF in children's caregivers, including teachers as well as parents. Although a relatively recent area of inquiry, this growing literature indicates that parental EF is relevant to the type of parenting that adults provide young children (Bridgett et al. 2015), which affects the development of EF in young children (e.g., Cuevas et al. 2014; Deater-Deckard 2014). Further inquiry in this area of research will help to address questions about the mechanisms of the intergenerational transmission of EF as well as information on the malleability of EF.

5.4 Summary

Individual differences in EF are to some extent associated with characteristics of individuals, such as temperament, genes, and other cognitive skills. There is some evidence for the presence of EF skills in infancy, and the study of temperament in infancy provides some basis for understanding early influences on the development of EF. Numerous studies, primarily with adult populations, examining the EF of working memory, have found that genes associated with increased availability in the brain of the neurotransmitters dopamine and norepinephrine have small but beneficial effects on EF. Individual differences in EF, however, are primarily associated with the environment in which the child is situated. That is, the contexts in which children are growing and developing are larger influences on EF. Stressful early experience and low quality of early parental care, for example, can lead to reduced early learning opportunities and increases in stress hormones that interfere with EF development. In some instances, environmental influences and individual characteristics such as genes interact to influence EF development. One important direction for future research on EF and education is to consider the interaction between the individual characteristics of children, including genes, and specific aspects of the classroom and learning environment.

6. Malleability of Executive Function

There is strong interest in the malleability and, hence, trainability of executive function (EF) skills in children. Given associations of EF with a wide variety of developmental outcomes, particularly educational outcomes, and the protracted development of brain circuitry associated with EF, EF training might hold substantial educational benefit. The literature on EF provides a number of examples of effective approaches to increasing EF, including specific types of educational practices and both direct and indirect approaches to improving EF. Three illustrative examples indicate the range of approaches that have been examined. The first study, perhaps the first of its kind with young children, demonstrated in 4- and 6-year-olds (N=25 per group) that 5 days of practice on game-like tasks designed to exercise attention and EF was associated with improvements on a measure of fluid reasoning and with a more mature pattern of electroencephalography (EEG) activity in response to an EF task in the experimental relative to the control group (Rueda et al. 2005). A later study (Mackey et al. 2011) used commercially available computerized and noncomputerized games and found that game use was associated with significant increases fluid reasoning and speed of processing in 7- and 9-year-old children (N=28) from low socioeconomic status (SES) homes. Finally, a third exemplary study utilized an approach involving parent training, focused on the development of selective attention (^Neville et al. 2013)[10] in preschoolers from low-income homes (N=141) and found that the program was effective in improving children's neural response to a selective auditory attention task and also with increases in fluid reasoning relative to an active control condition.

6.1 Educational Practices Designed to Promote Executive Function As a Means to Promote Academic Abilities

Research on early educational practices designed to enhance child learning and development through a focus on EF has grown substantially over the past two decades. The efficacy of several programs–primarily in pre-kindergarten (pre-K) but also in kindergarten and the elementary grades–has been

---

[10] Citations with an ^ reflect publications reporting findings from experimental studies that were examined by the What Works Clearinghouse (http://ies.ed.gov/ncee/wwc/) and that, as of May 2016, met What Works Clearinghouse's evidence standards without reservations.

demonstrated in evaluations using randomized controlled trials (RCTs) (see Diamond and Lee 2011 for review). Some of these programs were designed as comprehensive curricula, while others were designed to supplement existing curricula and approaches. There are also examples of direct, targeted approaches to supplement existing practice in which children engage in game-like activities designed to exercise EF.

The current focus on EF in innovative comprehensive early childhood education programs is best understood in relation to classic early intervention research such as the Abecedarian Project and Perry Preschool Project. Those projects focused on IQ as a primary outcome and mechanism of program effects on academic achievement, clearly demonstrating the capacity of early childhood education to support the school readiness and academic achievement of children in poverty. With the growth of research on EF and self-regulation as an aspect of school readiness and educational achievement, the focus in early education programs shifted to address these skills. As noted in chapter 3, relations between the development of EF and the development of language and math ability are recursive. As such, early education approaches that seek to promote children's academic abilities while simultaneously focusing on EF are highly likely to foster school readiness and academic ability in the early elementary grades.

An example of a comprehensive approach to the education of young children that focuses on early academic learning through the mechanism of EF is the Tools of the Mind program (Bodrova and Leong 2007). Tools of the Mind blends teacher-led scaffolding of a comprehensive curriculum of early literacy, mathematics, and science activities with child-directed activities and structured sociodramatic play. The program also includes the use of specific tactics to support EF and learning in young children. There have been several evaluations of Tools of the Mind, but the results are mixed. An early RCT evaluation with 147 children in subsidized pre-K programs found that Tools of the Mind improved EF ([#]Diamond et al. 2007), with limited and specific effects on aspects of child language development and academic outcomes ([*]Barnett et al. 2008).[11] A subsequent evaluation of the preschool version of the program in a large-scale cluster RCT with a predominantly middle-income sample of 794 preschool children in 60 classrooms found no effects of Tools of the Mind

[11] Citations with an * reflect publications reporting findings from experimental studies that were examined by the What Works Clearinghouse (http://ies.ed.gov/ncee/wwc/) and that, as of May 2016, met What Works Clearinghouse's group design standards with reservations.

on any aspect of children's development, including EF and language, literacy, and math outcomes (Wilson and Farran 2012). A recent large sample cluster RCT evaluation of the kindergarten version of Tools of the Mind (729 children in 79 classrooms in 29 schools in 12 school districts) found that the program was effective in the sample overall in improving EF (*d* =.11) and academic outcomes, including math (*d* = .14) and reading (*d* = .07), as well as improving the ability to control attention in the context of emotional stimulation (*d* = .10) (Blair and Raver 2014). Notably, effects on EF (*d* = .50), attention control, (*d* = .80), reasoning ability (*d* = .51), and vocabulary (*d* = .42) were large in high-poverty schools, those in which 75 percent or more of the students are eligible for free- or reduced-price lunch. Finally, results from a cluster RCT of pre-K Tools of the Mind with children in subsidized care at two sites, most of whom were predominantly Spanish-speaking English language learners (ELLs), indicate no effects at one site and substantial effects (*d* = ~.50) at the other on measures of EF, mathematics, and early literacy ability administered in English and in Spanish for children who were ELLs (Blair et al. under review).

Additional evidence of the effect of comprehensive early education on children's language, literacy, and mathematics learning as well as EF is also found in a large-scale evaluation (79 schools, 250 classrooms, 2,108 children) of a comprehensive language and mathematics pre-K program in Boston ([#]Weiland and Yoshikawa 2013). Using a regression discontinuity design, the analysis demonstrated that the combination of the Opening the World of Learning (Schickedanz and Dickinson 2005) language and literacy curriculum and the Building Blocks (^Clements and Sarama 2007) mathematics curriculum resulted in substantial gains (*ES*=.44-.62) on math and literacy outcomes and small to moderate gains on EF and emotion regulation measures (*ES*=.11-.21). Similar to the RCT evaluation of the kindergarten version of Tools of the Mind, gains in EF were larger (*ES*=.33) and in this instance specific to children in high-poverty schools, as indicated by percent of students eligible for free- or reduced-price lunch.

Examples of educational approaches that supplement existing practices include the Promoting Alternative Thinking Skills (PATHS; Greenberg et al. 1995) program and the Chicago School Readiness Project (CSRP; Raver et al. 2009). Both PATHS and CSRP focus specifically on children's social and emotional development and reduction of behavior problems, with the expectation that improvements in behavior and emotion regulation will benefit EF. The CSRP program is specific to pre-K and includes an adaptation of the Incredible Years program (Webster-Stratton 1998) in combination with providing mental health consultation and regular coaching and support to assist teachers in applying behavioral principles to reducing children's behavior problems. The PATHS program can be used from pre-K through the elementary grades and is implemented by the classroom teacher to increase children's knowledge of emotion and to provide children with strategies to regulate emotion and to solve problems that arise in social interactions with other children.

Evaluations of PATHS on its own or in combination with an efficacious approach to teaching early reading (dialogic reading) in a cluster RCT with children in subsidized pre-K have shown that the program's focus on emotion knowledge, emotion regulation, and social problem solving is effective in increasing aspects of children's social-emotional readiness for school with moderate effect sizes (e.g., *d* =.25) (ˆBierman, Domitrovich et al. 2008). There was also some evidence of small-to-moderate effects of this combined program on the *Dimensional Change Card Sort* (DCCS) (*d* = .20) and an examiner rating of child attention in which EF is implied (*d* = .28) (Bierman, Nix, et al. 2008). No effects were observed on the peg tapping task, backward span task, or walk-a-line task. There was also some evidence that measures in which EF is implied, such as the examiner rating of attention and the walk-a-line task, moderated program effects on print awareness and teacher and observer ratings of social-emotional readiness for school.

The CSRP evaluation, also in subsidized pre-K, included high numbers of children with challenging behaviors at high risk for school difficulty. A cluster RCT with 609 preschool children in 35 Head Start classrooms found large effects on reductions in problem behavior (*d* = .53–.89) (Raver et al. 2009). Additional analyses indicated that the CSRP program also improved children's EF and academic skills, with moderate to large effects (*d* = .20–.63). Mediation analysis indicated that the program-related increases in EF accounted in part for program-related increases in academic outcomes at the end of the Head Start year, including vocabulary, letter knowledge, and mathematics (Raver et al. 2011).

The moderate to large effects in efficacy trials seen for PATHS and the CSRP are in contrast to smaller effects seen in a large-scale (*N* = 2,200 students) cluster RCT evaluations of these programs in Head Start preschool programs (*d* = .1–.2; Morris et al. 2014). This demonstration project, known as Head Start CARES, also evaluated the play-based component of the Tools of the Mind preschool program as a classroom "add-on" and found no effects of this component on any aspects of children's school readiness, including EF. These findings indicate that attempts to take successful programs to scale can produce some positive benefits for children but that these benefits may not be as large as those seen in smaller scale efficacy trials.

Two studies have evaluated the efficacy of EF training through specific sets of adult-led, game-like classroom activities with preschoolers. These activities include typical children's games involving inhibitory control, cognitive flexibility, and working memory, similar to Simon Says and Red Light, Green Light. An initial evaluation of six activities with 65 preschool children delivered over 16 brief (20-30 minutes) playgroup sessions by a trained adult indicated no main effects of the activities on child EF (Tominey and McClelland 2011). A second evaluation of the activities with 276 children in 14 subsidized pre-K classrooms (Schmitt et al. 2015) found that the activities were associated with small to moderate gains on measures of EF, the DCCS (d = .16) and the Head-Toes-Knees-Shoulders task (d = .32).. In this study, there were strong effects of the intervention on gains in math (d = .44) for the subset of children (N = 88) who were identified as ELL.

6.2 Direct Approaches to the Improvement of Executive Function Without a Focus on Academic Abilities: Working Memory Training

The most extensively researched direct training for enhancing EF focuses specifically on working memory. Much of the research on working memory training has been conducted with young adults but research with young children is steadily increasing. Generally speaking, working memory training involves repeated practice on increasingly challenging versions of a specific type of working memory task with the expectation that performance will improve on that task and similar tasks and that it will also transfer to other types of working memory tasks and to the real world behaviors with which performance on the tasks is associated, such as academic abilities. The research base is largest for the training of visual-spatial working memory, a type of working memory focused on the retention of information about the location of an increasingly large number of sequentially presented stimuli (see Klingberg 2010). Another commonly researched task, the *n*-back task, requires the individual to retain sequentially presented information and continually update that information (Jaeggi et al. 2008).

6.2.1 Near Transfer of Working Memory Training

Research on visual-spatial working memory training and *n*-back training indicates that repeated practice on these types of tasks (approximately 20 sessions of 30+ minutes) in an adaptive computerized videogame-type format (meaning that the difficulty level increases or decreases so that the task is always appropriately challenging to the participant) leads to immediate improvement on the task and to improvements on similar types of working memory tasks. This is "near transfer." The conclusion of several meta-analyses of randomized controlled evaluations of various training programs is that training has moderate to large effects ($d = > .6$) on trained tasks and on near transfer tasks in children and adults (Melby-Lervag and Hulme 2013; Schwaighofer, Fischer, and Bühner 2015; Weicker, Villringer, and Thöne-Otto 2016).

Working memory training with young adults is associated with changes in the brain. The specific nature of changes, however, follows no clear pattern. Some studies demonstrate an increase in neural activity in relevant brain areas following the training and others demonstrate a decrease (Buschkuehl, Jaeggi, and Jonides 2012). Other studies have also demonstrated functional and structural changes in the brain associated with working memory training.

6.2.2 Far Transfer of Working Memory Training

Although studies demonstrating near transfer indicate the efficacy of training, "far transfer," in which the effects of working memory training can be seen in other contexts and in "real world" behaviors with which EF is associated is essential for any potential application of the science of direct training of EF to education. To date, however, findings of far transfer are much less definitive than for near transfer. Several studies have demonstrated that working memory training generalizes to measures of fluid intelligence, with an overall effect size of .25 (see Au et al. 2014, for a meta-analysis). At least three studies, however, have found no effect of working memory training on measures of fluid intelligence or on measures of working memory processes through which fluid intelligence would be enhanced (Chooi and Thompson 2012, Redick et al. 2012; Thompson et al. 2013). It is well established that working memory is important for performance on measures of fluid intelligence (Kyllonen and Christal 1990). It is also well established that fluid intelligence is an excellent predictor of general intelligence, and that general intelligence is an excellent predictor of academic achievement (McGrew and Hessler 1995).

Furthermore, only a limited but growing number of studies have examined transfer of working memory training to academic abilities in children. Perhaps the most definitive study to date included a population-based sample of 452 children with low working memory in first grade in Melbourne, Australia. Children were screened with working memory measures and those scoring in the bottom percentiles were randomly assigned to receive computerized visual-spatial working memory training delivered in 20-25 sessions over 5-7 weeks or to a control condition. Effects of the training on one measure of visual-spatial working memory were observed at 6 and 12 months following the training but not at 24 months. No effects were observed on any other measures of working memory or on academic assessments of math, reading, and spelling (Roberts et al. 2016). These results stand somewhat in contrast to those obtained in a number of similar studies with smaller samples of children (~*N* = 20 to 50 per group). Evaluations of visual-spatial working memory training, for example, have demonstrated far transfer to academic outcomes, some of which have been sustained over time (Holmes and Gathercole 2014; Kuhn and Holling 2014; Söderqvist and Nutley 2015; see Titz and Karbach 2014 for review). These relations suggest that working memory training holds potential promise, however, much remains to be learned about conditions under which such training is or is not effective.

6.2.3 Working Memory Training With Children With Attention Deficit Hyperactivity Disorder

A number of working memory training studies have been completed with children with developmental disorders, such as attention deficit hyperactivity disorder (ADHD). As with the working memory training literature generally, however, conclusions are mixed. One meta-analysis of 12 published studies of a specific training program focused on visual-spatial working memory found that the program was associated with a moderate decrease in inattention difficulties as rated by parents and/or teachers ($d = .47$) which was reduced somewhat at an approximate 2-4 month follow-up ($d = .33$) (Spencer-Smith and Klingberg 2015).

The findings of the Spencer-Smith and Klingberg meta-analysis, however, are called into question somewhat by two meta-analyses that have controlled for whether reporters on child behavior are "blinded," meaning that they are unaware of the child's participation in the treatment or control condition of the study (Cortese et al. 2015; Rapport et al. 2013). One of these (Cortese et al. 2015), analyzed 15 published reports on approximately six working memory and attention training programs with children with ADHD and found an effect on inattention symptoms identical to the analysis of Spencer-Smith and Klingberg (2015). (Notably, several of the published reports included in this analysis overlapped with those included in Spencer-Smith and Klingberg.) This effect was reduced, however, when reporters on inattention were considered as "probably blinded" (d = .33). This analysis also reported substantial effects of cognitive training on visual and verbal working memory of approximately (d = .52). There were no effects of cognitive training on hyperactivity symptoms and no effects on academic outcomes. The second of the two meta-analyses (Rapport et al. 2013), analyzed the findings of 25 published reports of approximately 12 cognitive training programs (again, several of which overlapped with those included in Spencer-Smith and Klingberg.) As with Cortese et al. (2015), this analysis found an effect of training on observer-rated inattention essentially identical to that of Spencer-Smith and Klingberg (2015). Here, however, restriction of the analysis to studies with blinded raters reduced the effect substantially, d = .12, *ns*. This analysis also reported substantial effects of working memory training specifically on objective measures of working memory, d = .63, but no effects of cognitive training on academic outcomes.

Overall, the foregoing review highlights the need to address several methodological shortcomings of EF training studies—for children and adults—to strengthen inference about this potentially efficacious approach to improving EF and academic outcomes. These include problems with the limited range of working memory skills measured, the extent to which the types of working memory training have focused on simple as opposed to complex tasks, and the need for various types of control groups—particularly active control conditions that address relevant alternative variables, such as social interaction and task engagement, which could reasonably be expected to account for any observed effects of training (Shipstead et al. 2014). In addition, few studies have been designed specifically to promote far transfer, for example by training EF skills in a wide range of contexts. Attention to a broader range of skills that would be improved by increases in EF could help to determine the extent to which direct training can be a productive approach to fostering educational outcomes in children.

6.2.4 Training of Inhibitory Control and Cognitive Flexibility

Although working memory training has dominated the scientific research on the malleability of EF, at least two studies have examined the direct training of inhibitory control. For example, one study with 4- to 6-year-old children (N=48) playing computerized inhibitory control games (e.g., involving go/no go types of activities) for 15 minutes per day for 5 weeks found little evidence of effectiveness (Thorrell et al. 2009), while a second (Berkman, Kahn, and Merchant 2014), which used a young adult sample (N=60), found improvement in an inhibitory control task (the Stop-Signal task) following 3 weeks of approximately 10 sessions. In addition, this study found that the improvement in inhibitory control was associated with increased activity in areas of PFC associated with inhibitory control following a cue signaling the need for control. No effects of the training on near or far transfer were examined. The one study to examine training of cognitive flexibility included children, young adults, and older adults (N=56 per group) who completed training using a task-switching procedure. Results confirmed effects of training on switching in all groups and also transfer to working memory and fluid intelligence (Karbach and Kray 2009). A similar study with an adolescent sample (N=80) found effects of training on task switching on indicators of cognitive flexibility with very limited evidence of transfer to other EF tasks. Additional studies examining training of inhibitory control and cognitive flexibility are clearly needed (Karbach and Unger 2014).

6.2.5 Reflection Training

One line of research on training EF has focused not only on providing practice with specific EF skills (such as cognitive flexibility) but also helping children learn to pause momentarily and reflect before responding. For example, in a randomized study by Espinet, Anderson, and Zelazo (2013), children were given the DCCS task, in which they are required to sort pictures, such as a red rabbit first with a blue rabbit (by shape) and then with a red car (by color). Children who failed the DCCS were given a new DCCS (with different shapes and colors) and taught during a brief, 15-minute session to pause before responding, reflect on the hierarchical nature of the task, and formulate higher order rules for responding flexibly. For example, children would receive rules such as, "In the color game, if it's a red rabbit, then it goes here; but in the shape game, that same red rabbit goes there." Children received either reflection training or one of two active control conditions: DCCS practice with no feedback at all, or DCCS practice with only minimal yes/no corrective feedback (i.e., without practice in reflection). Of these three groups, only children who received the reflection training showed significant improvements in performance on a subsequent administration of the DCCS. Reflection-training improvements on the DCCS were substantial, and greater than improvements seen for corrective feedback ($d = 1.04$) and mere practice ($d = 1.18$). Improvements were also evident on other tasks, including a measure of flexible perspective taking, showing transfer. These behavioral changes were accompanied by predictable changes in children's brain activity that suggest more efficient detection of the need for reflection and EF. This research suggests that even very brief (15 minute) interventions targeting high-level skills like reflection and cognitive flexibility are effective, and the corresponding neural changes may reflect use-dependent myelination, dendritic thickening, and synaptic pruning (reduction of connections among neurons that are not used). The trained networks may become more efficient, so reflection and EF occur more automatically and more quickly, providing more time for thoughtful reflection prior to overt action or decision making.

Moriguchi and colleagues (2015) also provided 3- to 5-year-old children with practice on the DCCS, but then had children teach the rules to a puppet. It has long been suggested that best way to really learn something is to teach it (e.g., Gartner et al. 1971), and teaching is arguably a form of reflection training insofar as it demands consideration and reconsideration of what is being taught. Compared to controls, trained children showed considerable improvement in performance on the DCCS along with increased brain activity (oxygenated hemoglobin) in the left lateral parts of PFC.

6.3 Indirect Approaches to the Improvement of Executive Function Without a Focus on Academic Abilities

Several lines of research examine a variety of activities that are designed to improve EF indirectly, including aerobic exercise, contemplative practices, and videogame playing. Although less extensive in some instances than research on direct training, the research base on these approaches suggests that indirect approaches may be highly effective.

