1

WHY IMPROVING AND ASSESSING EXECUTIVE FUNCTIONS EARLY IN LIFE IS CRITICAL

ADELE DIAMOND

To be successful in school or in one's career takes creativity, flexibility, self-control, and discipline. Central to all those are executive functions (EFs), including mentally playing with ideas, giving a considered response rather than an impulsive one, and being able to change course or perspectives as needed, resist temptations, and stay focused. These are core skills critical for cognitive, social, and psychological development, success in school and in life, and mental and physical health. They begin to emerge early (even during infancy) but are not fully mature until young adulthood, although EFs in early childhood are highly predictive of EF skills later in life. EFs are very sensitive to environmental factors (including negative ones such as poverty and positive ones such as sensitive parenting). Accumulating evidence indicates that several different approaches can successfully improve EFs and that improving them early in life may be absolutely critical for an individual's happiness and success throughout life and for reducing social disparities in

http://dx.doi.org/10.1037/14797-002
Executive Function in Preschool-Age Children: Integrating Measurement, Neurodevelopment, and Translational Research, J. A. Griffin, P. McCardle, and L. S. Freund (Editors)

achievement and health. Whether an approach produces sustained benefits to EFs can be determined only by assessing EFs over time using the same or comparable measures. Hence longitudinal assessment tools for the early years of life become critical to the goal of finding what works. I delve into each of these points briefly in this chapter and invite you to read the other chapters in this volume where these points are elaborated in greater depth.

EXECUTIVE FUNCTIONS DEFINED

I refer to EFs in the plural because the term refers to a family of skills, not just one skill. These skills are needed when you have to concentrate and think, when going on automatic or acting on your initial impulse might be ill-advised. In the title to this volume and in some of the other chapters within, the singular term *executive function* is used. These skills depend on a neural circuit in which prefrontal cortex plays a pivotal role (Aron, Behrens, Smith, Frank, & Poldrack, 2007; Braver, Cohen, & Barch, 2002; Eisenberg & Berman, 2010; Leh, Petrides, & Strafella, 2010; Zanto, Rubens, Thangavel, & Gazzaley, 2011).

Working Memory and Inhibitory Control

One core component of EFs is working memory (holding information in mind and working with it). Working memory is critical for making sense of anything that unfolds over time, for that always involves relating what came earlier to what came later. Understanding written or spoken language requires this because as you focus on the next phrase, the previous one is no longer present or you are no longer looking at it. Doing any math in