6.3.1 Aerobic Exercise as a Means to Improve Executive Function

A growing research literature on physical activity indicates a robust relation between aerobic exercise and EF in children as well as adults. Correlational and within subject designs indicate relations of measures of physical activity and physical fitness in children with behavioral and neurophysiological indicators of EF as well as with academic outcomes (Castelli et al. 2007; Hillman, Castelli, and Buck 2005; Hillman et al. 2009). Controlled studies demonstrate effects of both chronic (over several weeks) and acute (15-20 mins) aerobic activity on multiple aspects of EF in children in the elementary grades (e.g., ˆHillman et al. 2014). There is also some evidence to suggest that aerobic exercise involving some form of cognitive engagement, as in videogames involving exercise (referred to as *exergames*), have a greater effect on EF than do less cognitively engaging forms of exercise (reviewed in Best 2010). Meta-analysis of 19 studies on the effects of acute exercise on EF indicates that the effect size is moderate (d = .52) and does not vary by age, with similar effects in children, adolescents, and young adults (Verburgh et al. 2013). Analysis of five studies examining chronic exercise on EF failed to find a significant overall effect (d = .14), a result that the authors attribute to the small number of studies available for the analysis. No studies, however, have examined the duration of gains associated with acute activity or the transfer of exercise-related gains in EF to academic achievement.

6.3.2 Contemplative Practice as a Means to Improve Executive Function

Research on the effects of contemplative practices on EF includes a variety of practices that can generally be grouped as mindfulness (for reviews see Gallant 2016; Shapiro et al. 2014; Zelazo and Lyons 2012). Mindfulness involves sustained, focused attention on moment-to-moment experience. A number of studies, most with adults, indicate that repeated engagement in mindfulness practices (e.g., paying attention to one's breathing and gently redirecting attention back to one's breathing when the mind wanders) improves performance on measures of EF and emotion regulation (e.g., Baer 2003; Chambers, Yee Lo, and Allan 2007; Grossmann et al. 2004; Heeren, Van Broeck, and Philippot 2009; Tang et al. 2007; Zeidan et al. 2010; Zylowska et al. 2008). For example, in a randomized design, 7 weeks of mindfulness training lessened the interfering effect of negative stimuli on performance of a simple cognitive task. Specifically, adult participants saw emotionally charged pictures, such as a photograph of a bloody car accident, and then while the picture remained visible, heard a tone that was either high-pitched or low-pitched. They were told to ignore the pictures and categorize the tones as quickly and accurately as possible. Compared to an active control group trained in relaxation meditation, mindfulness participants were better able to disengage from the emotional pictures and categorize the tones. Mindfulness training also led to corresponding reductions in skin conductance responses to those stimuli (Ortner, Kilner, and Zelazo 2007). Similar results have been found after a shorter training period (10-15 minutes per day over 5-10 days) in research on integrative body-mind training (IBMT), designed to enhance physiological regulation (heart rate variability, skin conductance) through changes in activity in an area of the neural network that underlies EF, including the anterior cingulate cortex (ACC) (Tang et al. 2009). The ACC is a key structure in the interaction between limbic structures and PFC and is central to the coordination of physiological responses to stimulation (see section 1.5). IBMT also enhances white matter connectivity in the ACC (Tang et al. 2010). As an instance of the potential efficacy of contemplative practice on EF, IBMT is notable in that effects have emerged after very brief periods of training (10-15 minutes over 5 days).

Some U.S. and Canadian schools and preschools are now introducing contemplative practices adapted for use with children (Wisner, Jones, and Gwin 2010). Children's lessons in these programs typically include activities designed to foster self-reflection (e.g., reflection on one's breathing, sensations, emotions, or thoughts) and observation of one's surroundings (e.g., awareness of others, awareness of stimuli in the environment). A growing body of research suggests that these practices are beneficial (e.g., Burke 2010; Biegel et al. 2009) for reducing anxiety in a range of populations, including adolescent outpatients with psychiatric disorders (Biegel et al. 2009); children in dense urban settings (Semple et al. 2010); and typically developing first-, second-, and third-graders ([#]Napoli, Krech, and Holley 2005). Mindfulness practice also appears to reduce depressive symptoms in children and adolescents (Biegel et al. 2009; Liehr and Diaz 2010), including rumination and intrusive thoughts (Mendelson et al. 2010). Reductions in anxiety and depressive symptomatology may be expected to improve EF performance, given the reciprocal interaction between bottom-up and top-down influences discussed previously. There is also preliminary direct evidence that mindfulness training may enhance EF in children, although we need more research to establish the effectiveness of these approaches. No studies to date have examined the duration of training-related gains or the transfer of gains to academic achievement.

6.3.3 Action Videogames as a Means to Improve Executive Function

Researchers have also been examining the effects of action videogame playing on EF. Using randomized designs, researchers have found action videogames (e.g., first-person shooter games) to affect multiple aspects of cognition, including aspects of attention, such as enhanced visual search skill and a faster attentional blink (i.e., the amount of time in milliseconds it takes an individual to register that a stimulus has been presented), as well as faster reaction time and improvements to EF (Bavelier et al. 2012; see also Granic et al. 2014). No studies appear to have examined the duration or transfer of cognitive gains associated with videogame playing. However, one randomized controlled experiment with children with dyslexia found that 12 hours of action videogame playing improved reading ability (phonological decoding of pseudo-words and word text reading) relative to a control group playing non-action games (Franceschini et al. 2013). Meta-analysis of videogame playing on multiple aspects of cognition found small to medium effect sizes on auditory and visual processing and motor skills but no evidence of effects on EF (Powers et al. 2013).

6.4 Summary

A number of programs have shown that high-quality early education can foster EF development. All of these programs have targeted children in preschool or kindergarten. Some have focused more directly on EF and self-regulation, while others have focused on the improvement of emotion regulation and the control of behavior, with evidence of effects on EF. Other, non-academic interventions may also help to improve EF. For example, aerobic exercise, contemplative practices such as mindfulness meditation, and videogame playing can also improve EF. A large body of research examining the direct trainability of EF through repeated practice on EF types of tasks complements such indirect training of EF. This literature, much of which focuses on the training of working memory, shows an increase in working memory on the trained tasks and on tasks similar to the trained tasks. Evaluation of the extent to which direct training generalizes to other cognitive skills and academic achievement, has produced mixed results. Relatively few studies have examined the direct or indirect trainability of other aspects of EF, such as inhibitory control, though studies have found that teaching children to pause and reflect prior to responding improves cognitive flexibility. Overall, the literature on the malleability of EF suggests that training can lead to improvements in performance on the trained tasks, as well as corresponding changes in the brain.

There is a pressing need, however, to definitively address the conditions under which such training might lead to the generalization of trained skills, including gains in academic achievement. Given the close link between EF and progress in school, the prospect that EF training can increase academic achievement is of strong interest.

7. Overall Summary, Directions for Future Research, and Implications for Educational Policy and Practice

As described in this paper, executive function (EF) skills are the set of neurocognitive, attention-regulation skills involved in conscious goal-directed problem solving. These skills include cognitive flexibility, working memory, and inhibitory control, and in "hotter" emotional contexts, they also include the flexible reappraisal of whether to approach or avoid stimuli. This characterization of EF differentiates it clearly from other related constructs, such as stable individual differences in personality or behavior (e.g., effortful control; grit) and the broader construct of self-regulation (which includes both top-down, EF-influenced conscious control and less deliberate forms of regulation). Research on EF and its development during childhood has underscored the importance of these skills for flexible adaptation in a wide range of contexts, and added considerably to our understanding of the construct, resulting in a sharper, more focused definition.[12]

EF skills make it possible to pay attention, keep relevant information in mind, reflect on that information and consider it relative to past knowledge and future goals, inhibit old ways of responding, and flexibly consider new interpretations. These skills are obviously essential for learning and problem solving, and research on EF has established clearly that individual differences in EF are related to school readiness and academic achievement, both concurrently and prospectively, even after controlling for intelligence and prior knowledge. As reviewed, individual differences in EF measured in childhood not only predict academic outcomes, but also predict other important outcomes, including long-term physical and mental health. There is also evidence that children with better EF skills actually learn more (i.e., retain more information) from a given amount of instruction and practice. Together, this research suggests that EF skills, and the reflective processes that underlie them, allow children to learn more easily and effectively.

[12] This chapter summarizes the main findings of this review, outlines future directions for research, and addresses the implications of research on EF for education policy and practice. As such, specific citations upon which findings are based are not restated. For information on the specific research included in this review, please refer back to chapters 1 through 6.

EF skills are also important for managing emotional reactions and social behavior. Children with better EF skills are less likely to display disruptive behavior, and difficulties with EF are associated with learning difficulties and disabilities, as well as a wide range of other conditions, from attention deficit hyperactivity disorder (ADHD) to mathematics anxiety. Whereas difficulty with hot EF is more associated with social and emotional behavior problems (e.g., EBDs), difficulty with cool EF is more associated with poorer academic achievement.

Clearly, school readiness and learning are a function not only of EF skills, but also of prior experience and opportunities for learning as well as many other characteristics (e.g., temperament). EF and learning are subject to a wide range of promotive influences (e.g., autonomy supportive parenting) and inhibitory influences (e.g., prolonged, uncontrollable stress). Compared to national norms, children growing up in poverty often show a lag in the acquisition of EF skills, and it seems likely that poverty often leads to lower academic outcomes, at least in part, because of its effects on EF. There is also evidence that EF interacts reciprocally, over time, with bottom-up influences, such as arousal and stress. These bottom-up influences vary over the course of the day, and can result in both positive and negative cascades. For example, the strong association between childhood stress and lower levels of EF skill is likely reciprocal, in a downward spiral: higher levels of stress in childhood impair EF and EF development, and impaired EF in turn leads to more failures and more stress. There is also evidence, however, that good EF skills can protect against the risk of academic failure associated with poverty and adversity. Efforts targeting the improvement of EF skills in children from disadvantaged environments may lead to beneficial changes in many domains of activity, including social relationships and these may lead, in turn, to further improvement in EF skill.

Recent advances in our characterization of EF have co-occurred with major improvements in the tools available for assessing EF skills reliably and validly. There are now direct behavioral measures of EF with strong psychometric properties, allowing for the repeated assessment of EF across a wide range of ages. These national norm-referenced measures assess EF in ways that map clearly onto relevant neural systems and allow for objective progress monitoring of EF comparable to the progress monitoring of literacy and numeracy.

Research using psychometrically sound, direct behavioral measures of EF has yielded clear evidence that EF skills improve markedly during the preschool period but continues to develop into early adulthood. These age-related improvements correspond to increases in the efficiency and effectiveness of neural circuits involving the prefrontal cortex (PFC) and related regions of the brain. Recent advances in understanding EF and influences on it have been greatly enriched by major advances in neuroscience. The neural correlates of the cognitive skills that characterize EF, particularly working memory, have been extensively studied. This research has yielded information about the neuroanatomy and brain chemistry that underlie EF and confirm the role of EF in coordinating activity throughout the brain. This research has also confirmed the relevance of emotional and motivational influences on EF. In addition, research in neuroscience has provided valuable insight into the extended time course of EF development and the malleability of these aspects of cognition across the lifespan. Periods of particularly rapid improvement in EF skill—the preschool years and the transition to adolescence—co-occur with rapid changes in neural structure and function, and suggest the possibility of sensitive periods during which EF skills may be especially malleable. Research shows that EF skills can be trained across the lifespan, but it is possible that earlier investments in EF skills (at younger ages) may yield larger EF gains.

7.1 EF and Learning

EF provides a valuable lens for looking at the challenges that learners may face in mastering specific academic content, such as those aspects of mathematics and reading that make substantial demands on EF. The distinction between EF and knowledge-based aspects of ability and learning is an important one for education. Both are vitally important, but effective approaches to fostering EF skills are particularly important in the early stages of development because these skills allow children to acquire content knowledge more easily. There are currently some good examples of programs and approaches that are effective in promoting EF skills, reviewed in chapter 6. A growing body of intervention studies has established that the acquisition of EF skills can be enhanced through repeated practice in the process of reflecting upon and using specific EF skills. This research suggests that it is important to keep children motivated to practice EF skills and to challenge those skills continually using a graduated series of exercises that vary in difficulty. Much more work is needed, however, to develop and refine promising approaches and to extend these programs to the later elementary and secondary grades. Although the acquisition of EF skills may be especially important in early childhood, these skills continue to be necessary for learning and adaptation across the lifespan. To date, programs focusing on EF in education have been developed primarily for early childhood. However, the principles on which these programs are based also apply to learning and achievement throughout the elementary and secondary grades. An important direction for future research is to develop programs to foster EF that are applicable throughout the school years.

A related point is the need for continued research on the measurement of EF skills and on the typical course of EF development in childhood. As reviewed in chapter 5, although there are increasingly well-established measures of EF appropriate for longitudinal use, ongoing psychometric and longitudinal developmental research is needed. A central goal of this research will be to develop measures that can be used in formative assessments of school-based programs designed to foster self-regulation. This is highly relevant to the development and refinement of programs for children with or at risk for specific learning disabilities and other developmental disorders that interfere with learning, including ADHD and EBDs. Assessment of EF prior to kindergarten and during the school years would provide for more rapid detection of potential EF difficulties, potentially leading to earlier and more effective intervention and remediation. In addition, however, information about developmental and individual differences in EF may support the tailoring of individual and classroom-based instruction, as when teachers scaffold children's EF skills when introducing new concepts.

7.2 Topics for Future Research

Despite the enormous advances in our understanding of EF and its development, many important questions remain unanswered. In this section, we highlight just a few of the topics that require additional research. We conclude with a number of implications for educational policy and instructional practice.

7.2.1. Transfer

Although there is considerable evidence that EF skills can be trained, and that the benefits of this training extend to tasks that are similar to the ones used during training (near transfer), there is less evidence that trained skills transfer to behavior on less similar non-trained tasks (far transfer). Few intervention studies have been designed specifically to promote far transfer, including far transfer of trained EF skills to academic achievement. Future research may explore the benefits of training EF skills in a wide range of contexts, including in the context of acquiring academic skills, and promoting transfer to specific contexts via the use of techniques such as fading of visual cues (e.g., Salomon and Perkins 1989). For example, future research may investigate how the likelihood of transfer varies as a function of the frequency and duration of training, and whether transfer to academic achievement is promoted by "embedding" EF training into curricular lessons on math, reading, and other academic areas.

7.2.2 EF and Individualized Approaches to Education

Based on what is known about sensitive periods for other aspects of neural function, it seems likely that there are sensitive periods for acquiring EF skills, but this remains difficult to determine. Future research might usefully examine whether the potency of particular interventions varies as a function of age, considering, for example, whether particular EF interventions are especially effective during the preschool years and around the transition to adolescence, compared to the years in between. This research might also consider the development and deployment of interventions in light of developmental changes in the efficiency of EF skills and changes in strategy use. During periods of improving efficiency, interventions that focus on repeated practice may be optimal. During periods of improving strategy, interventions that focus on new approaches (e.g., reflection training) may be optimal. Finally, interventions might be strategically timed to provide a boost in EF skills prior to key transitions (e.g., pre-K intervention to improve transition to kindergarten; elementary intervention to improve transition to middle; high school intervention to improve transition to workforce/college).

A related set of questions concerns how best to facilitate EF development at different ages and for different children. Different interventions may be more or less effective for individuals with different levels of EF skill, where effectiveness is measured not only in terms of improvements in EF skills but also in terms of transfer to learning and classroom behavior.

7.2.3 Developing the Research Base on the Reciprocal Relation between EF and Learning

Although there is a strong association between EF and learning, much more information is needed. Much of the research base is correlational, and research using designs that allow stronger causal inferences are needed. As well, much of the research base on the relation between EF and learning in school has focused on school readiness and on the early elementary grades. Research examining the relation of EF to learning at all educational levels is needed. Much more information is needed on exactly how EF interacts with learning at different periods in development and in different contexts.

Further information is also needed on the role that EF plays in supporting the transfer of learning—in the generalization of what is learned to new contexts. A better understanding of how EF contributes to learning and generalization, and how difficulties with EF interfere with learning, may lead to refinements in curricula and instructional style. This is true at the level of the classroom, but may also support individualized education programs (IEPs) for students with disabilities and a more universal personalization of learning to meet individual children's needs. Individual and developmental differences in EF may help inform selection of optimal instructional styles (e.g., more concrete, practice-based approaches vs. more abstract, reasoning-based approaches that place heavy demands on EF skills).

As noted, EF training can also be embedded into traditional content-based instruction, and it will be important to determine to what extent specific curricular approaches and/or instructional styles may affect EF development itself, with potential synergistic effects over time (e.g., see Grammer, Coffman, and Ornstein 2013, for work on teaching memory-relevant language during science instruction).

7.2.4 The Role of Stress in EF and Learning

One of the key insights that research on EF has provided is that EF interacts with more bottom-up processes such as arousal, motivation, and stress. One way in which EF appears to be related to learning is through the management of stress, including stress that results from the complexity and uncertainty inherent in learning new material. Much more research is needed to address the specific ways in which stress is related to EF and to learning in the school context. Extant research suggests that a moderate amount of stress, psychologically and physiologically, facilitates EF and its application to novel information and contexts. This basic aspect of research on EF requires translation into educational applications. For example, can educational approaches be tailored in ways that optimize EF and learning for individual students? And can physiological indicators of a moderate response to stress be incorporated in the evaluation of novel, individualized approaches to teaching? There is strong interest in the potential applications of neuroscience to education. Research on stress, EF, and learning provides one important avenue for this application.

7.2.5 Resolving Discrepancies Between Questionnaire and Performance-Based Assessments

Over the last decade, a number of questionnaires were introduced to obtain teacher and parent ratings of EF, in part to address concerns that performance-based assessments may not adequately characterize EF skills in "everyday" contexts. Although questionnaire-based assessments have proven to be useful for both intervention planning and evaluation, they measure individual differences in behavior that are largely unrelated to performance-based metrics. The poor correspondence between questionnaire and performance-based assessments contradicts conventional wisdom in psychological measurement, which has contended that the use of multiple methods and informants results in improved measurement of the construct of interest (Campbell and Fiske 1959). At a more practical level, educators and researchers, alike, have been provided with little guidance about how to resolve discrepancies that may arise between questionnaire and performance-based assessments of EF.

Future research would benefit from a more systematic treatment of discrepancies between questionnaire and performance-based assessments of EF. As described in chapters 1 and 2, EF can be studied at multiple levels of analysis. The poor correspondence between questionnaire and performance-based assessments can be construed as evidence of the loose association between behavioral and cognitive levels of analysis, and/or as evidence of the subjectivity and bias inherent in parent- and teacher ratings. Future research should identify for whom or under what conditions questionnaire and performance-based assessments are in agreement. Future research might also consider a range of statistical approaches that make joint use of questionnaire and performance-based measures but that do not assume that they are interchangeable indicators of the same underlying construct (e.g., statistical interactions; person-based profiling methods). Finally, future research would benefit from using neuroimaging and neurophysiological measurement to help "ground" our understanding of what performance-based and questionnaire-based assessments of EF are actually measuring. That is, it will be important to determine the extent to which performance-based and questionnaire-based assessments of EF reflect variation not only in similar vs. different types of behavior but also in similar vs. different neural circuitry. There are a multitude of factors that potentially account for variance in children's performance on EF assessments and parent or teacher ratings of children's EF behaviors that are distinct from variance associated with the underlying neural processes that support EF. The failure of most assessments to explicitly address this "conceptual slippage" undermines the quality of current EF research and impedes progress in the application of this research for clinical and educational use.

7.3 Implications for Policy and Practice

Although there are numerous implications of research on EF for educational policy and practice we could consider, here we present three broad policy and practice implications.

1. Much of the focus of current research on EF and education, and consequently of this review, is on the way in which EF contributes to academic learning. EF, and self-regulation more broadly, however, are meaningful educational outcomes in their own right. EF and self-regulation generally are important aspects of individual development. EF skills themselves can be a target of practice-based instruction in early childhood. This has the potential to help provide children with the foundational skills that they need to learn and adapt to school. It will be increasingly important to consider not only the ways in which improvements in EF may lead to improvements in academic ability, but also the extent to which improvements in EF can contribute to the growth of personal responsibility and social-emotional competence that are also highly relevant to the mission of elementary and secondary education.

2. A continued research and policy focus is needed on the measurement of EF and on trajectories of EF development from early childhood through young adulthood. It is important to assess EF skill development so that an understanding of children's EF skills can inform individual and classroom-based instruction. Much of the focus of current research on EF in the context of education has been on the early elementary grades. A concomitant focus on the middle and secondary grades, as well as post-secondary and adult education, is also needed. Continued work on the longitudinal measurement of EF is needed so that benchmarks will be available against which to gauge the relative effect of novel educational approaches. Also, given increasing interest in the measurement of EF as an educational outcome of interest on its own, there is a need for psychometrically strong longitudinal measures that can be readily administered in school settings.

3. Knowledge of EF can be used to develop psychological and physiological measures of engagement in learning activities and hence provide information about effective teaching practices and approaches. Measures of EF and of electrophysiological activity in the brain can provide information to educators about levels of attentiveness and engagement in learning activities. Further, given relations between EF and motivation, measures of EF and brain electrophysiology could be used to evaluate approaches to support EF and to enhance motivation. In addition, EF varies as a function of physiological arousal and time of day, and this EF-arousal interaction itself varies as a function of development. School schedules could be arranged to enhance both EF and learning. For example, around the transition to adolescence, when most children undergo a phase shift in their circadian rhythms, it has been shown that children get more sleep and do better academically when school starts later. Topics such as math, which depend heavily on EF skills, might usefully be scheduled for later in the day, not first thing in the morning. Other considerations are the timing of lunch (post-prandial dip in arousal and EF) and the benefits of cardiovascular exercise for EF. Scheduling multiple daily bouts of moderate to vigorous physical activity might be an effective means of "priming" kids for learning (e.g., recess and PE could strategically occur prior to core classes).

Overall, research suggests that EF provides a foundation for learning and adaptation in a wide range of circumstances, including school. This research indicates that the EF skills needed to pay attention, keep information in mind, think flexibly, and inhibit impulsive responding can be acquired in school settings, leading not only to improved EF but also to improved academic achievement. Regular, longitudinal assessment of children's EF skill can inform teaching practices and approaches, including differentiated instruction. The extent to which EF difficulties contribute to learning difficulties, behavior problems, suspension, expulsion, or being held back, is currently unknown, but assessment of individual students' EF skills as they develop may help educators understand obstacles to students' learning that can be addressed more directly and effectively.

References

Ackerman, P.L., Beier, M.E., and Boyle, M.O. (2005). Working Memory and Intelligence: The Same or Different Constructs? *Psychological Bulletin, 131*(1): 30-60.

Alderman, N., Burgess, P.W., Knight, C., and Henman, C. (2003). Ecological Validity of a Simplified Version of the Multiple Errands Shopping Test. *Journal of the International Neuropsychological Society*, 9(01): 31-44.

Allain, P., Foloppe, D.A., Besnard, J., Yamaguchi, T., Etcharry-Bouyx, F., Le Gall, D., Nolin, P. and Richard, P. (2014). Detecting Everyday Action Deficits in Alzheimer's Disease Using a Nonimmersive Virtual Reality Kitchen. *Journal of the International Neuropsychological Society*, *20*(05): 468-477.

Allan, N.P., Hume, L.E., Allan, D.M., Farrington, A.L., and Lonigan, C.J. (2014). Relations Between Inhibitory Control and the Development of Academic Skills in Preschool and Kindergarten: A Meta-Analysis. *Developmental Psychology, 50*(10): 2368–2379.

Alloway, T.P., Gathercole, S.E., Adams, A.M., Willis, C., Eaglen, R., and Lamont, E. (2005). Working Memory and Other Cognitive Skills as Predictors of Progress Towards Early Learning Goals At School Entry. *British Journal of Developmental Psychology*, *23*: 417-426.

Alloway, T.P., and Alloway, R.G. (2010). Investigating the Predictive Roles of Working Memory and IQ in Academic Attainment. *Journal of Experimental Child Psychology*, *106*: 20-29.

Alloway, T.P., Gathercole, S.E., Kirkwood, H., and Elliott, J. (2009). The Cognitive and Behavioral Characteristics of Children With Low Working Memory. *Child Development, 80*(2): 606-621.

Anderson, P.A.W., Sleeper, L.A., Mahony, L., Colan, S.D., Atz, A.M., Breitbart, R.E., … for the Pediatric Heart Network Investigators. (2008). Contemporary Outcomes After the Fontan Procedure: A Pediatric Heart Network Multicenter Study. *Journal of the American College of Cardiology*, *52*(2): 85–98. doi: 10.1016/j.jacc.2008.01.074

Anderson, P. (2002). Assessment and Development of Executive Function (EF) During Childhood. *Child Neuropsychology, 8*(2): 71-82.

Anderson, V., Jacobs, R., and Anderson, P.J. (Eds.). (2008). *Executive Functions and the Frontal Lobes: A Lifespan Perspective* (pp. 22-56). New York: Taylor and Francis.

Archibald, L.M., and Gathercole, S.E. (2006). Visuospatial Immediate Memory in Specific Language Impairment. *Journal of Speech, Language, and Hearing Research, 49*(2): 265-277.

Archibald, S.J., and Kerns, K.A. (1999). Identification and Description of New Tests of Executive Functioning in Children. *Child Neuropsychology, 5*(2): 115-129. doi: 10.1076/chin.5.2.115.3167

Ardila, A., Ostrosky-Solis, F., Rosselli, M. and Gomez, C. (2000). Age Related Cognitive Decline During Normal Aging: The Complex Effect of Education. *Archives of Clinical Neuropsychology*, *15*: 495-514.

Arnsten, A.F.T. (2009). Stress Signaling Pathways That Impair Prefrontal Cortex Structure and Function. *Nature Reviews Neuroscience, 10*: 410-422. doi: 10.1038/nrn2648

Ashcraft, M.H., and Krause, J.A. (2007). Working Memory, Math Performance, and Math Anxiety. *Psychonomic Bulletin and Review, 14*(2): 243-248.

Au, J., Sheehan, E., Tsai, N., Duncan, G.J., Buschkuehl, M., and Jaeggi, S.M. (2014). Improving Fluid Intelligence With Training on Working Memory: A Meta-Analysis. *Psychonomic Bulletin and Review, 22(*2): 366-377.

Baer, R.A. (2003). Mindfulness Training as a Clinical Intervention: A Conceptual and Empirical Review. *Clinical Psychology: Science and Practice, 10*: 125-143.

Barkley, R.A. (1997). Behavioral Inhibition, Sustained Attention, and Executive Functions: Constructing a Unifying Theory of ADHD. *Psychological Bulletin, 12*(1): 65-94.

Barkley, R.A., and Murphy, K.R. (2010). Impairment in Occupational Functioning and Adult ADHD: The Predictive Utility of Executive Function (EF) Ratings Versus EF Tests. *Archives of Clinical Neuropsychology, 25*(3): 157-173. doi: 10.1093/arclin/acq014

Barkley, R.A., and Murphy, K.R. (2011). The Nature of Executive Function (EF) Deficits in Daily Life Activities in Adults With ADHD and Their Relationship to Performance on EF Tests. *Journal of Psychopathology and Behavioral Assessment, 33*(2): 137-158. doi: 10.1007/s10862-011-9217

Barnes, J.J., Dean, A.J., Nandam, L.S., O'Connell, R.G., and Bellgrove, M.A. (2011). The Molecular Genetics of Executive Function: Role of Monoamine System Genes. *Biological Psychiatry, 69*: e127–e143. doi: 10.1016/j.biopsych.2010.12.040

[13]*Barnett, W.S., Jung, K., Yarosz, D.J., Thomas, J., Hornbeck, A., Stechuk, R., and Burns, S. (2008). Educational Effects of the Tools of the Mind Curriculum: A Randomized Trial. *Early Childhood Research Quarterly, 23*(3): 299-313.

Bauer, P.J., and Zelazo, P.D. (2014). The NIH Toolbox for the Assessment of Neurological and Behavioral Function: A Tool for Developmental Science. *Child Development Perspectives*, *8*: 119-124. doi: 10.1111/cdep.12080

Bavelier, D., Green, C.S., Pouget, A., and Schrater, P. (2012). Brain Plasticity Through the Life Span: Learning to Learn and Action Video Games. *Annual Review of Neuroscience, 35*: 391-416. doi: 10.1146/annurev-neuro-060909-152832

Bechara, A., Damasio, A.R., Damasio, H., and Anderson S.W. (1994). Insensitivity to Future Consequences Following Damage to Human Prefrontal Cortex. *Cognition, 50*(1-3): 7-15.

---

[13] References with an * reflect publications reporting findings from experimental studies that were examined by the What Works Clearinghouse (http://ies.ed.gov/ncee/wwc/) and that, as of May 2016, met What Works Clearinghouse's group design standards with reservations.

Becker, M.G., Isaac, W., and Hynd, G.W. (1987). Neuropsychological Development of Nonverbal Behaviors Attributed to "Frontal Lobe" Functioning. *Developmental Neuropsychology, 3*(3-4): 275-298.

Beilock, S.L., and Carr, T.H. (2005). When High-Powered People Fail Working Memory and “Choking Under Pressure” in Math. *Psychological Science, 16*(2): 101-105.

Belsky, J., and Pluess, M. (2009). Beyond Diathesis Stress: Differential Susceptibility to Environmental Influences. *Psychological Bulletin, 135*(6): 885-908.

Benes, F.M. (2001). The Development of Prefrontal Cortex: The Maturation of Neurotransmitter Systems and Their Interactions. In C. Nelson, and M. Luciana (Eds.). *Handbook of Developmental Cognitive Neuroscience* (pp. 79-92). Cambridge, MA: MIT Press.

Bengtsson, S.L., Nagy, Z., Skare, S., Forsman, L., Forssberg, H., and Ullén, F. (2005). Extensive Piano Practicing has Regionally Specific Effects on White Matter Development. *Nature Neuroscience, 8*: 1148-1150. doi: 10.1038/nn1516

Benson, J., Sabbagh, M., Carlson, S.M., and Zelazo, P.D. (2013). Individual Differences in Executive Functioning Predict Preschoolers’ Improvement From Theory-of-Mind Training. *Developmental Psychology, 49*(9): 1615-1627.

Berg C, Edwards D.R, and King A. (2012). Executive Function Performance on the Children’s Kitchen Task Assessment With Children With Sickle Cell Disease and Matched Controls. *Child Neuropsychology*, *18*(5):432–448. doi: 10.1080/09297049.2011.613813

Berkman, E.T., Kahn, L.E., and Merchant, J.S. (2014). Training-Induced Changes in Inhibitory Control Network Activity. *The Journal of Neuroscience, 34*(1): 149-157.

Bernier, A., Carlson, S.M., and Whipple, N. (2010). From External Regulation to Self-Regulation: Early Parenting Precursors of Young Children’s Executive Functioning. *Child Development, 81*(1): 326-339.

Bernier, A., Carlson, S.M., Deschênes, M., and Matte-Gagné, C. (2012). Social Factors in the Development of Early Executive Functioning: A Closer Look at the Caregiving Environment. *Developmental Science*, *15*(1): 12-24.

Best, J.R. (2010). Effects of Physical Activity on Children's Executive Function: Contributions of Experimental Research on Aerobic Exercise. *Developmental Review, 30*(4): 331-351.

Best, J.R., Miller, P.H., and Jones, L.L. (2009). Executive Functions After Age 5: Changes and Correlates. *Developmental Review, 29*(3): 180-200.

Bialystok, E. (2010). Global-local and Trail-making Tasks by Monolingual and Bilingual Children: Beyond Inhibition. *Developmental Psychology*, *46*(1): 93-105.

Bialystok, E., and Martin, M.M. (2004). Attention and Inhibition in Bilingual Children: Evidence From the Dimensional Change Card Sort Task. *Developmental Science*, *7*: 325-339.

Biederman, J., Petty, C.R., Doyle, A.E., Spencer, T., Henderson, C.S., Marion, B., Fried, R., and Faraone, S.V. (2008). Stability of Executive Function Deficits in Girls With ADHD: A Prospective Longitudinal Follow-Up Study Into Adolescence. *Developmental Neuropsychology, 33*(1): 44-61.

Biederman, J., Petty, C.R., Fried, R., Doyle, A.E., Spencer, T., Seidman, L.J., Gross, L., Poetzl, K., and Faraone, S.V. (2007). Stability of Executive Function Deficits Into Young Adult Years: A Prospective Longitudinal Follow-Up Study of Grown-Up Males With ADHD. *Acta Psychiatrica Scandinavica, 116*(2): 129-136. doi: 10.1111/j.1600-0447.2007.01008

Biegel, G.M, Brown, K.W., Shapiro, S.L., and Schubert, C. M. (2009). Mindfulness-Based Stress Reduction for the Treatment of Adolescent Psychiatric Outpatients: A Randomized Clinical Trial. *Journal of Consulting and Clinical Psychology, 77*(5): 855-866.

[14]^Bierman, K.L., Domitrovich, C.E., Nix, R.L., Gest, S.D., Welsh, J.A., Greenberg, M.T., Blair, C., Nelson, K., and Gill, S. (2008). Promoting Academic and Social-Emotional School Readiness: The Head Start REDI Program. *Child Development, 79*(6): 1802-1817.

Bierman, K.L., Nix, R.L., Greenberg, M.T., Blair, C., and Domitrovich, C.E. (2008). Executive Functions and School Readiness Interventions: Impact, Moderation, and Mediation in the Head Start REDI Program. *Development and Psychopathology, 20*(3): 821-843. doi: 10.1017/S0954579408000394

Bjorklund, D.F., and Kipp, K. (1996). Parental Investment Theory and Gender Differences in the Evolution of Inhibition Mechanisms. *Psychological Bulletin, 120*(2): 163-188.

Blair, C. (2002). School Readiness: Integrating Cognition and Emotion in a Neurobiological Conceptualization of Children's Functioning at School Entry. *American Psychologist, 57*(2): 111–127. doi: 10.1037/0003-066X.57.2.111

Blair, C. (2006). How Similar are Fluid Cognition and General Intelligence? A Developmental Neuroscience Perspective on Fluid Cognition as an Aspect of Human Cognitive Ability. *Behavioral and Brain Sciences, 29*(2): 109-125.

Blair, C. (2010). Stress and the Development of Self-Regulation in Context. *Child Development Perspectives, 4*(3): 181-188.

Blair, C. (2014). Stress and the Development of Executive Functions: Experiential Canalization of Brain and Behavior. In P.D. Zelazo, and M. Sera (Eds.), *Minnesota Symposia on Child Psychology: Developing Cognitive Control Processes: Mechanisms, Implications, and Interventions, Vol. 37* (pp. 145-180). New York: Wiley.

---

[14] References with an ^ reflect publications reporting findings from experimental studies that were examined by the What Works Clearinghouse (http://ies.ed.gov/ncee/wwc/) and that, as of May 2016, met What Works Clearinghouse's evidence standards without reservations.

Blair, C., and Diamond, A. (2008). Biological Processes in Prevention and Intervention: Promotion of Self-Regulation and the Prevention of Early School Failure. *Development and Psychopathology, 20*(3): 899-911. doi: 10.1017/S0954579408000436

Blair, C., Granger, D., and Razza, R.P. (2005). Cortisol Reactivity is Positively Related to Executive Function in Preschool Children Attending Head Start. *Child Development, 76*(3): 554-567.

Blair, C., Granger, D. Willoughby, M., Mills-Koonce, R., Cox, M., Greenberg, M.T., Kivlighan, K., Fortunato, C., and the FLP Investigators. (2011). Salivary Cortisol Mediates Effects of Poverty and Parenting on Executive Functions in Early Childhood. *Child Development, 82*(6): 1970-1984.

Blair, C., Hammer, C., and Lopez, L. (under review). Effect of the Tools of the Mind Program on the School Readiness of English Language Learners. Manuscript submitted for publication.

Blair, C., and Raver, C.C. (2012). Child Development in the Context of Adversity: Experiential Canalization of Brain and Behavior. *American Psychologist, 67*(4): 309-318.

[15]#Blair, C., and Raver, C.C. (2014). 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*(11): e112393. doi: 10.1371/journal.pone.0112393

Blair, C., and Raver, C.C. (2015). School Readiness and Self-Regulation: A Developmental Psychobiological Approach. *Annual Review of Psychology, 66*: 711-731.

Blair, C., and Razza, R.P. (2007). Relating Effortful Control, Executive Function, and False Belief Understanding to Emerging Math and Literacy Ability in Kindergarten. *Child Development, 78*(2): 647-680. doi: 10.1111/j.1467-8624.2007.01019

[15] References with an # reflect publications reporting findings from experimental studies that were examined by the What Works Clearinghouse (http://ies.ed.gov/ncee/wwc/) and that, as of May 2016, did not met What Works Clearinghouse's group design standards.

Blair, C., and Ursache, A. (2011). A Bidirectional Model of Executive Functions and Self-Regulation. In K.D. Vohs, and R.F. Baumeister, *Handbook of Self-Regulation: Research, Theory, and Applications* (2nd Edition) (pp. 300-320). New York: Guilford Press.

Blair, C., Protzko, J., and Ursache, A. (2011). Self-Regulation and the Development of Early Literacy. In D. Dickinson, and S. Neuman (Eds.), *Handbook of Early Literacy Research*, *Vol. 3* (pp. 20-35). New York: Guilford Press.

Bodrova, E., and Leong, D.J. (2007). *Tools of the Mind: The Vygotskian Approach to Early Childhood Education* (2nd ed.). New York: Merrill/Prentice Hall.

Boelema, S.R., Harakeh, Z., Ormel, J., Hartman, C.A., Vollebergh, W.A.M., and van Zandvoort, M.J.E. (2014). Executive Functioning Shows Differential Maturation From Early to Late Adolescence: Longitudinal Findings From a TRAILS Study. *Neuropsychology, 28*(2): 177-187. doi: 10.1037/Neu0000049

Booth, J.N., Boyle, J.M., and Kelly, S.W. (2010). Do Tasks Make a Difference? Accounting for Heterogeneity of Performance of Children With Reading Difficulties on Tasks of Executive Function: Findings From a Meta-Analysis. *British Journal of Developmental Psychology*, *28*(1): 133-176.

Boyce, W.T., and Ellis, B.J. (2005). Biological Sensitivity to Context: I. An Evolutionary–Developmental Theory of the Origins and Functions of Stress Reactivity. *Development and Psychopathology, 17*(2): 271-301.

Bridgett, D.J., Burt, N.M., Edwards, E.S., and Deater-Deckard, K. (2015). Intergenerational Transmission of Self-Regulation: A Multidisciplinary Review and Integrative Conceptual Framework. *Psychological Bulletin, 141*(3): 602-654.

Briscoe, J., and Rankin, P.M. (2009). Exploration of a 'Double-Jeopardy' Hypothesis Within Working Memory Profiles for Children With Specific Language Impairment. *International Journal of Language and Communication Disorders*, *44*(2): 236-250.

Brock, L.L., Rimm-Kaufman, S.E., Nathanson, L., and Grimm, K.J. (2009). The Contributions of 'Hot' and 'Cool' Executive Function to Children's Academic Achievement, Learning-Related Behaviors, and Engagement in Kindergarten. *Early Childhood Research Quarterly, 24*(3): 337-349.

Brocki, K.C., and Tillman, C. (2014). Mental Set Shifting in Childhood: The Role of Working Memory and Inhibitory *Control. Infant and Child Development*, *23*(6): 588–604. doi: 10.1002/icd.1871

Brydges, C.R., Reid, C.L., Fox, A.M., and Anderson, M. (2012). A Unitary Executive Function Predicts Intelligence in Children. *Intelligence, 40*(5): 458-469. doi: 10.1016/j.intell.2012.05.006

Buchanan, T., Heffernan, T. M., Parrott, A. C., Ling, J., Rodgers, J., and Scholey, A. B. (2010). A Short Self-Report Measure of Problems With Executive Function Suitable for Administration via the Internet. *Behavior Research Methods*, *42*(3): 709-714.

Buchanan, T. (2016) Self-Report Measures of Executive Function Problems Correlate With Personality, Not Performance-Based Executive Function Measures, in Nonclinical Samples. *Psychological Assessment*, *28*(4): 372-385.

Bull, R., Espy, K.A., and Wiebe, S.A. (2008). Short-Term Memory, Working Memory, and Executive Functioning in Preschoolers: Longitudinal Predictors of Mathematical Achievement at Age 7 Years. *Developmental Neuropsychology, 33*(3): 205-228.

Bull, R., Espy, K.A., Wiebe, S.A., Sheffield, T.D., and Nelson, J.M. (2011). Using Confirmatory Factor Analysis to Understand Executive Control in Preschool Children: Sources of Variation in Emergent Mathematic Achievement. *Developmental Science*, *14*(4): 679-692.

Bull, R., and Lee, K. (2014.) Executive Functioning and Mathematics Achievement . *Child Development Perspectives*, *8*(1): 36-41.

Bull, R., and Scerif, G. (2001). Executive Functioning as a Predictor of Children's Mathematics Ability: Inhibition, Switching, and Working Memory. *Developmental Neuropsychology, 19*(3): 273-293.

Bunge, S.A., Dudukovic, N.M., Thomason, M.E., Vaidya, C.J., and Gabrieli, J.D. (2002). Immature Frontal Lobe Contributions to Cognitive Control in Children: Evidence From fMRI. *Neuron, 33*(2): 301-311.

Burgess, P.W., Alderman, N., Evans, J., Emslie, H., and Wilson, B.A. (1998). The Ecological Validity of Tests of Executive Function. *Journal of the International Neuropsychological Society, 4*(6): 547-558.

Burgess, P.W., Alderman, N., Forbes, C., Costello, A., Coates, L.M.A., Dawson, D.R., Anderson, N.D., Gilbert, S.J., Dumontheil, I., and Channon, S. (2006). The Case for the Development and Use of "Ecologically Valid" Measures of Executive Function in Experimental and Clinical Neuropsychology. *Journal of the International Neuropsychological Society, 12*(2): 194-209. doi: 10.1017/S135561770606310

Burke, C.A. (2010). Mindfulness-Based Approaches With Children and Adolescents: A Preliminary Review of Current Research in an Emergent Field. *Journal of Child and Family Studies, 19*(2): 133-144.

Buschkuehl, M., Jaeggi, S. M., and Jonides, J. (2012). Neuronal Effects Following Working Memory Training. *Developmental Cognitive Neuroscience*, *2*(Suppl 1): S167–S179. doi: 10.1016/j.dcn.2011.10.001

Buss, A.T., and Spencer, J.P. (2014). The Emergent Executive: A Dynamic Field Theory of the Development of Executive Function. *Monographs of the Society for Research in Child Development*, *79*(2): vii.

Campbell, D.T., and Fiske, D.W. (1959). Convergent and Discriminant Validation by the Multitrait-Multimethod Matrix. *Psychological Bulletin*, *56*(2): 81-105. doi: 10.1037/h0046016

Carlson, S.A. (2005). Developmentally Sensitive Measures of Executive Function in Preschool Children. *Developmental Neuropsychology, 28*(2): 595-616.

Carlson, S.M., Davis, A.C., and Leach, J.G. (2005). Less is More: Executive Function and Symbolic Representation in Preschool Children. *Psychological Science, 16*(8): 609-616.

Carlson, S.M., Mandell, D., and Williams, L. (2004). Executive Function and Theory of Mind: Stability and Prediction From Ages 2 to 3. *Developmental Psychology, 40*(6): 1105-1122.

Carlson, S.M., and Meltzoff, A.N. (2008). Bilingual Experience and Executive Functioning in Young Children. *Developmental Science, 11*(2): 282-298. doi: 10.1111/j.1467-7687.2008.00675.x

Carlson, S.M., and Moses, L.J. (2001). Individual Differences in Inhibitory Control and Children's Theory of Mind. *Child Development, 72*(4): 1032-1053.

Carlson, S.M., Zelazo, P.D., and Faja, S. (2013). Executive Function. *Oxford Handbook of Developmental Psychology*, *Vol. 1* (pp. 706-742). doi: 10.1093/oxfordhb/9780199958450.013.0025

Carskadon, M.A., Wolfson, A.R., Acebo, C., Tzischinsky, O., and Seifer, R., (1998). Adolescent Sleep Patterns, Circadian Timing, and Sleepiness at a Transition to Early School Days. *Sleep, 21*(8): 871-881.

Casey, B.J., Getz, S., and Galvan, A. (2008). The Adolescent Brain. *Developmental Review. 28*(1): 62–77.

Castellanos, F.X., Sonuga-Barke, E.J.S., Milham, M.P., and Tannock, R. (2006). Characterizing Cognition in ADHD: Beyond Executive Dysfunction. *Trends in Cognitive Sciences, 10*(3): 117-123.

Castellanos, F.X., and Tannock, R. (2002). Neuroscience of Attention-Deficit/Hyperactivity Disorder: The Search for Endophenotypes. *Nature Reviews Neuroscience, 3*(8): 617-628. doi: 10.1038/nrn896

Castelli, D.M., Hillman, C.H., Buck, S.M., and Erwin, H.E. (2007). Physical Fitness and Academic Achievement in Third-and Fifth-Grade Students. *Journal of Sport and Exercise Psychology, 29*(2): 239-252.

Catale, C., Meulemans, T., and Thorell, L. B. (2013). The Childhood Executive Function Inventory: Confirmatory Factor Analyses and Cross-Cultural Clinical Validity in a Sample of 8- to 11-Year-Old Children. *Journal of Attention Disorders*, *19*: 489–495. doi: 10.1177/1087054712470971

Center on the Developing Child at Harvard University (2011). *Building the Brain's "Air Traffic Control" System: How Early Experiences Shape the Development of Executive Function*, Working Paper No. 11. Retrieved from www.developingchild.harvard.edu.

Chambers, R., Lo, B.C.Y., and Allen, N.B. (2007). The Impact of Intensive Mindfulness Training on Attentional Control, Cognitive Style, and Affect. *Cognitive Therapy and Research, 32*(3): 303-322.

Chan, R.C.K., Shum, D., Toulopoulou, T., and Chen, E.Y.H. (2008). Assessment of Executive Functions: Review of Instruments and Identification of Critical Issues. *Archives of Clinical Neuropsychology, 23*(2): 201-216. doi: 10.1016/j.acn.2007.08.010

Chaytor, N., Schmitter-Edgecombe, M., and Burr, R. (2006). Improving the Ecological Validity of Executive Functioning Assessment. *Archives of Clinical Neuropsychology, 21*(3): 217-227. doi: 10.1016/j.acn.2005.12.002

Chevalier, N., Huber, K.L., Wiebe, S.A., and Espy, K.A. (2013). Qualitative Change in Executive Control During Childhood and Adulthood. *Cognition, 128*(1): 1-12. doi: 10.1016/j.cognition.2013.02.012

Chevalier, N., Wiebe, S.A., Huber, K.L., and Espy, K.A. (2011). Switch Detection in Preschoolers' Cognitive Flexibility. *Journal of Experimental Child Psychology, 109*(3): 353-370. doi: 10.1016/j.jecp.2011.01.006

Chooi, W.-T., and Thompson, L.A. (2012) Working Memory Training Does Not Improve Intelligence in Healthy Young Adults. *Intelligence, 40*: 531–542.

Cirino, P.T., Fletcher, J.M., Ewing-Cobbs, L., Barnes, M.A., and Fuchs, L.S. (2007). Cognitive Arithmetic Differences in Learning Difficulty Groups and the Role of Behavioral Inattention. *Learning Disabilities Research and Practice*, *22*(1): 25-35.

Clark, C.A., Pritchard, V.E., and Woodward, L.J. (2010). Preschool Executive Functioning Abilities Predict Early Mathematics Achievement. *Developmental Psychology, 46*(5): 1176-1191. doi: 10.1037/a0019672

Clark, C.A.C., Sheffield, T.D., Chevalier, N., Nelson, J.M., Wiebe, S.A., and Espy, K.A. (2013). Charting Early Trajectories of Executive Control With the Shape School. *Developmental Psychology, 49*(8): 1481-1493. doi: 10.1037/A0030578

^Clements, D. H., and Sarama, J. (2007). Effects of a Preschool Mathematics Curriculum: Summative Research on the Building Blocks Project. *Journal for Research in Mathematics Education*, *38*: 136-163.

Connor, C.M., Morrison, F.J., Fishman, B., Giuliani, S., Luck, M., Underwood, P.S., Bayraktar, A., Crowe, E.C., and Schatschneider, C. (2011). Testing the Impact of Child Characteristics X Instruction Interactions on Third Graders' Reading Comprehension by Differentiating Literacy Instruction. *Reading Research Quarterly, 46*(3): 189-221. doi: 10.1598/Rrq.46.3.1

Connor, C.M., Ponitz, C.C., Phillips, B.M., Travis, Q.M., Glasney, S., and Morrison, F.J. (2010). First Graders' Literacy and Self-Regulation Gains: The Effect of Individualizing Student Instruction. *Journal of School Psychology, 48*(5): 433-455. doi: 10.1016/j.jsp.2010.06.003

Cools, R., and D'Esposito, M. (2011). Inverted-U-Shaped Dopamine Actions on Human Working Memory and Cognitive Control. *Biological Psychiatry, 69*(12): e113–e125.

Cortese, S., Ferrin, M., Brandeis, D., Buitelaar, J., Daley, D., Dittmann, R. W., … and European ADHD Guidelines Group (EAGG). (2015). Cognitive Training for Attention-Deficit/Hyperactivity Disorder: Meta-Analysis of Clinical and Neuropsychological Outcomes From Randomized Controlled Trials. *Journal of the American Academy of Child and Adolescent Psychiatry*, *54*(3): 164–174. doi: 10.1016/j.jaac.2014.12.010

Crone, E.A., and Dahl, R.E.(2012). Understanding Adolescence as a Period of Social–Affective Engagement and Goal Flexibility. *Nature Reviews Neuroscience, 13*(9): 636–650.

Cuberos-Urbano, G., Caracuel, A., Vilar-López, R., Valls-Serrano, C., Bateman, A., and Verdejo-García, A. (2013) Ecological Validity of the Multiple Errands Test Using Predictive Models of Dysexecutive Problems in Everyday Life, *Journal of Clinical and Experimental Neuropsychology*, *35*(3): 329-336.

Cuevas, K., Deater-Deckard, K., Kim-Spoon, J., Wang, Z., Morasch, K.C., and Bell, M.A. (2014). *British Journal of Developmental Psychology, 32*(1): 50-64. doi: 10.1111/bjdp.12021

Cunningham, W. A., and Zelazo, P. D. (2007). Attitudes and Evaluations: A Social Cognitive Neuroscience Perspective. *Trends in Cognitive Sciences*, *11*: 97–104.

Cutting, L.E., Materek, A., Cole, C.A., Levine, T.M., and Mahone, E.M. (2009). Effects of Fluency, Oral Language, and Executive Function on Reading Comprehension Performance. *Annals of Dyslexia*, *59*(1): 34-54. doi: 10.1007/s11881-009-0022-0

Daneman M, Carpenter PA. Individual differences in working memory and reading. Journal of Verbal Learning and Verbal Behavior. 1980;19:450–466.

Daneman M, Merikle PM. Working memory and language comprehension: A meta-analysis. Psychonomic Bulletin and Review. 1996;3:422–433.

Davidson, M.C., Amso, D., Anderson, L.C., and Diamond, A. (2006). Development of Cognitive Control and Executive Functions From 4 to 13 Years: Evidence From Manipulations of Memory, Inhibition, and Task Switching. *Neuropsychologia, 44*(11): 2037-2078. doi: 10.1016/j.neuropsychologia.2006.02.006

Dawson D.R., Anderson N.D., Burgess P., Cooper E., Krpan K.M., and Stuss D.T. (2009). Further Development of the Multiple Errands Test: Standardized Scoring, Reliability, and Ecological Validity for the Baycrest Version. *Archives of Physical Medicine and Rehabilitation*, *90*(11), S41–S51.

Deater-Deckard, K. (2014). Family Matters Intergenerational and Interpersonal Processes of Executive Function and Attentive Behavior. *Current Directions in Psychological Science, 23*(3): 230-236.

De Luca, C.R., and Leventer, R.J. (2008). Developmental Trajectories of Executive Functions Across the Life Span. In V. Anderson, R. Jacobs, and P.J. Anderson (Eds.), *Executive Functions and the Frontal Lobes* (pp. 22-56). New York: Taylor and Francis.

Delis, D.C., Kaplan, E., and Kramer, J.H. (2001a). *Delis-Kaplan Executive Function System (D-KEFS).* San Antonio, TX: The Psychological Corporation.

Denckla, M.B. (1996). Biological Correlates of Learning and Attention: What is Relevant to Learning Disability and Attention-Deficit Hyperactivity Disorder? *Journal of Developmental and Behavioral Pediatrics, 17*(2): 114-119.

D'Esposito, M., and Postle, B.R. (2015). The Cognitive Neuroscience of Working Memory. *Annual Review of Psychology, 66*: 115-142.

Derryberry, D., and Rothbart, M.K. (1988). Arousal, Affect, and Attention as Components of Temperament. *Journal of Personality and Social Psychology, 55*(6): 958-966.

Diamond, A. (2013). Executive Functions. *Annual Review of Psychology, 64*: 135-168.

Diamond, A., and Lee, K. (2011). Interventions Shown to Aid Executive Function Development in Children 4 to 12 Years Old. *Science, 333*(6045): 959-964. doi: 10.1126/science.1204529

[#]Diamond, A., Barnett, W.S., Thomas, J., and Munro, S. (2007). Preschool Program Improves Cognitive Control. *Science, 318*(5855): 1387-1388.

Diamond, A., Briand, L., Fossella, J., and Gehlbach, L. (2004) Genetic and Neurochemical Modulation of Prefrontal Cognitive Functions in Children. *American Journal of Psychiatry, 161*(1): 125–132.

Diamond, A., Prevor, M.B., Callendar, G., and Druin, D.P. (1997). Prefrontal Cognitive Deficits in Children Treated Early and Continuously for PKU. *Monographs of the Society for Research in Child Development, 62*(4): i-v, 1-208.

Diamond, A., and Wright, A. (2014). An Effect of Inhibitory Load in Children While Keeping Working Memory Load Constant. *Frontiers in Psychology*, *5*: 213.

Dickinson, D., and Elvevåg, B. (2009). Genes, Cognition and Brain Through a COMT Lens. *Neuroscience, 164*(1): 72-87.

Dignath, C., Buettner, G., and Langfeldt, H.P. (2008). How can Primary School Students Learn Self-Regulated Learning Strategies Most Effectively?: A Meta-Analysis on Self-Regulation Training Programmes. *Educational Research Review*, *3*(2): 101-129.

Duckworth, A.L., and Seligman, M.E.P. (2005). Self-Discipline Outdoes IQ in Predicting Academic Performance of Adolescents. *Psychological Science, 16*(12): 939-944.

Duncan, J., Burgess, P., and Emslie, H. (1995). Fluid Intelligence After Frontal Lobe Lesions. *Neuropsychologia, 33*(3): 261-268.

Duncan, G.J., Dowsett, C.J., Claessens, A., Magnuson, K., Huston, A.C., Klebanov, P., Pagani, L.S., Feinstein, L., Engel, M., Brooks-Gunn, J., Sexton, H., Duckworth, K., and Japel, C. (2007). School Readiness and Later Achievement. *Developmental Psychology, 43*(6): 1428-1446.

Dunning, D.L., Holmes, J., and Gathercole, S.E. (2013). Does Working Memory Training Lead to Generalized Improvements in Children With Low Working Memory? A Randomized Controlled Trial. *Developmental Science, 16*(6): 915-925.

Durston, S., Davidson, M.C., Tottenham, N., Galvan, A., Spicer, J., Fossella, J.A., and Casey, B.J. (2006). A Shift From Diffuse to Focal Cortical Activity With Development. *Developmental Science, 9*(1): 1-8.

Dweck, C. (2006). *Mindset: The New Psychology of Success*. New York: Random House.

Elbert, T., Pantev, C., Wienbruch, C., Rockstroh, B., and Taub, E. (1995). Increased Cortical Representation of the Fingers of the Left Hand in String Players. *Science, 270*: 305-307.

Engelhardt, L.E., Briley, D.A., Mann, F.D., Harden, K.P., and Tucker-Drob, E.M. (2015). Genes Unite Executive Functions in Childhood. *Psychological Science*, *26*: 1151-1163.

Eriksen, B. A., and Eriksen, C. W. (1974). Effects of Noise Letters Upon Identification of Target in Nonsearch Task. *Perception and Psychophysics*, *16*: 143- 149.

Ernst, M. (2014). The Triadic Model Perspective for the Study of Adolescent Motivated Behavior. *Brain and Cognition ,89*: 104–111.

Eslinger, P., Blair, C., Wang, J., Lipovsky, B., Realmuto, J., Baker, D., Thorne, S., Gamson, D., Zimmerman, E., Yang, Q., and Rohrer, L. (2009). A Developmental Functional Magnetic Resonance Imaging Study of Neural Systems Subserving Relational Reasoning in Childhood and Adolescence. *Brain and Cognition, 69*: 1-10.

Espinet, S.D., Anderson, J.E., and Zelazo, P.D. (2013). Reflection Training Improves Executive Function in Preschool Children: Behavioral and Neural Effects. *Developmental Cognitive Neuroscience, 4*: 3-15. doi: 10.1016/j.dcn.2012.11.009

Espy, K.A. (1997). The Shape School: Assessing Executive Function in Preschool Children. *Developmental Neuropsychology, 13*(4): 495-499.

Espy, K.A., Kaufmann, P.M., and Glisky, M.L. (1999). Neuropsychologic Function in Toddlers Exposed to Cocaine in Utero: A Preliminary Study. *Developmental Neuropsychology, 15*(3): 447-460.

Espy, K.A., Kaufmann, P.M., McDiarmid, M.D., and Glisky, M.L. (1999). Executive Functioning in Preschool Children: Performance on A-not-B and Other Delayed Response Format Tasks. *Brain and Cognition, 41*(2): 178-199.

Espy, K.A., McDiarmid, M.M., Cwik, M.F., Stalets, M.M., Hamby, A., and Senn, T.E. (2004). The Contribution of Executive Functions to Emergent Mathematic Skills in Preschool Children. *Developmental Neuropsychology, 26*(1): 465-486.

Evans, G.W. (2003). A Multimethodological Analysis of Cumulative Risk and Allostatic Load Among Rural Children. *Developmental Psychology, 39*(5): 924-933.

Evans, G.W., and Schamberg, M.A. (2009). Childhood Poverty, Chronic Stress, and Adult Working Memory. *Proceedings of the National Academy of Sciences, 106*(16): 6545-6549. doi: 10.1073/pnas.0811910106

Evans, J.J., Floyd, R.G., McGrew, K.S., and Leforgee, M.H. (2002). The Relations Between Measures of Cattell-Horn-Carroll (CHC) Cognitive Abilities and Reading Achievement During Childhood and Adolescence. *School Psychology Review, 31*(2): 246-262.

Evans, W. D., Powers, A., Hersey, J., and Renaud, J. (2006). The Influence of Social Environment and Social Image on Adolescent Smoking. *Health Psychology*, *25*(1): 26.

Fair, D.A., Bathula, D., Nikolas, M.A., and Nigg, J.T. (2012). Distinct Neuropsychological Subgroups in Typically Developing Youth Inform Heterogeneity in Children With ADHD. *Proceedings of the National Academy of Sciences, 109*(17): 6769-6774.

Fair, D.A., Cohen, A.L., Power, J.D., Dosenbach, N.U.F., Church, J.A., Miezin, F.M., Schlaggar, B.L., and Petersen, S.E. (2009) Functional Brain Networks Develop From a "Local to Distributed" Organization. *PLoS Computational Biology, 5*(5): e1000381. doi: 10.1371/journal.pcbi.1000381

Farah M.J., Betancourt L., Shera D.M., Savage J.H., Giannetta J.M., Brodsky N.L., Malmud, E.K., and Hurt, H. (2008). Environmental Stimulation, Parental Nurturance and Cognitive Development in Humans. *Developmental Science*, *11*:793–801.

Farah, M.J., Shera, D.M., Savage, J.H., Betancourt, L., Giannetta, J.M., Brodsky, N.L., Malmud, E.K., and Hurt, H. (2006). Childhood Poverty: Specific Associations With Neurocognitive Development. *Brain Research*, *1110*(1): 166-174.

Fisher, P.A., Gunnar, M.R., Dozier, M., Bruce, J., and Pears, K.C. (2006). Effects of Therapeutic Interventions for Foster Children on Behavioral Problems, Caregiver Attachment, and Stress Regulatory Neural Systems. *Annals of the New York Academy of Sciences*, *1094*(1): 215-225.

Fitzpatrick, C., McKinnon, R.D., Blair, C.B., and Willoughby, M.T. (2014). Do Preschool Executive Function Skills Explain the School Readiness Gap Between Advantaged and Disadvantaged Children? *Learning and Instruction*, *30*: 25-31.

Fletcher, J.M. (1996). Executive Functions in Children: Introduction to the Special Series. *Developmental Neuropsychology, 12*(1): 1-3.

Fletcher, J.M., Brookshire, B.L., Landry, S.H., Bohan, T.P., Davidson, K.C., Francis, D.J., Levin, H.S., Brandt, M.E., Kramer, L.A., and Morris, R.D. (1996). Attentional Skills and Executive Functions in Children With Early Hydrocephalus. *Developmental Neuropsychology, 12*(1): 53-76.

Franceschini, S., Gori, S., Ruffino, M., Viola, S., Molteni, M., and Facoetti, A. (2013). Action Video Games Make Dyslexic Children Read Better. *Current Biology, 23*(6): 462-466.

Frank, M.J., and Fossella, J.A. (2011). Neurogenetics and Pharmacology of Learning, Motivation, and Cognition. *Neuropsychopharmacology 36*(1): 133–152. doi: 10.1038/npp.2010.96

Friedman, N.P., Miyake, A., Young, S.E., DeFries, J.C., Corley, R.P., and Hewitt, J.K. (2008). Individual Differences in Executive Functions Are Almost Entirely Genetic in Origin. *Journal of Experimental Psychology: General*, *137*: 201-225.

Fuchs, L.S., Fuchs, D., Compton, D.L., Powell, S.R., Seethaler, P.M., Capizzi, A.M., and Fletcher, J.M. (2006). The Cognitive Correlates of Third-Grade Skill in Arithmetic, Algorithmic Computation, and Arithmetic Word Problems. *Journal of Educational Psychology*, *98*(1): 29-43.

Fuchs, L.S., Fuchs, D., Prentice, K., Burch, M., Hamlett, C.L., Owen, R., and Schroeter, K. (2003). Enhancing Third-Grade Student's Mathematical Problem Solving With Self-Regulated Learning Strategies. *Journal of Educational Psychology*, *95*(2): 306-315.

Fuchs, L.S., Geary, D.C., Compton, D.L., Fuchs, D., Hamlett, C.L., and Bryant, J.V. (2010). The Contributions of Numerosity and Domain-General Abilities to School Readiness. *Child Development*, *81*: 1520-1533.

Fuhs, M.W., Nesbitt, K.T., Farran, D.C., and Dong, N. (2014). Longitudinal Associations Between Executive Functioning and Academic Skills Across Content Areas. *Developmental Psychology, 50*(6): 1698-709. doi: 10.1037/a0036633

Fuhs, M.W., and Day, J.D. (2011). Verbal Ability and Executive Functioning Development in Preschoolers at Head Start. *Developmental Psychology*, *47*: 404-416. doi: 10.1037/a0021065

Fuster, J. M. (2015). *The Prefrontal Cortex* (5thEdition). Academic Press, London.

Gallant, S.N. (2016). Mindfulness Meditation Practice and Executive Functioning: Breaking Down the Benefit. *Consciousness and Cognition, 4*: 116-130.

Gandolfi, E., Viterbori, P., Traverso, L., and Usai, M.C. (2014). Inhibitory Processes in Toddlers: A Latent-Variable Approach. *Frontiers in Psychology, 5*: 381. doi: 10.3389/fpsyg.2014.00381

Garon, N., Bryson, S.E., and Smith, I.M. (2008). Executive Function in Preschoolers: A Review Using an Integrative Framework. *Psychological Bulletin, 134*(1): 31-60.

Garon, N., Smith, I.M., and Bryson, S.E. (2014). A Novel Executive Function Battery for Preschoolers: Sensitivity to Age Differences. *Child Neuropsychology, 20*(6): 713-736. doi: 10.1080/09297049.2013.857650

Gartner, A., Kohler, M.C., and Riessman, F. (1971). *Children Teach Children: Learning by Teaching*. New York: Harper and Row.

Gathercole, S.E., and Baddeley, A.D. (1989). Development of Vocabulary in Children and Short-Term Phonological Memory. *Journal of Memory and Language*, *28*: 200–213.

Gathercole, S.E., and Alloway, T.P. (2008). *Working Memory and Learning. A Practical Guide for Teachers*. Thousand Oaks, CA: SAGE Publications.

Geary, D.C. (2011). Cognitive Predictors of Achievement Growth in Mathematics: A 5-Year Longitudinal Study. *Developmental Psychology, 47*(6): 1539.

Geoffroy, M-C., Côté, S.M., Giguère, C-É., Dionne, G., Zelazo, P.D., Tremblay, R.E., Boivin, M., and Séguin, J.R. (2010). Closing the Gap in Academic Readiness and Achievement: The Role of Early Childcare. *Journal of Child Psychology and Psychiatry, 51*(12): 1359-1367. doi: 10.1111/j.1469-7610.2010.02316.x

Gerardi Caulton, G. (2000). Sensitivity to Spatial Conflict and the Development of Self-Regulation in Children 24-36 Months of Age. *Developmental Science, 3*(4): 397-404.

Gerstadt, C., Hong, Y., and Diamond, A. (1994). The Relationship Between Cognition and Action: Performance of Children 3 1/2 -7 Years Old on a Stroop-Like Day-Night Test. *Cognition, 53*(2): 129-153.

Geurten, M., Catale, C., Geurten, C., Wansard, M., and Meulemans, T. (2016). Studying Self-Awareness in Children: Validation of the Questionnaire of Executive Functioning (QEF). *The Clinical Neuropsychologist, 30*(4): 558-578.

Geurts, H.M., van der Oord, S., and Crone, E.C. (2006). Hot and Cool Aspects of Cognitive Control in Children With ADHD: Decision-Making and Inhibition. *Journal of Abnormal Child Psychology, 34*(6): 811-822.

Giedd, J.N., Blumenthal, J., Jeffries, N.O., Castellanos, F.X., Liu, H., Zijdenbos, A., Paus, T., Evans, A.C., and Rapoport, J.L. (1999). Brain Development During Childhood and Adolescence: A Longitudinal MRI Study. *Nature Neurosciene, 2*(10): 861-863. doi: 10.1038/13158

Gioia, G.A., Espy, K.A., and Isquith, P.K. (2003). *BRIEF-P: Behavior Rating Inventory of Executive Function--Preschool Version: Professional Manual.* Psychological Assessment Resources.

Gioia, G.A., Isquith, P.K., Guy, S.C., and Kenworthy, L. (2000). Behavior Rating Inventory of Executive Function. *Child Neuropsychology, 6*(3): 235-238.

Golden, C.J. (1981). Luria-Nebraska Children's Battery: Theory and Formulation. In G.W. Hynd and J.E. Orbzut (Eds.), *Neuropsychological Assessment and the School-Age Child* (pp. 277-302). New York: Grune and Stratton.

Goldman, D., Weinberger, D.R., Malhotra, A.K., and Goldberg, T.E. (2009). The Role of COMT Val158Met in Cognition. *Biological Psychiatry, 65*(1): e1-e4.

Goldstein, D., Hahn, C., Hasher, L., Wiprzycka, L.J., and Zelazo, P.D. (2007). Time of Day, Intellectual Performance, and Behavioral Problems in Morning Versus Evening Type Adolescents: Is There a Synchrony Effect? *Personality and Individual Differences, 43*(3): 431-440.

Grammer, J., Coffman, J.L., and Ornstein, P. (2013). The Effect of Teachers' Memory-Relevant Language on Children's Strategy Use and Knowledge. *Child Development, 84*(6): 1989–2002. doi: 10.1111/cdev.12100

Granic, I., Lobel, A., and Engels, R.C. (2014). The Benefits of Playing Video Games. *American Psychologist, 69*(1): 66-78.

Greenberg, M. T., Kusche, C. A., Cook, E. T., and Quamma, J. P. (1995). Promoting Emotional Competence in School-Aged Children: The Effects of the PATHS Curriculum. *Development and Psychopathology*, *7*: 117-136.

Greenough, W.T., Black, J.E., and Wallace, C.S. (1987). Experience and Brain Development. *Child Development*, *58*(3): 539-559.

Gropen, J., Clark-Chiarelli, N., Hoisington, C., and Ehrlich, S. B. (2011). The Importance of Executive Function in Early Science Education. *Child Development Perspectives, 5*(4): 298-304.

Grossman, P., Niemann, L., Schmidt, S., and Walach, H. 2004. Mindfulness-Based Stress Reduction and Health Benefits. A Meta-Analysis. *Journal of Psychosomatic Research. 57*(1): 35-43.

Gunnar, M., and Quevedo, K. (2007). The Neurobiology of Stress and Development. *Annual Review of Psycholoogy, 58*: 145-173.

Gur, R.C., Richard, J., Calkins, M.E., Chiavacci, R., Hansen, J.A., Bilker, W.B., Loughead, J., Connolly, J.J., Qiu, H., Mentch, F.D., Abou-Sleiman, P.M., Hakonarson, H., and Gur, RE. (2012). Age Group and Sex Differences in Performance on a Computerized Neurocognitive Battery in Children Age 8-21. *Neuropsychology, 26*(2): 251-265. doi: 10.1037/A0026712

Hahn, C., Cowell, J.M., Wiprzycka, U.J., Goldstein, D., Ralph, M., Hasher, L., and Zelazo, P.D. (2012). Circadian Rhythms in Executive Function During the Transition to Adolescence: The Effect of Synchrony Between Chronotype and Time of Day. *Developmental Science, 15*(3): 408-416.

Harms, M.B., Zayae, V., Meltzoff, A.N., and Carlson, S.M. (2014). Stability of Executive Function and Predictions to Adaptive Behavior From Middle Childhood to Pre-Adolescence. *Frontiers in Psychology, 5*: 331. doi: 10.3389/Fpsyg.2014.00331

Hassinger-Das, B., Jordan, N.C., Glutting, J., Irwin, C., and Dyson, N. (2014). Domain-General Mediators of the Relation Between Kindergarten Number Sense and First-Grade Mathematics Achievement. *Journal of Experimental Child Psychology, 118*: 78-92.

Heckman, J.J., Stixrud, J., and Urzua, S. (2006). The Effects of Cognitive and Noncognitive Abilities on Labor Market Outcomes and Social Behavior. *Journal of Labor Economics, 24*(3): 411-482. doi: 10.1086/504455

Heeren, A., Van Broeck, N., and Philippot, P. (2009). The Effects of Mindfulness on Executive Processes and Autobiographical Memory Specificity. *Behaviour Research and Therapy, 47*(5): 403-409.

Hillman, C.H., Castelli, D.M., and Buck, S.M. (2005). Aerobic Fitness and Neurocognitive Function in Healthy Preadolescent Children. *Medicine and Science in Sports and Exercise, 37*(11): 1967.

Hillman, C.H., Pontifex, M.B., Raine, L.B., Castelli, D.M., Hall, E.E., and Kramer, A.F. (2009). The Effect of Acute Treadmill Walking on Cognitive Control and Academic Achievement in Preadolescent Children. *Neuroscience 159* (3): 1044-1054

^Hillman, C.H., Pontifex, M.B., Castelli, D.M., Khan, N.A., Raine, L.B., Scudder, M.R., Drollette, E.S., Moore, R.D., Wu, C-T. and Kamijo, K. (2014). Effects of the FITKids Randomized Controlled Trial on Executive Control and Brain Function. *Pediatrics*, *134*(4): e1063-e1071.

Hintze, J.M., Christ, T.J., and Methe, S.A. (2006). Curriculum-Based Assessment. *Psychology in the Schools, 43*(1): 45-56.

Hobson, C.W., Scott, S., and Rubia, K. (2011). Investigation of Cool and Hot Executive Function in ODD/CD Independently of ADHD. *Journal of Child Psychology and Psychiatry, 52*(10): 1035-1043.

Holmes, J., and Gathercole, S.E. (2014). Taking Working Memory Training From the Laboratory Into Schools. *Educational Psychology*, *34*(4): 440-450.

Holmes, A., and Wellman, C.L. (2009). Stress-Induced Prefrontal Reorganization and Executive Dysfunction in Rodents. *Neuroscience and Biobehavioral Reviews, 33*(6): 773-783.

Hongwanishkul, D., Happaney, K.R., Lee, W., and Zelazo, P.D. (2005). Assessment of Hot and Cool Executive Function in Young Children: Age-Related Changes and Individual Differences. *Developmental Neuropsychology, 28*(2): 617-644.

Hostinar, C.E., Sullivan, R.M., and Gunnar, M.R. (2014). Psychobiological Mechanisms Underlying the Social Buffering of the Hypothalamic–Pituitary–Adrenocortical Axis: A Review of Animal Models and Human Studies Across Development. *Psychological Bulletin, 140*(1): 256.

Hughes, C. (2011). Changes and Challenges in 20 Years of Research Into the Development of Executive Functions. *Infant and Child Development, 20*(3): 251-271. doi: 10.1002/icd.736

Hughes, C., and Ensor, R. (2007). Executive Function and Theory of Mind: Predictive Relations From Ages 2 to 4. *Developmental Psychology, 43*(6): 1447-1459.

Hughes, C., and Ensor, R. (2011). Individual Differences in Growth in Executive Function Across the Transition to School Predict Externalizing and Internalizing Behaviors and Self-Perceived Academic Success at 6 Years of Age. *Journal of Experimental Child Psychology, 108*(3): 663-676.

Hughes, C., Ensor, R., Wilson, A., and Graham, A. (2010). Tracking Executive Function Across the Transition to School: A Latent Variable Approach. *Developmental Neuropsychology, 35*(1): 20-36.

Hughes, C., Russell, J., and Robbins, T.W. (1994). Evidence for Executive Dysfunction in Autism. *Neuropsychologia, 32*(4): 477-492. doi: 10.1016/0028-3932(94)90092-2

Hughes, C., White, A., Sharpen, J., and Dunn, J. (2000). Antisocial, Angry, and Unsympathetic: "Hard-to-Manage" Preschoolers' Peer Problems and Possible Cognitive Influences. *Journal of Child Psychology and Psychiatry, 41*(2): 169–179.

Huizinga, M., Dolan, C.V., and van der Molen, M.W. (2006). Age-Related Change in Executive Function: Developmental Trends and a Latent Variable Analysis. *Neuropsychologia, 44*(11): 2017-2036.

Huttenlocher, P.R. (2002). *Neural Plasticity: The Effects of Environment on the Development of the Cerebral Cortex*. Cambridge, MA: Harvard University Press.

Isquith, P.K., Crawford, J.S., Espy, K.A., and Gioia, G.A. (2005). Assessment of Executive Function in Preschool-Aged Children. *Mental Retardation and Developmental Disabilities Research Reviews*, *11*: 209 – 215.

Isquith, P.K., Gioia, G.A., and Espy, K.A. (2004). Executive Function in Preschool Children: Examination Through Everyday Behavior. *Developmental Neuropsychology, 26*(1): 403-422.

Isquith, P.K., Roth, R.M., and Gioia, G. (2013). Contribution of Rating Scales to the Assessment of Executive Functions. *Applied Neuropsychology Child, 2*(2): 125-132. doi: 10.1080/21622965.2013.748389

Isquith, P.K., Roth, R.M., Kenworthy, L., and Gioia, G. (2014). Contribution of Rating Scales to Intervention for Executive Dysfunction. *Applied Neuropsychology Child, 3*(3): 197-204. doi: 10.1080/21622965.2013.870014

Jacob, R., and Parkinson, J. (2015). The Potential for School-Based Interventions That Target Executive Function to Improve Academic Achievement:A Review. *Review of Educational Research*, *85*(4): 512-552.

Jacques, S., and Marcovitch, S. (2010). Development of Executive Function Across the Life Span. In W. Overton (Ed.), *Handbook of Lifespan Development* (online). New York: Wiley. doi: 10.1002/9780470880166.hlsd001013

Jaeggi, S.M., Buschkuehl, M., Jonides, J., and Perrig, W.J. (2008). Improving Fluid Intelligence With Training on Working Memory. *Proceedings of the National Academy of Sciences, 105*(19): 6829-6833.

Johnson, M.H. (2011). Interactive Specialization: A Domain-General Framework for Human Functional Brain Development? *Developmental Cognitive Neuroscience, 1*(1): 7-21.

Jones, L.B., Rothbart, M.K., and Posner, M.I. (2003). Development of Executive Attention in Preschool Children. *Developmental Science, 6*(5): 498-504.

Just, M.A., and Carpenter, P.A. (1992). A Capacity Theory of Comprehension: Individual Differences in Working Memory. *Psychological Review*, *99*(1): 122.

Kalkut, E.L., Han, S.D., Lansing, A.E., Holdnack, J.A., and Delis, D.C. (2009). Development of Set-Shifting Ability From Late Childhood Through Early Adulthood. *Archives of Clinical Neuropsychology*: acp048.

Kane, M.J., and Engle, R.W. (2002). The Role of Prefrontal Cortex in Working-Memory Capacity, Executive Attention, and General Fluid Intelligence: An Individual-Differences Perspective. *Psychonomic Bulletin and Review, 9*(4): 637-671.

Kane, M.J., Hambrick, D.Z., and Conway, A.R. (2005). Working Memory Capacity and Fluid Intelligence are Strongly Related Constructs: Comment on Ackerman, Beier, and Boyle (2005). *Psychological Bulletin*, *131*(1): 66-71.

Karbach, J., and Kray, J. (2009). How Useful is Executive Control Training? Age Differences in Near and Far Transfer of Task-Switching Training. *Developmental Science, 12*(6): 978-990.

Karbach, J., and Unger, K. (2014) Executive Control Training From Middle Childhood to Adolescence. *Frontiers in Psychology, 5*: 390. doi: 10.3389/fpsyg.2014.00390

Karbach, J., Strobach, T., and Schubert, T. (2014). Adaptive Working-Memory Training Benefits Reading, but not Mathematics in Middle Childhood. *Child Neuropsychology*, *21*(3), 285-301.

Kenworthy, L., Yerys, B.E., Anthony, L.G., and Wallace, G.L. (2008). Understanding Executive Control in Autism Spectrum Disorders in the Lab and in the Real World. *Neuropsychology Review, 18*(4): 320-338.

Kerr, A., and Zelazo, P.D. (2004). Development of "Hot" Executive Function: The Children's Gambling Task. *Brain and Cognition, 55*(1): 148-157.

Kieffer, M.J., Vukovic, R.K., and Berry, D. (2013). Roles of Attention Shifting and Inhibitory Control in Fourth-Grade Reading Comprehension. *Reading Research Quarterly*. *48*: 333–348.

Kim, S., Nordling, J.K., Yoon, J.E., Boldt, L.J., and Kochanska, G. (2013). Effortful Control in "Hot" and "Cool" Tasks Differentially Predicts Children's Behavior Problems and Academic Performance. *Journal of Abnormal Child Psychology, 41*(1): 43-56.

Klingberg, T. (2006). Development of a Superior Frontal–Intraparietal Network for Visuo-Spatial Working Memory. *Neuropsychologia, 44*(11): 2171-2177.

Klingberg, T. (2010). Training and Plasticity of Working Memory. *Trends in Cognitive Sciences*, *14*(7): 317-324.

Klingberg, T. (2014). Childhood Cognitive Development as a Skill. *Trends in Cognitive Sciences, 18*(11): 573-579.

Klingberg, T., Fernell, E., Olesen, P.J., Johnson, M., Gustafsson, P., Dahlstrom, K., Gillberg, C.G., Forssberg, H., and Westerberg, H. (2005). Computerized Training of Working Memory in Children With ADHD-A Randomized, Controlled Trial. *Journal of the American Academy of Child and Adolescent Psychiatry, 44*(2): 177-186. doi: 10.1097/00004583-2005020000-00010

Kloo, D., Perner, J., Kerschhuber, A., Dabernig, S., and Alchhorn, M. (2008). Sorting Between Dimensions: Conditions of Cognitive Flexibility in Preschoolers. *Journal of Experimental Child Psychology, 100*(2): 115-134.

Kochanska, G., Murray, K., Jacques, T.Y., Koenig, A.L., and Vandegeest, K.A. (1996). Inhibitory Control in Young Children and its Role in Emerging Internalization. *Child Development, 67*(2): 490–507.

Kopp, C.B. (1989). Regulation of Distress and Negative Emotions: A Developmental View. *Developmental Psychology*, *25*(3): 343.

Kuhn, J.-T., and Holling, H. (2014). Number Sense or Working Memory? The Effect of Two Computer-Based Trainings on Mathematical Skills in Elementary School. *Advances in Cognitive Psychology*, *10*(2): 59–67. doi: 10.5709/acp-0157-2

Kyllonen, P.C., and Christal, R.E. (1990). Reasoning Ability Is (Little More Than) Working-Memory Capacity?! *Intelligence*, *14*(4): 389-433.

Lalonde, G., Henry, M., Drouin-Germain, A., Nolin, P., and Beauchamp, M.H. (2013). Assessment of Executive Function in Adolescence: A Comparison of Traditional and Virtual Reality Tools. *Journal of Neuroscience Methods*, *219*: 76–82. doi: 10.1016/j.jneumeth.2013.07.005.

Langberg, J.M., Dvorsky, M.R., and Evans, S.W. (2013). What Specific Facets of Executive Function are Associated With Academic Functioning in Youth With Attention-Deficit/Hyperactivity Disorder? *Journal of Abnormal Child Psychology, 41*(7): 1145-1159. doi: 10.1007/s10802-013-9750-z

Law, A., Logie, R., and Pearson, D. (2006). The Impact of Secondary Tasks on Multitasking in a Virtual Environment. *Acta Psychologica*, *122*(1): 27-44. doi: 10.1016/j.actpsy.2005.09.002

Lee, K., Bull, R., and Ho, R.M. (2013). Developmental Changes in Executive Functioning. *Child Development, 84*(6): 1933-1953. doi: 10.1111/cdev.12096

Lehto, J.E., Juujarvi, P., Kooistra, L., and Pulkkinen, L. (2003). Dimensions of Executive Functioning: Evidence From Children. *British Journal of Developmental Psychology, 21*(1): 59-80.

Lerner, M.D., and Lonigan, C.J. (2014). Executive Function Among Preschool Children: Unitary Versus Distinct Abilities. *Journal of Psychopathology and Behavioral Assessment*, *36*(4): 626–639. doi: 10.1007/s10862-014-9424-3

Levin, H.S., Culhane, K.A., Hartmann, J., Evankovich, K., Mattson, A.J., Harward, H., Ringholz, G., Ewing-Cobbs, L., and Fletcher, J.M. (1991). Developmental-Changes in Performance on Tests of Purported Frontal-Lobe Functioning. *Developmental Neuropsychology, 7*(3): 377-395.

Liehr, P., and Diaz, N. (2010). A Pilot Study Examining the Effect of Mindfulness on Depression and Anxiety for Minority Children. *Archives of Psychiatric Nursing, 24*(1): 69-71.

Liew, J. (2012). Effortful Control, Executive Functions, and Education: Bringing Self-Regulatory and Social-Emotional Competencies to the Table. *Child Development Perspectives, 6*(2): 105-111.

Liston, C., McEwen, B.S., and Casey, B.J. (2009). Psychosocial Stress Reversibly Disrupts Prefrontal Processing and Attentional Control. *Proceedings of the National Academy of Sciences*, *106*(3): 912-917.

Logie, R.H., Trawley, S. and Law, A. (2011). Multitasking: Multiple, Domain-Specific Cognitive Functions in a Virtual Environment. *Memory and Cognition*, *39*(8): 1561. doi: 10.3758/s13421-011-0120-1

Loosli, S.V., Buschkuehl M., Perrig W.J., and Jaeggi S.M. (2012). Working Memory Training Improves Reading Processes in Typically Developing Children. *Child Neuropsycholy, 18*(1): 62–78.

Luciana, M., Lindeke, L., Georgieff, M., Mills, M., and Nelson, C.A. (1999). Neurobehavioral Evidence for Working Memory Deficits in School-Aged Children With Histories of Prematurity. *Developmental Medicine and Child Neurology, 41*(8): 521-533. doi: 10.1017/S0012162299001140

Luciana, M., and Nelson, C.A. (2002). Assessment of Neuropsychological Function Through Use of the Cambridge Neuropsychological Testing Automated Battery: Performance in 4- to 12-Year-Old Children. *Developmental Neuropsychology, 22*(3): 595-624.

Luna, B., Garver, K.E., Urban, T.A., Lazar, N.A., and Sweeney, J.A. (2004). Maturation of Cognitive Processes From Late Childhood to Adulthood. *Child Development, 75*(5): 1357-1372.

Luna, B., Paulsen, D.J., Padmanabhan, A., and Geier, C. (2013). The Teenage Brain Cognitive Control and Motivation. *Current Directions in Psychological Science*, *22*(2): 94-100.

Lupien, S.J., McEwen, B.S., Gunnar, M.R., and Heim, C. (2009). Effects of Stress Throughout the Lifespan on the Brain, Behaviour and Cognition. *Nature Reviews Neuroscience*, *10*(6), 434-445.

Lyons, K.E., and Zelazo, P.D. (2011). Monitoring, Metacognition, and Executive Function: Elucidating the Role of Self-Reflection in the Development of Self-Regulation. *Advances in Child Development and Behavior, 40*: 379-412.

Mackey, A.P., Hill, S.S., Stone, S.I., and Bunge, S.A. (2011). Differential Effects of Reasoning and Speed Training in Children. *Developmental Science, 14*(3): 582-590.

Maeir, A., Krauss, S., and Katz, N. (2011). Ecological Validity of the Multiple Errands Test (MET) on Discharge From Neurorehabilitation Hospital. *OTJR: Occupation, Participation and Health*, *31*(s1): s38 - s46. doi: 10.3928/15394492-20101108-07

Magar, E.C.E., Phillips, L.H., and Hosie, J.A. (2010). Brief Report: Cognitive-Regulation Across the Adolescent Years. *Journal of Adolescence, 33*(5): 779-781. doi: 10.1016/j.adolescence.2009.10.002

Maguire, E.A., Gadian, D.G., Johnsrude, I.S., Good, C.D., Ashburner, J., Frackowiak, R.S.J., and Frith, C.D. (2000). Navigation-Related Structural Change in the Hippocampi of Taxi Drivers. *Proceedings of the National Academy of Sciences, 97*(8): 4398-4403.

Mahone E.M., Cirino P.T., Cutting L.E., Cerrone P.M., Hagelthorn K.M., and Hiemenz J.R., (2002). Validity of the Behavior Rating Inventory of Executive Function in Children With ADHD and/or Tourette Syndrome. *Archives of Clinical Neuropsychology*, *17*: 643–662.

Mahone E.M., and Hoffman J. (2007). Behavior Ratings of Executive Function Among Pre-Schoolers With ADHD. *Clinical Neuropsychologist. 21*: 569–586.

Marcovitch, S., Jacques, S., Boseovski, J.J., and Zelazo, P.D. (2008). Self-Reflection and the Cognitive Control of Behavior: Implications for Learning. *Mind, Brain, and Education, 2*(3): 136-141.

Marcovitch, S., and Zelazo, P.D. (2009). A Hierarchical Competing Systems Model of the Emergence and Early Development of Executive Function (Target article with commentaries). *Developmental Science, 12*: 1-18.

Masten, A.S., Herbers, J.E., Desjardins, C.D., Cutuli, J.J., McCormick, C.M., Sapienza, J.K., Long, J.D., and Zelazo, P.D. (2012). Executive Function Skills and School Success in Young Children Experiencing Homelessness. *Educational Researcher, 41*(9): 375-384. doi: 10.3102/0013189x12459883

Mattay V.S., Goldberg T.E., Fera F., Hariri A.R., Tessitore A., Egan M.F., Kolachana B., Callicott J.H., and Weinberger D.R. (2003). Catechol-O-Methyltransferase Val158Met Genotype and Individual Variation in the Brain Response to Amphetamine. *Proceedings of the National Academy of Sciences*, *100*: 6186–6191.

Mazzocco, M.M.M., and Kover, S.T. (2007). A Longitudinal Assessment of Executive Function Skills and Their Association With Math Performance. *Child Neuropsychology, 13*(1): 18-45.

McClelland, M.M., Acock A.C., and Morrison, F.J. (2006). The Impact of Kindergarten Learning-Related Skills on Academic Trajectories at the End of Elementary School. *Early Childhood Research Quarterly, 21*(4): 471-490. doi: 10.1016/j.ecresq.2006.09.003

McClelland, M.M., Acock, A.C., Piccinin, A., Rhea, S.A., and Stallings, M.C. (2013). Relations Between Preschool Attention Span-Persistence and age 25 Educational Outcomes. *Early Childhood Research Quarterly*, *28*(2): 314-324.

McClelland, M.M., Cameron, C.E., Connor, C.M., Farris, C.L., Jewkes, A.M., and Morrison, F.J. (2007). Links Between Behavioral Regulation and Preschoolers' Literacy, Vocabulary, and Math Skills. *Developmental Psychology, 43*(4): 947-959. doi: 10.1037/0012-1649.43.4.947

McClelland, M.M., Cameron, C.E., Duncan, R., Bowles, R.P., Acock, A.C., Miao, A., and Pratt, M.E. (2014). Predictors of Early Growth in Academic Achievement: The Head-Toes-Knees-Shoulders Task. *Frontiers in Psychology, 5*: 599. doi: 10.3389/fpsyg.2014.00599

McGeorge, P., Phillips, L.H., Crawford, J.R., Garden, S.E., Della Sala, S., and Milne, A.B. (2001). Using Virtual Environments in the Assessment of Executive Dysfunction. *Presence-Teleoperators and Virtual Environments*, *10*(4): 375-383.

McGrew, K.S., and Hessler, G.L. (1995). The Relationship Between the WJ–R Gf–Gc Cognitive Clusters and Mathematics Achievement Across the Lifespan.. *Journal of Psychoeducational Assessment*, *13*: 21–38.

McLean, J.F., and Hitch, G.J. (1999). Working Memory Impairments in Children With Specific Arithmetic Learning Difficulties. *Journal of Experimental Child Psychology*, *74*(3): 240-260.

McNab, F., Varrone, A., Farde, L., Jucaite, A., Bystritsky, P., Forssberg, H., and Klingberg, T. (2009). Changes in Cortical Dopamine D1 Receptor Binding Associated With Cognitive Training. *Science*, *323*(5915): 800-802.

Melby-Lervåg, M., and Hulme, C. (2013). Is Working Memory Training Effective? A Meta-Analytic Review. *Developmental Psychology*, *49*(2): 270-291.

Melby-Lervåg, M., Redick, T. S., and Hulme, C. (2016). Working Memory Training Does Not Improve Performance on Measures of Intelligence or Other Measures of "Far Transfer" Evidence From a Meta-Analytic Review.*Perspectives on Psychological Science*, *11*(4): 512-534.

Mendelson, T., Greenberg, M.T., Dariotis, J.K., Gould, L.F., Rhoades, B.L., and Leaf, P.J. (2010). Feasibility and Preliminary Outcomes of a School-Based Mindfulness Intervention for Urban Youth. *Journal of Abnormal Child Psychology, 38*(7): 985-994.

Meuwissen, A.S., and Zelazo, P.D. (2014). Hot and Cool Executive Function: Foundations for Learning and Healthy Development. *Zero to Three, 35*(2): 18-23.

Mezzacappa, E. (2004). Alerting, Orienting, and Executive Attention: Developmental Properties and Sociodemographic Correlates in an Epidemiological Sample of Young, Urban Children. *Child Development*, *75*(5): 1373-1386.

Mier, D., Kirsch, P., and Meyer-Lindenberg, A. (2010). Neural Substrates of Pleiotropic Action of Genetic Variation in COMT: a Meta-analysis. *Molecular Psychiatry, 15*(9): 918–927.

Miller, E.K., and Cohen, J.D. (2001). An Integrative Theory of Prefrontal Cortex Function. *Annual Review of Neuroscience, 24*: 167-202.

Miller, M.R., Giesbrecht, G.F., Müller, U., McInerney, R.J., and Kerns, K.A. (2012). A Latent Variable Approach to Determining the Structure of Executive Function in Preschool Children. *Journal of Cognition and Development, 13*(3): 395-423. doi: 10.1080/15248372.2011.585478

Milner, B. (1963). Effects of Different Brain Lesions on Card Sorting. *Archives of Neurology, 9*(1): 90-100.

Mischel, W., Shoda, Y., and Peake, P.K. (1988). The Nature of Adolescent Competencies by Preschool Delay of Gratification. *Journal of Personality and Social Psychology, 54*(4): 687-696.

Mischel, W., Shoda, Y., and Rodriguez, M.L. (1989). Delay of Gratification in Children. *Science, 244*(4907): 933-938.

Miyake, A., and Friedman, N.P. (2012). The Nature and Organization of Individual Differences in Executive Functions, Four General Conclusions. *Current Directions in Psychological Science*, *21*(1): 8-14.

Miyake, A., Emerson, M.J., and Friedman, N.P. (2000). Assessment of Executive Functions in Clinical Settings: Problems and Recommendations. *Seminars in Speech and Language*, *21*: 169–183.

Miyake, A., Friedman, N.P., Emerson, M.J., Witzki, A.H., Howerter, A., and Wager, T.D. (2000). The Unity and Diversity of Executive Functions and Their Contributions to Complex "Frontal Lobe" Tasks: A Latent Variable Analysis. *Cognitive Psychology, 41*(1): 49-100.

Moffitt, T.E., Arseneault, L., Belsky, D., Dickson, N., Hancox, R.J., Harrington, H., Houts, R., Poulton, R., Roberts, B.W., Ross, S., Sears, M.R., Thomson, W.M., and Caspi, A. (2011). A Gradient of Childhood Self-Control Predicts Health, Wealth, and Public Safety. Proceedings of the National Academy of Sciences of the United States of America, 108(7): 2693-2698. doi: 10.1073/pnas.1010076108

Molfese, D.L., Ivanenko, A., Key, A.F., Roman, A., Molfese, V.J., O'Brien, L.M., ... and Hudac, C.M. (2013). A One-Hour Sleep Restriction Impacts Brain Processing in Young Children Across Tasks: Evidence From Event-Related Potentials. *Developmental Neuropsychology*, *38*(5): 317-336.

Monette, S., Bigras, M., and Guay, M-C. (2011) The Role of the Executive Functions in School Achievement at the End of Grade 1. *Journal of Experimental Child Psychology, 109*(2): 158-173.

Moriguchi, Y., and Hiraki, K. (2009). Neural Origin of Cognitive Shifting in Young Children. *Proceedings of the National Academy of Sciences*, *106*(14): 6017-6021.

Moriguchi, Y., Sakata, Y., Ishibashi, M., and Ishikawa, Y. (2015) Teaching Others Rule-Use Improves Executive Function and Prefrontal Activations in Young Children. *Frontiers in Psychology, 6*:894. doi: 10.3389/fpsyg.2015.00894

Morris, P., Mattera, S.K., Castells, N., Bangser, M., Bierman, K., and Raver, C. (2014). *Impact Findings From the Head Start CARES Demonstration: National Evaluation of Three Approaches to Improving Preschoolers' Social and Emotional Competence*, *OPRE Report 2014-44*. Washington, DC: Office of Planning, Research and Evaluation, Administration for Children and Families, U.S. Department of Health and Human Services.

Morrison, M.T., Giles, G.M., Ryan, J.D., Baum, C.M., Dromerick, A.W., Polatajko, H.J., and Edwards, D.F. (2013). Multiple Errands Test–Revised (MET–R): A Performance-Based Measure of Executive Function in People With Mild Cerebrovascular Accident. *American Journal of Occupational Therapy*, *67*(4): 460-468.

Morrison, F.J., Ponitz, C.C., and McClelland, M.M. (2010). Self-Regulation and Academic Achievement in the Transition to School. In S.D. Calkins, and M.A. Bell, (Eds.), *Child Development at the Intersection of Emotion and Cognition*: *Human Brain Development* (pp. 203-224). Washington, DC: American Psychological Association. doi: 10.1037/12059-011

Mulder, H., Pitchford, N.J., Hagger, M.S., and Marlow, N. (2009). Development of Executive Function and Attention in Preterm Children: A Systematic Review. *Developmental Neuropsychology, 34*(4): 393-421.

Mulder, H., Hoofs, H., Verhagen, J., van der Veen, I., and Leseman, P.P. (2014). Psychometric Properties and Convergent and Predictive Validity of an Executive Function Test Battery for Two-Year-Olds. *Frontiers in Psychology, 5*: 733. doi: 10.3389/fpsyg.2014.00733

Müller, U., and Kerns, K. (2015). The Development of Executive Function. In L.S. Liben, U. Müller and R.M. Lerner (Eds.), *Handbook of Child Psychology and Developmental Science*, *Vol. 2: Cognitive Processes* (7th ed.) (pp. 571-623). Hoboken, NJ: Wiley.

Munakata, Y., Snyder, H.R., and Chatham, C.H. (2012). Developing Cognitive Control: Three Key Transitions. *Current Directions in Psychological Science, 21*(2): 71-77. doi: 10.1177/0963721412436807

Munakata, Y., Snyder, H.R., and Chatham, C.H. (2013). Developing Cognitive Control: The Costs and Benefits of Active, Abstract Representations. In Zelazo P. and M. Sera (Eds). *Developing Cognitive Control Processes: Mechanisms, Implications, and Interventions*, *Vol. 37* (pp. 55–90). Mahwah, NJ: Erlbaum.

Mungas, D., Widaman, K., Zelazo, P.D., Tulsky, D., Heaton, R.K., Slotkin, J., and Gershon, R.C. (2013). Vii. NIH Toolbox Cognition Battery (CB): Factor Structure for 3- to 15-Year-Olds. *Monographs of the Society for Research in Child Development, 78*(4): 103-118. doi: 10.1111/Mono.12037

Naglieri, J.A., and Goldstein, S. (2013). *Comprehensive Executive Function Inventory*. North Tonawanda, NY: Multi-Health Systems.

[#]Napoli, M., Krech, P.R., and Holley, L.C. (2005). Mindfulness Training for Elementary School Students: The Attention Academy. *Journal of Applied School Psychology, 21*(1): 99-125.

Nayfeld, I., Fuccillo, J., and Greenfield, D.B. (2013). Executive Functions in Early Learning: Extending the Relationship Between Executive Functions and School Readiness to Science. *Learning and Individual Differences, 26*: 81-88.

Nesbitt, K.T., Baker-Ward, L., and Willoughby, M.T. (2013). Executive Function Mediates Socio-Economic and Racial Differences in Early Academic Achievement. *Early Childhood Research Quarterly*, *28*(4): 774-783.

^Neville, H.J., Stevens, C., Pakulak, E., Bell, T.A., Fanning, J., Klein, S., and Isbell, E. (2013). Family-Based Training Program Improves Brain Function, Cognition, and Behavior in Lower Socioeconomic Status Preschoolers.*Proceedings of the National Academy of Sciences, 110*(29): 12138-12143.

Nigg, J.T. (2001). Is ADHD a Disinhibitory Disorder?. *Psychological Bulletin*, *127*(5): 571.

Nigg, J.T., and Casey, B.J. (2005). An Integrative Theory of Attention-Deficit/Hyperactivity Disorder Based on the Cognitive and Affective Neurosciences. *Development and Psychopathology, 17*(3): 785-806.

Nigg, J.T., Willcutt, E.G., Doyle, A.E., and Sonuga-Barke, E.J.S. (2005). Causal Heterogeneity in Attention-Deficit/Hyperactivity Disorder: Do we Need Neuropsychologically Impaired Subtypes? *Biological Psychiatry, 57*(11): 1224-1230.

Nilsen E.S., Huyder V., McAuley T., and Liebermann D. (2016). Ratings of Everyday Executive Functioning (REEF): A Parent-Report Measure of Preschoolers' Executive Functioning Skills. *Psychological Assessment.* Apr 7. [Epub ahead of print]. doi: 10.1037/pas0000308

Noble, K.G., Norman, M.F., and Farah, M.J. (2005). Neurocognitive Correlates of Socioeconomic Status in Kindergarten Children. *Developmental Science, 8*(1): 74-87.

Noël, X., Brevers, D., and Bechara, A. (2013). A Neurocognitive Approach to Understanding the Neurobiology of Addiction. *Current Opinion in Neurobiology, 23*(4): 632–638. doi: 10.1016/j.conb.2013.01.018

Obradović, J. (2010). Effortful Control and Adaptive Functioning of Homeless Children: Variable-Focused and Person-Focused Analyses. *Journal of Applied Developmental Psychology*, *31*(2): 109-117.

O'Hearn K., Asato M., Ordaz S., and Luna B. (2008). Neurodevelopment and Executive Function in Autism. *Developmental Psychopathology*, *20*(4): 1103-32. doi: 10.1017/S0954579408000527

Olesen, P.J., Westerberg, H., and Klingberg, T. (2003). Increased Prefrontal and Parietal Activity After Training of Working Memory. *Nature Neuroscience, 7*(1): 75-79.

Ordaz, S.J., Foran, W., Velanova, K., and Luna, B. (2013). Longitudinal Growth Curves of Brain Function Underlying Inhibitory Control Through Adolescence. *Journal of Neuroscience, 33*(46): 18109-18124. doi: 10.1523/Jneurosci.1741-13.2013

Ortner, C.M.N., and Kilner, S., and Zelazo, P.D. (2007). Mindfulness Meditation and Emotional Interference in a Simple Cognitive Task. *Motivation and Emotion, 31*(4): 271-283.

Parker, K.J., and Maestripieri, D. (2011). Identifying Key Features of Early Stressful Experiences That Produce Stress Vulnerability and Resilience in Primates. *Neuroscience and Biobehavioral Reviews, 35*(7): 1466-1483.

Parsons, T.D., Carlew, A.R., Magtoto, J., and Stonecipher, K. (2015). The Potential of Function-Led Virtual Environments for Ecologically Valid Measures of Executive Function in Experimental and Clinical Neuropsychology. *Neuropsychological Rehabilitation*: 1-31.

Passler, M.A., Isaac, W., and Hynd, G.W. (1985). Neuropsychological Development of Behavior Attributed to Frontal Lobe Functioning in Children. *Developmental Neuropsychology, 1*(4): 349-370.

Passolunghi, M.C., and Costa, H.M. (2016). Working Memory and Early Numeracy Training in Preschool Children. *Child Neuropsychology, 22*(1): 81-98.

Pears, K.C., Fisher, P.A., Kim, H.K., Bruce, J., Healey, C.V., and Yoerger, K. (2013). Immediate Effects of a School Readiness Intervention for Children in Foster Care. *Early Education & Development*, *24*(6): 771-791.

Pennington, B.F., Groisser, D., and Welsh, M.C. (1993). Contrasting Cognitive Deficits in Attention Deficit Hyperactivity Disorder Versus Reading Disability. *Developmental Psychology, 29*(3): 511-523.

Petersen, S.E., and Posner, M.I. (2012). The Attention System of the Human Brain: 20 Years After. *Annual Review of Neuroscience*, *35*: 73-89.

Peterson, E., and Welsh, M.C. (2014). The Development of Hot and Cool Executive Functions in Childhood and Adolescence: Are We Getting Warmer? In S. Goldstein and J.A. Naglieri (Eds.), *Handbook of Executive Functioning* (pp.45-65). New York: Springer. doi 10.1007/978-1-4614-8106-5_4

Pietrefesa, A.S., and Evans, D.W. (2007). Affective and Neuropsychological Correlates of Children's Rituals and Compulsive-Like Behaviors: Continuities and Discontinuities With Obsessive–Compulsive Disorder. *Brain and Cognition*, *65*(1): 36-46.

Pluess, M., and Belsky, J. (2010). Differential Susceptibility to Parenting and Quality Child Care. *Developmental Psychology*, *46*(2): 379-390.

Posner, M.I., and Rothbart, M.K. (2000). Developing Mechanisms of Self-Regulation. *Development and Psychopathology, 12*(3): 427-441.

Posner, M.I., and Rothbart, M.K. (2007). Research on Attention Networks as a Model for the Integration of Psychological Science. *Annual Review of Psychology, 58*: 1-23.

Powers, K.L., Brooks, P.J., Aldrich, N.J., Palladino, M.A., and Alfieri, L. (2013). Effects of Video-Game Play on Information Processing: A Meta-Analytic Investigation. *Psychonomic Bulletin and Review, 20*(6): 1055-1079.

Prencipe, A., Kesek, A., Cohen, J., Lamm, C., and Zelazo, P.D. (2011). Development of Hot and Cool Executive Function During the Transition to Adolescence. *Journal of Experimental Child Psychology, 108*: 621-637.

Prencipe, A., and Zelazo, P.D. (2005). Development of Affective Decision-Making for Self and Other: Evidence for the Integration of First- and Third-Person Perspectives. *Psychological Science, 16*(7): 501-505.

Qin, S., Cousijn, H., Rijpkema, M., Luo, J., Franke, B., Hermans, E., and Fernández, G. (2012). The Effect of Moderate Acute Psychological Stress on Working Memory-Related Neural Activity Is Modulated by a Genetic Variation in Catecholaminergic Function in Humans. *Frontiers in Integrative Neuroscience*, *6*: 16.

Rabin, L.A., Roth, R.M., Isquith, P.K., Wishart, H.A., Nutter-Upham, K.E., Pare, N., ... and Saykin, A.J. (2006). Self-and Informant Reports of Executive Function on the BRIEF-A in MCI and Older Adults With Cognitive Complaints. *Archives of Clinical Neuropsychology*, *21*(7): 721-732.

Rapport, M.D., Orban, S.A., Kofler, M.J., and Friedman, L.M. (2013). Do Programs Designed to Train Working Memory, Other Executive Functions, and Attention Benefit Children With ADHD? A Meta-Analytic Review of Cognitive, Academic, and Behavioral Outcomes. *Clinical Psychology Review*, *33*(8): 1237-1252.

Raspelli, S., Pallavicini, F., Carelli, L., Morganti, F., Poletti, B., Corra, B., ... and Riva, G. (2010). Validation of a Neuro Virtual Reality-Based Version of the Multiple Errands Test for the Assessment of Executive Functions. *Studies in Health Technology and Informatics*, *167*: 92-97.

Raver, C.C., Jones, S.T., Li-Grining, C., Zhai, F., Metzger, M., and Solomon B. (2009). Targeting Children's Behavior Problems in Preschool Classrooms: A Cluster-Randomized Controlled Trial. *Journal of Consulting and Clinical Psychology, 77*(2): 302-316.

Raver, C.C., Li-Grining, C., Bub, K., Jones, S.M., Zhai, F., and Pressler, E. (2011). CSRP's Impact on Low-Income Preschoolers' Preacademic Skills: Self-Regulation as a Mediating Mechanism. *Child Development, 82*(1): 362-378.

Rebok, G., Smith, C., Pascualvaca, D., Mirsky, A., Anthony, B., and Kellam, S. (1996). Developmental Changes in Attentional Performance in Urban Children From Eight to Thirteen Years. *Child Neuropsychology, 3*(1): 28-46.

Redick, T.S., Broadway, J.M., Meier, M.E., Kuriakose, P.S., Unsworth, N., Kane, M.J., and Engle, R.W. (2012). Measuring Working Memory Capacity With Automated Complex Span Tasks. *European Journal of Psychological Assessment, 28*(3): 164–171. doi: 10.1027/1015-5759/a000123

Renison, B., Ponsford, J., Testa, R., Richardson, B., and Brownfield, K. (2012). The Ecological and Construct Validity of a Newly Developed Measure of Executive Function: The Virtual Library Task. *Journal of the International Neuropsychological Society*, *18*(03): 440-450.

Riggs, N., Blair, C., and Greenberg, M. (2003). Concurrent and 2-Year Longitudinal Relations Between Executive Function and the Behavior of 1st and 2nd Grade Children. *Child Neuropsychology, 9*(4): 267-276.

Roberts, G., Quach, J., Spencer-Smith, M., Anderson, P.J., Gathercole, S.E., Gold, L., Sia, K-L., Mensah, F., Rickards, F., Ainley, J., and Wake, M. (2016). Academic Outcomes 2 Years After Working Memory Training for Children With Low Working Memory: A Randomized Clinical Trial. *JAMA Pediatrics*. [Epub ahead of print] doi: 10.001/jamapediatrics.2015.4568

Rocke, K., Hays, P., Edwards, D., and Berg, C. (2008). Development of a Performance Assessment of Executive Function: The Children's Kitchen Task Assessment. *American Journal of Occupational Therapy*, *62*(5): 528-537.

Roid, G.H. (2003). *Stanford-Binet Intelligence Scales*. Itasca, IL: Riverside Publishing.

Romine, C.B., and Reynolds, C.R. (2005). Model of the Development of Frontal Lobe Functioning: Findings From a Meta-Analysis. *Applied Neuropsychology, 12*(4): 190-201.

Roth, R.M., Lance, C.E., Isquith, P.K., Fischer, A.S., and Giancola, P.R. (2013). Confirmatory Factor Analysis of the Behavior Rating Inventory of Executive Function-Adult Version in Healthy Adults and Application to Attention-Deficit/Hyperactivity Disorder. *Archives of Clinical Neuropsychology*, *28*(5): 425-434.

Rothbart, M.K. (2011). *Becoming who we are: Temperament, Personality and Development*. New York: Guilford Press.

Rothbart, M.K., and Ahadi, S.A. (1994). Temperament and the Development of Personality. *Journal of Abnormal Psychology, 103*(1): 55-66.

Rueda, M.R., Rothbart, M.K., McCandliss, B.D., Saccomanno, L., and Posner, M.I. (2005). Training, Maturation, and Genetic Influences on the Development of Executive Attention. *Proceedings of the National Academy of Sciences, 102*(41): 14931-14936.

Rypma, B., and Prabhakaran, V. (2009). When Less is More and When More is More: The Mediating Roles of Capacity and Speed in Brain-Behavior Efficiency. *Intelligence*, *37*(2): 207-222.

Salomon, G., and Perkins, D.N. (1989). Rocky Roads to Transfer: Rethinking Mechanism of a Neglected Phenomenon. *Educational Psychologist*, *24*(2): 113-142.

Sbordone, R.J. (2001). Limitations of Neuropsychological Testing to Predict the Cognitive and Behavioral Functioning of Persons With Brain Injury in Real-World Settings. *NeuroRehabilitation, 16*(4): 199-201.

Sbordone, R.J., and Purisch, A.D. (1996). Hazards of Blind Analysis of Neuropsychological Test Data in Assessing Cognitive Disability: The Role of Confounding Factors. *NeuroRehabilitation, 7*(1): 15-26. doi 10.3233/NRE-1996-7103

Schaie, K.W. (1994). The Course of Adult Intellectual Development. *American Psychologist, 49*(4): 304-313.

Schickedanz, J.A., and Dickinson, D.K. (2005). *Opening the World of Learning: A Comprehensive Early Literacy Program*. Pearson Early Learning.

Schmiedek, F., Lövdén, M., and Lindenberger, U. (2014). A Task is a Task is a Task: Putting Complex Span, N-Back, and Other Working Memory Indicators in Psychometric Context. *Frontiers in Psychology*, *5*: 1475.

Schmitt, S.A., McClelland, M.M., Tominey, S.L., and Acock, A.C. (2015). Strengthening School Readiness for Head Start Children: Evaluation of a Self-Regulation Intervention. *Early Childhood Research Quarterly*, *30*: 20-31.

Schoemaker, K., Bunte, T., Wiebe, S.A., Espy, K.A., Dekovic, M., and Matthys, W. (2012). Executive Function Deficits in Preschool Children With ADHD and DBD. *Journal of Child Psychology and Psychiatry, 53*(2): 111-119. doi: 10.1111/j.1469-7610.2011.02468.x

Schwaighofer, M., Fischer, F., and Bühner, M. (2015). Does Working Memory Training Transfer? A Meta-Analysis Including Training Conditions as Moderators. *Educational Psychologist*, *50*(2): 138-166.

Séguin, J.R. (2004). Neurocognitive Elements of Antisocial Behavior: Relevance of an Orbitofrontal Cortex Account. *Brain and Cognition*, *55*(1): 185-197.

Séguin, J.R. and Zelazo, P.D. (2005). Executive Function in Early Physical Aggression. In R.E. Tremblay, W.W. Hartup, and J. Archer (Eds.), *Developmental Origins of Aggression* (pp. 307-329). New York: Guilford.

Semple, R.J., Lee, J., Rosa, D., and Miller, L.F. (2010). A Randomized Trial of Mindfulness-Based Cognitive Therapy for Children: Promoting Mindful Attention to Enhance Social-Emotional Resiliency in Children. *Journal of Child and Family Studies, 19*(2): 218-229.

Sesma, H.W., Mahone, E.M., Levine, T., Eason, S.H., and Cutting, L.E. (2009). The Contribution of Executive Skills to Reading Comprehension. *Child Neuropsychology*, *15*(3): 232-246.

Shallice, T.I.M., and Burgess, P.W. (1991). Deficits in Strategy Application Following Frontal Lobe Damage in Man. *Brain*, *114*(2): 727-741.

Shapiro, S.L., Lyons, K.E., Miller, R.C., Butler, B., Vieten, C., and Zelazo, P.D. (2014). Contemplation in the Classroom: A New Direction for Improving Self-Regulation in Early Childhood. *Educational Psychology Review, 27*(1): 1-30.

Shaw, S., Oei, T.P., and Sawang, S. (2015). Psychometric Validation of the Dysexecutive Questionnaire (DEX). *Psychological Assessment*, *27*(1): 138.

Sheridan, M., Kharitonova, M., Martin, R.E., Chatterjee, A., and Gabrieli, J.D.E. (2014). Neural Substrates of the Development of Cognitive Control in Children Ages 5-10 Years. *Journal of Cognitive Neuroscience, 26*(8): 1840-1850. doi: 10.1162/Jocn_a_00597

Schneider, W., and Shiffrin, R.M. (1977). Controlled and Automatic Human Information Processing: I. Detection, Search, and Attention. *Psychological Review*, *84*(1): 1.

Shiner, R.L., and DeYoung, C.G. (2013). The Structure of Temperament and Personality Traits: A Developmental Perspective. In P. Zelazo (Ed.), *Oxford Handbook of Developmental Psychology, Vol. 2*, (pp. 113-141). New York: Oxford University Press.

Shing, Y.L., Lindenberger, U., Diamond, A., Li, S.C., and Davidson, M.C. (2010). Memory Maintenance and Inhibitory Control Differentiate From Early Childhood to Adolescence. *Developmental Neuropsychology, 35*(6): 679-697.

Shipstead, Z., Redick, T.S., and Engle, R.W. (2012). Is Working Memory Training Effective?. *Psychological Bulletin, 138*(4): 628.

Short, S.J., Elison, J.T., Goldman, B.D., Styner, M., Gu, H., Connelly, M., Maltie, E.., Wilson, S., Lin, W., Gerig, G., Resnick. J.S., and Gilmore, J.H. (2013). Associations Between White Matter Microstructure and Infants' Working Memory. *NeuroImage*, *64*: 156-166. doi: 10.1016/j.neuroimage.2012.09.021

Siegler, R.S., and Pyke, A.A. (2013). Developmental and Individual Differences in Understanding of Fractions. *Developmental Psychology*, *49*(10): 1994.

Silver, C.H. (2014). Sources of Data About Children's Executive Functioning: Review and Commentary. *Child Neuropsychology, 20*(1): 1-13. doi: 10.1080/09297049.2012.727793

Söderqvist, S., and Nutley, S.B. (2015). Working Memory Training is Associated With Long Term Attainments in Math and Reading. *Frontiers in Psychology*: 6.

Solanto, M.V., Abikoff, H., Sonuga-Barke, E., Schachar, R., Logan, G.D., Wigal, T., et al. (2001). The Ecological Validity of Delay Aversion and Response Inhibition as Measures of Impulsivity in AD/HD: A Supplement to NIMH Multimodal Treatment Study of AD/HD. *Abnormal Child Psychology, 29*(3): 215–228.

Speltz, M., Deklyen, M., Calderon, R., Greenberg, M., and Fisher, P. (1999). Neuropsychological Characteristics and Test Behaviors of Boys With Early Onset Conduct Problems. *Journal of Abnormal Psychology, 108*(2): 315-325.

Spencer-Smith, M., and Klingberg, T. (2015). Benefits of a Working Memory Training Program for Inattention in Daily Life: A Systematic Review and Meta-Analysis. *PLoS ONE*, *10*(3):e0119522. doi: 10.1371/journal.pone.0119522

St. Clair-Thompson, H.L., and Gathercole, S.E. (2006). Executive Functions and Achievements in School: Shifting, Updating, Inhibition, and Working Memory. *Quarterly Journal of Experimental Psychology, 59*(4): 745-759.

Steinberg, L. (2010). A Dual Systems Model of Adolescent Risk-Taking. *Developmental Psychobiology, 52*(3): 216–224.

Sulik, M., Daneri, P., Pintar, A., and Blair, C. (2015). Self-Regulation in Early Childhood. In C. Tamis-Lemonda and L. Balter (Eds.), *Child Psychology: A Handbook of Contemporary Issues* (3rd ed.) (pp. 123-140). New York: Psychology Press.

Swanson, H.L., and Berninger, V. (1995). The Role of Working-Memory in Skilled and Less Skilled Readers Comprehension. *Intelligence, 21*(1): 83-108. doi: 10.1016/0160-2896(95)90040-3

Swanson, H.L., Howard, C.B., and Saez, L. (2006). Do Different Components of Working Memory Underlie Different Subgroups of Reading Disabilities? *Journal of Learning Disabilities*, *39*(3): 252-269.

Swanson, H.L., and Alexander, J.E. (1997). Cognitive Processes as Predictors of Word Recognition and Residing Comprehension in Learning-Disabled and Skilled Readers: Revisiting the Specificity Hypothesis. *Journal of Educational Psychology, 89*(1): 128-158. doi: 10.1037/0022-0663.89.1.128

Tang, Y.Y., and Posner, M.I. (2009). Attention Training and Attention State Training. *Trends in Cognitive Sciences, 13*(5): 222-227.

Tang, Y.Y., Lu, Q., Geng, X., Stein, E.A., Yang, Y., and Posner, M.I. (2010). Short-Term Meditation Induces White Matter Changes in the Anterior Cingulate. *Proceedings of the National Academy of Sciences*, *107*(35): 15649-15652.

Tang, Y.Y., Ma, Y., Fan, Y., Feng, H., Wang, J., Feng, S., and Fan, M. (2009). Central and Autonomic Nervous System Interaction Is Altered by Short-Term Meditation. *Proceedings of the National Academy of Sciences*, *106*(22): 8865-8870.

Tang, Y.Y., Ma, Y., Wang, J., Fan, Y., Feng, S., Lu, Q., and Posner, M.I. (2007). Short-Term Meditation Training Improves Attention and Self-Regulation. *Proceedings of the National Academy of Sciences*, *104*(43): 17152-17156.

Taylor, H.G., Schatschneider, C., Petrill, S., Barry, C.T., and Owens, C. (1996). Executive Dysfunction in Children With Early Brain Disease: Outcomes Post Haemophilus Influenzae Meningitis. *Developmental Neuropsychology, 12*(1): 35-51.

Teeter, P.A., Eckert, L., Nelson, A., Platten, P., Semrud-Clikeman, M., and Kamphaus, R.W. (2009). Assessment of Behavior and Personality in the Neuropsychological Diagnosis of Children. In C.R. Reynolds and E. Fletcher-Janzen (Eds.), *Handbook of Clinical Child Neuropsychology* (pp. 349-382). New York: Springer.

Temple, C.M., Carney, R.A., and Mullarkey, S. (1996). Frontal Lobe Function and Executive Skills in Children With Turner's Syndrome. *Developmental Neuropsychology, 12*(3): 343-363.

Thompson, T.W., Waskom, M.L., Garel, K-LA, Cardenas-Iniguez, C., Reynolds, G,O., Winter, R., … and Gabrieli, J.D.E. (2013) Failure of Working Memory Training to Enhance Cognition or Intelligence. *PLoS ONE 8*(5): e63614. doi: 10.1371/journal.pone.006361

Thorell, L.B., Eninger, L., Brocki, K.C., and Bohlin, G. (2010). Childhood Executive Function Inventory (CHEXI): A Promising Measure for Identifying Young Children With ADHD?. *Journal of Clinical and Experimental Neuropsychology*, *32*(1): 38-43.

Thorell, L.B., and Nyberg, L. (2008). The Childhood Executive Functioning Inventory (CHEXI): A New Rating Instrument for Parents and Teachers. *Developmental Neuropsychology, 33*(4): 536-552.

Titz, C., and Karbach, J. (2014). Working Memory and Executive Functions: Effects of Training On Academic Achievement. *Psychological Research*, *78*(6): 852-868.

Toll, S.W., Van der Ven, S.H., Kroesbergen, E.H., and Van Luit, J.E. (2011). Executive Functions as Predictors of Math Learning Disabilities. *Journal of Learning Disabilities, 44*(6): 521-532. doi: 10.1177/0022219410387302

Tominey, S.L., and McClelland, M.M. (2011). 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*(3): 489-519.

Toplak, M.E., Jain, U., and Tannock, R. (2005) Executive and Motivational Processes in Adolescents With Attention-Deficit-Hyperactivity Disorder. *Behavioral and Brain Functions, 1*(1):8. doi: 10.1186/1744-9081-1-8

Toplak, M.E., West, R.F., and Stanovich, K.E. (2013). Practitioner Review: Do Performance-Based Measures and Ratings of Executive Function Assess the Same Construct? *Journal of Child Psychology and Psychiatry, 54*(2): 131-143. doi: 10.1111/Jcpp.12001

Tucker-Drob, E.M., Rhemtulla, M., Harden, K.P., Turkheimer, E., and Fask, D. (2011). Emergence of a Gene× Socioeconomic Status Interaction on Infant Mental Ability Between 10 Months and 2 Years. *Psychological Science*, *22*(1): 125-133.

Tunbridge, E.M., Harrison, P.J., and Weinberger, D.R. (2006). Catechol-O-Methyltransferase, Cognition, and Psychosis: Val 158 Met and Beyond. *Biological Psychiatry*, *60*(2): 141-151.

Ursache, A., Blair, C., and Raver, C.C . (2012). The Promotion of Self-Regulation as a Means of Enhancing School Readiness and Early Achievement in Children at Risk for School Failure. *Child Development Perspectives, 6*(2): 122-128. doi: 10.1111/j.1750-8606.2011.00209

Usai, M.C., Viterbori, P., Traverso, L., and De Franchis, V. (2014). Latent Structure of Executive Function in 5- and 6-Year-Old Children: A Longitudinal Study. *European Journal of Developmental Psychology, 11*(4): 447-462. doi: 10.1080/17405629.2013.840578

U.S. Department of Education Office for Civil Rights. (2014). *Civil Rights Data Collection: Data Snapshot (Early Childhood)*. Washington, DC: U.S. Department of Education.

Vartanian, O., Bouak, F., Caldwell, J.L., Cheung, B., Cupchik, G., Jobidon, M. E., ... and Silvia, P.J. (2014). The Effects of a Single Night of Sleep Deprivation On Fluency and Prefrontal Cortex Function During Divergent Thinking. *Frontiers in Human Neuroscience, 8:* 214

Vallat-Azouvi, C., Pradat-Diehl, P., and Azouvi, P. (2012). The Working Memory Questionnaire: A Scale to Assess Everyday Life Problems Related to Deficits of Working Memory in Brain Injured Patients. *Neuropsychological Rehabilitation*, *22*(4): 634-649.

Verbruggen, F., Logan, G.D., and Stevens, M.A. (2008). STOP-IT: Windows Executable Software for the Stop-Signal Paradigm. *Behavior Research Methods*, *40*(2): 479-483.

Verburgh, L., Königs, M., Scherder, E.J., and Oosterlaan, J. (Online 2013) (2014). Physical Exercise and Executive Functions in Preadolescent Children, Adolescents, and Young Adults: A Meta-Analysis. *British Journal of Sports Medicine, 48*(12): 973-979. doi: 10.1136/bjsports-2012-091441

Vitaro, F., Brendgen, M., Larose, S., and Tremblay, R.E. (2005). Kindergarten Disruptive Behaviors, Protective Factors, and Educational Achievement by Early Adulthood. *Journal of Educational Psychology, 97*(4): 617-629.

Vukovic, R.K., Fuchs, L.S., Geary, D.C., Jordan, N.C., Gersten, R., and Siegler, R.S. (2014). Sources of Individual Differences in Children's Understanding of Fractions. *Child Development*, *85*(4): 1461-1476.

Waltz, J.A., Knowlton, B.J., Holyoak, K J., Boone, K.B., Mishkin, F.S., and de Menezes Santos, M. (1999). A System for Relational Reasoning in Human Prefrontal Cortex. *Psychological Science, 10*(2): 119-125.

Webster-Stratton, C. (1998). Preventing Conduct Problems in Head Start Children: Strengthening Parenting Competencies. *Journal of Consulting and Clinical Psychology*, *66*(5): 715-730.

Wechsler, D. (2012). *Wechsler Preschool and Primary Scale of Intelligence— Fourth Edition Technical and Interpretative Manual*. San Antonio, TX: Psychological Corporation.

Wechsler, D. (2014). *Wechsler Intelligence scale for Children®–Fifth Edition*. Bloomington, MN: Pearson.

Weicker, J., Villringer, A., and Thöne-Otto, A. (2016). Can Impaired Working Memory Functioning Be Improved By Training? A Meta-Analysis With a Special Focus on Brain Injured Patients. *Neuropsychology*, *30*(2): 190-212.

#Weiland, C., and Yoshikawa, H. (2013). Impacts of a Prekindergarten Program on Children's Mathematics, Language, Literacy, Executive Function, and Emotional Skills. *Child Development, 84*(6): 2112-2130. doi: 10.1111/Cdev.12099

Welsh, J.A., Nix, R.L., Blair, C., Bierman, K.L., and Nelson, K.E. (2010). The Development of Cognitive Skills and Gains in Academic School Readiness for Children From Low-Income Families. *Journal of Educational Psychology*, *102*(1): 43-53.

Welsh, M.C., and Pennington, B.F. (1988). Assessing Frontal Lobe Functioning in Children: Views From Developmental Psychology. *Developmental Neuropsychology, 4*(3): 199-230.

Welsh, M.C., Pennington, B.F., and Groisser, D.B. (1991). A Normative-Developmental Study of Executive Function: A Window on Prefrontal Function in Children. *Developmental Neuropsychology, 7*(2): 131-149.

Wiebe, S.A., Epsy, K.A., and Charak, D. (2008). Using Confirmatory Factor Analysis to Understand Executive Control in Preschool Children: I. Latent Structure. *Developmental Psychology, 44*(2): 575-587.

Wiebe, S.A., Sheffield, T., Nelson, J.M., Clark, C.A.C., Chevalier, N., and Espy, K.A. (2011). The Structure of Executive Function in 3-Year-Olds. *Journal of Experimental Child Psychology, 108*(3): 436-452. doi: 10.1016/j.jecp.2010.08.008

Wiebe, S.A., Sheffield, T.D., and Espy, K.A. (2012). Separating the Fish From the Sharks: A Longitudinal Study of Preschool Response Inhibition. *Child Development, 83*(4): 1245-1261. doi: 10.1111/j.1467-8624.2012.01765.x

Williams, B.R., Ponesse, J.S., Schachar, R.J., Logan, G.D., and Tannock, R. (1999). Development of Inhibitory Control Across the Life Span. *Developmental Psychology, 35*(1): 205-213. doi: 10.1037//0012-1649.35.1.205

Willcutt, E.G., Doyle, A.E., Nigg, J.T., Faraone, S.V., and Pennington, B.F. (2005). Validity of the Executive Function Theory of Attention-Deficit/Hyperactivity Disorder: A Meta-Analytic Review. *Biological Psychiatry*, *57*(11): 1336-1346.

Willoughby, M., Kupersmidt, J., Voegler-Lee, M., and Bryant, D. (2011). Contributions of Hot and Cool Self-Regulation to Preschool Disruptive Behavior and Academic Achievement. *Developmental Neuropsychology, 36*(2): 162-180.

Willoughby, M.T., Blair, C.B., Wirth, R.J., Greenberg, M., and Investigators, F.L.P. (2010). The Measurement of Executive Function at Age 3 Years: Psychometric Properties and Criterion Validity of a New Battery of Tasks. *Psychological Assessment, 22*(2): 306-317.

Willoughby, M.T., Wirth, R.J., and Blair, C.B. (2011). Contributions of Modern Measurement Theory to Measuring Executive Function in Early Childhood: An Empirical Demonstration. *Journal of Experimental Child Psychology*, *108*(3): 414-435.

Willoughby, M.T., Wirth, R.J., Blair, C.B., and Investigators, F.L.P. (2012). Executive Function in Early Childhood: Longitudinal Measurement Invariance and Developmental Change. *Psychological Assessment, 24*(2): 418-431.

Willoughby, M.T., Blair, C.B., and Family Life Project Investigators. (2015). Measuring Executive Function in Early Childhood: A Case for Formative Measurement. *Psychological Assessment, 28*(3): 319-330. doi: 10.1037/pas0000152

Wilson, C.R.E., Gaffan, D., Browning, P.G.F., and Baxter, M.G. (2010). Functional Localization Within the Prefrontal Cortex: Missing the Forest for the Trees? *Trends in Neurosciences, 33*(12): 533-540.

Wilson, S., and Farran, D. (2012, March). *Experimental Evaluation of the Tools of the Mind Curriculum*. Paper presented at the Society for Research on Educational Effectiveness Spring 2012 Conference, Washington, DC.

Wisner, B., Jones, B., and Gwin, D. (2010). School-Based Meditation Practices for Adolescents: A Resource for Strengthening Self-Regulation, Emotional Coping, and Self-Esteem. *Children and Schools, 32*(3): 150-159.

Xu, F., Han, Y., Sabbagh, M.A., Wang, T., Ren, X., and Li, C. (2013). Developmental Differences in the Structure of Executive Function in Middle Childhood and Adolescence. *PLoS ONE, 8*(10): e77770. doi: 10.1371/journal.pone.0077770

Yeager, D.S., and Walton, G.M. (2011). Social-Psychological Interventions in Education They're not Magic. *Review of Educational Research, 81*(2): 267-301.

Yerkes, R. M., and Dodson, J. D. (1908). The Relation of Strength of Stimulus to Rapidity of Habit-Formation. *Journal of Comparative Neurology and Psychology*, *18*: 459–482. doi:10.1002/cne.920180503

Zaitchik, D., Iqbal, Y., and Carey, S. (2014). The Effect of Executive Function on Biological Reasoning in Young Children: An Individual Differences Study. *Child Development, 85*(1): 160-75. doi: 10.1111/cdev.12145

Zeidan, F., Johnson, S.K., Diamond, B.J., David, Z., and Goolkasian, P. (2010). Mindfulness Meditation Improves Cognition: Evidence of Brief Mental Training. *Consciousness and Cognition: An International Journal, 19*(2): 597-605.

Zelazo, P.D., Craik, F.I.M., and Booth, L. (2004). Executive Function Across the Life Span. *Acta Psychologica, 115*(2): 167-184.

Zelazo, P.D. (2006). The Dimensional Change Card Sort: A Method of Assessing Executive Function in Children. *Nature Protocols, 1*(1): 297-301.

Zelazo, P.D. (2015). Executive Function: Reflection, Iterative Reprocessing, Complexity, and the Developing Brain. *Developmental Review, 38*: 55–68. doi: 10.1016/j.dr.2015.07.001

Zelazo, P.D., Anderson, J.E., Richler, J., Wallner-Allen, K., Beamont, J.L., and Weintraub, S. (2013). NIH Toolbox Cognition Battery (CB): Measuring Executive Function and Attention. *Monographs of the Society for Research in Child Development, 78*(4). doi: 10.1111/Mono.12039

Zelazo, P.D., Anderson, J.E., Richler, J., Wallner-Allen, K., Beaumont, J.L., Conway, K.P., and Weintraub, S. (2014). NIH Toolbox Cognition Battery (CB): Validation of Executive Function Measures in Adults. *Journal of the International Neuropsychological Society*, *20*(06): 620-629.

Zelazo, P.D., and Carlson, S.M. (2012). Hot and Cool Executive Function in Childhood and Adolescence: Development and Plasticity. *Child Development Perspective, 6*(4): 354-360.

Zelazo, P.D., Carter, A., Reznick, J.S., and Frye, D. (1997). Early Development of Executive Function: A Problem-Solving Framework. *Review of General Psychology, 1*(2): 198-226.

Zelazo, P.D., and Cunningham, W. (2007). Executive Function: Mechanisms Underlying Emotion Regulation. In J. Gross (Ed.), *Handbook of Emotion Regulation* (pp. 135-158). New York: Guilford.

Zelazo, P.D., Frye, D., and Rapus, T. (1996). An Age-Related Dissociation Between Knowing Rules and Using Them. *Cognitive Development, 11*(1), 37-63. doi: 10.1016/S0885-2014(96)90027-1

Zelazo, P.D., and Lee, W.S.C. (2010). Brain Development: An Overview. In W.F. Overton (Ed). Cognition, Biology, and Methods Across the Lifespan. *Handbook of Life-Span Development*, *Vol. 1* (pp. 89-114). Hoboken, NJ: Wiley.

Zelazo, P.D., and Lyons, K.E. (2012). The Potential Benefits of Mindfulness Training in Early Childhood: A Developmental Social Cognitive Neuroscience Perspective. *Child Development Perspectives, 6*(2): 154-160.

Zelazo, P.D. and Müller, U. (2002). Executive Function in Typical and Atypical Development. In U. Goswami (Ed.), *Handbook of Childhood Cognitive Development* (pp. 445-469). Oxford: Blackwell.

Zelazo, P.D. and Reznick, J.S. (1991). Age Related Asynchrony of Knowledge and Action. *Child Development, 62*(4): 719-735.

Zhong, J.D., Rifkin-Graboi, A., Ta, A.T., Yap, K.L., Chuang, K.H., Meaney, M.J., and Qiu, A.Q. (2014). Functional Networks in Parallel With Cortical Development Associate With Executive Functions in Children. *Cerebral Cortex, 24*(7): 1937-1947. doi: 10.1093/cercor/bht051

Zhou, Q., Chen, S.H., and Main, A. (2012). Commonalities and Differences in the Research on Children's Effortful Control and Executive Function: A Call for an Integrated Model of Self-Regulation. *Child Development Perspectives*, *6*(2): 112-121.

Zimmerman, B.J. (2008). Investigating Self-Regulation and Motivation: Historical Background, Methodological Developments, and Future Prospects. *American Educational Research Journal, 45*(1): 166-183.

Zylowska, L., Ackerman, D.L., Yang, M.H., Futrell, J.L., Horton, N.L., Hale, T.S., Pataki, C., and Smalley, S.L. (2008). Mindfulness Meditation Training in Adults and Adolescents With ADHD: A Feasibility Study. *Journal of Attention Disorders, 11*(6): 737-746.

Glossary

A-Not-B Task: This task is a variant of the delayed-response paradigm in which the location of the object is not random, but rather follows a prescribed sequence. The object is hidden first at one location (Location A) for a number of trials and then at the other location (Location B). Retrieving the object when it is hidden at Location B requires the infant to keep the location in mind, respond flexibly, and inhibit any tendency to search at the previously correct Location A.

Amygdala: An almond-shaped mass of gray matter in the front part of the temporal lobe of the cerebrum that is part of the limbic system and is involved in the processing and expression of emotions, especially anger and fear.

Anterior Cingulate Cortex: The frontal part of the cingulate cortex that resembles a "collar" surrounding the frontal part of the corpus callosum. It appears to play a role in a wide variety of autonomic nctions, such as regulating blood pressure and heart rate. It is also involved in rational cognitive functions, such as reward anticipation, decision-making, empathy, impulse control, and emotion.

Attention-Regulation Skills: The ability to process stimuli, focus and sustain attention, and maintain engagement in accordance with social and cultural contexts.

Bottom-Up Processing: Processing sensory information as it is coming in.

Child Ability: From the perspective of modern test theory, all children have an underlying latent ability that informs their performance on EF tasks, as well as their likelihood of exhibiting behaviors that are presumed to be indicative of EF. This ability level is latent because it is not directly measurement (only inferred based on children's performance or rated behaviors). In the case of EF, the underlying latent ability that corresponds to a child's performance on an EF task appears to be largely distinct from their latent ability that corresponds to EF-related behaviors.

Circadian Rhythms: A 24-hour cycle that tells our bodies when to sleep and regulates many other physiological processes.

Cognitive Flexibility: The mental ability to switch between thinking about two different concepts, and to think about multiple concepts simultaneously.

Cohen d Effect Size: The difference between two means divided by a standard deviation for the data.

Confirmatory Factor Analysis (CFA): A special form of factor analysis, a statistical method used to describe variability among observed, correlated variables in terms of a potentially lower number of unobserved variables called factors. CFA is used to test whether measures of a construct are consistent with a researcher's understanding of the nature of that construct (or factor). The objective of confirmatory factor analysis is to test whether the data fit a hypothesized measurement model. This hypothesized model is based on theory and/or previous analytic research.

Crystallized Intelligence: The ability to use skills, knowledge, and experience. It does not equate to memory, but it does rely on accessing information from long-term memory.

Delayed-Response Paradigm: In delayed-response tasks, an attractive object is shown to an infant and then very conspicuously hidden at one of two or more locations (e.g., an infant watched as a toy is hidden under one of two cloths). A delay is imposed and then the infant is allowed to retrieve the object. Across trials, the hiding location of the object is determined randomly. Retrieving the object requires the infant to keep the location in mind, and across trials, it also requires that infants respond flexibly and inhibit any tendency to search at locations that were previously correct.

Dendritic Thickening: Extreme skeletal thickening along axes of colony branches.

Developmental Cognitive Neuroscience: An interdisciplinary scientific field devoted to understanding psychological processes and their neurological bases in the developing organism. It examines how the mind changes as children grow up, interrelations between that and how the brain is changing, and environmental and biological influences on the developing mind and brain.

Dopamine: An organic chemical that plays several important roles in the brain and body. It's a neurotransmitter that helps control the brain's reward and pleasure centers. It also helps regulate movement and emotional responses, and it enables us not only to see rewards, but to take action to move toward them.

Educational Neuroscience: A scientific field that brings together researchers in cognitive neuroscience, developmental cognitive neuroscience, educational psychology, educational technology, education theory and other related disciplines to explore the interactions between biological processes and education. Researchers in this area may link basic findings in cognitive neuroscience with educational technology to help in curriculum implementation for mathematics education and reading education.

Executive Attention: The ability to effectively block outside distractions while focusing on a single object or task.

Fluid Intelligence: The capacity to think logically and solve problems in novel situations, independent of acquired knowledge.

fMRI: Functional magnetic resonance imaging or functional MRI (fMRI) is a functional neuroimaging procedure using MRI technology that measures brain activity by detecting changes associated with blood flow. This technique relies on the fact that cerebral blood flow and neuronal activation are coupled.

Formative Assessments: Monitors student learning to provide ongoing feedback that can be used by instructors to improve their teaching and by students to improve their learning. More specifically, to help students identify their strengths and weaknesses and target areas that need work.

Inhibitory Control: The capacity voluntarily to inhibit or regulate prepotent (i.e., strong or automatic) attentional or behavioral responses.

Longitudinal Measurement Invariance: The individual items that comprise a test score are characterized by their difficulty level (e.g., how frequently they were endorsed) and their discrimination (the extent to which item responses help distinguish children in terms of their true ability). When a given measure is administered at multiple points in time, the properties of individual items (i.e., difficulty, discrimination) must be unchanged in order for the resulting scores to be interpretable. Longitudinal measurement invariance refers to a general analytic approach that is used to formally evaluate the consistency of item functioning across time.

Mean Effect Size: A name given to a family of indices that measure the magnitude of a treatment effect. Unlike significance tests, these indices are independent of sample size. ES measures are the common currency of meta-analysis studies that summarize the findings from a specific area of research. One type of effect size, the standardized mean effect, expresses the mean difference between two groups in standard deviation units.

Mediation Analysis: A hypothesized causal chain in which one variable affects a second variable that, in turn, affects a third variable. The intervening variable, M, is the mediator. It "mediates" the relationship.

Minimally Detectable Change (MDC): A statistical estimate of the smallest amount of change that can be detected by a measure that corresponds to a noticeable change in ability.

Myelination: A term in anatomy that is defined as the process of forming a fatty white substance (myelin sheath) around a nerve to allow nerve impulses to move more quickly.

Negative Affectivity: A personality variable that involves the experience of negative emotions and poor self-concept.

Neurocognitive skills: Skills that involve cognitive functioning and associated structures and processes of the central nervous system.

Neurotransmitter: A chemical that is released from a nerve cell which, by diffusing across the synapse or junction, transmits an impulse from a nerve cell to another nerve, muscle, organ, or other tissue. A neurotransmitter is a messenger of neurologic information from one cell to another.

Norepinephrine (NE): A stress hormone that affects parts of the brain where attention and responding actions are controlled. Its release is lowest during sleep, rises during wakefulness, and reaches much higher levels during situations of stress or danger, in the so-called fight-or-flight response.

Norm-Referenced Scores: All questionnaires and performance based tests have some process through which individual items or ratings are converted into summary scores. These raw scores can be used to communicate how well a child performed relative to similar children who have completed the same task (or who were rated on the same items). Norm-referenced scores represent the transformation of raw scores into a metric that facilitates between-child inferences (e.g., percentile or T scores). Norm-reference scores communicate information about a child's standing on a given measure relative to some broader population of similar children (nationally representative samples are ideal).

Polynomial Model: A tool for determining which input factors drive responses and in what direction.

Prefontal Cortex - The gray matter of the anterior part of the frontal lobe that is highly developed in humans and plays a role in the regulation of complex cognitive, emotional, and behavioral functioning. Neuroanatomically, the executive function skills of cognitive flexibility, working memory, and inhibitory control are associated with distinct and partially overlapping networks involving regions of the prefrontal cortex (PFC).

Randomized Controlled Trials (RCTs): (A type of scientific (often medical) experiment, where the people being studied are randomly allocated one or other of the different treatments under study. RCTs are often used to test the efficacy or effectiveness of various types of medical intervention and may provide information about adverse effects, such as drug reactions. Random assignment of intervention is done after subjects have been assessed for eligibility and recruited, but before the intervention to be studied begins.

Reflection: To pause, consider the options, and put things into context prior to responding.

Reflective Learning: Active and intentional learning that involves critical reflection upon the learning experience and what is learned.

School Readiness: The skills, knowledge, and attitudes necessary for success in kindergarten.

Self-Regulated Learning Strategies: Strategies that include self-monitoring and goal setting to facilitate learning objectives.

Surgency/Extraversion: Surgency is a trait aspect of emotional reactivity in which a person tends towards high levels of positive affect and engagement with their environment. Extraversion tends to be manifested in outgoing, talkative, and energetic behavior.

Synaptic Pruning: The process by which extra neurons and synaptic connections are eliminated in order to increase the efficiency of neuronal transmissions.

Temperament: Enduring biological predispositions to react to things in a particular way; the foundations of relatively stable personality traits.

Test-Retest Reliability: A quantitative index of the stability or repeatability of score across a given interval of time. Test-retest reliability is of special concern for performance-based EF tasks because they represent an assessment of a child's ability during a single testing occasion. In order for performance-based scores to be useful, it is assumed that they have some enduring quality to them (though still malleable). Test-retest reliability is less frequently a source of concerns for questionnaire measures, as they typically measure a broad set of behaviors over a longer period of time (weeks).

Test Information: The utility of a test score depends, in part, on its associated standard error of measurement. Scores with larger standard errors are less precise (due to greater uncertainty about the accuracy of the estimated score) than are scores with smaller standard errors of measurement. In item response theory, test information curves are used to visually depict the relative precision of measurement of a score as a function of the child's true ability (see above for definition). Test information curves are important because they demonstrate how the precision of measurement that is associated with an instrument depends on child ability. As such, some measures may be more appropriate for distinguishing between children at some ability levels (e.g., low) than others (e.g., high). Although test information curves have not been provided for most EF measures (questionnaires or performance-based tasks), at a minimum, they help to inform educators of the types of questions that they should ask when trying to select a measurement tool.

Theory of Mind: The ability to attribute and differentiate mental states to oneself and others, that is, to perceive how others think and feel, and how that relates to oneself.

Top-Down Processing: Perception that is driven by cognition. Top-down processing involves the recognition of patterns through the use of contextual information.

Two-Factor Models: A form of confirmatory factor analysis that involves two continuous latent variables, or factors.

Working Memory: The system responsible for the transient holding and processing of new and already-stored information, and is an important process for reasoning, comprehension, learning and memory updating.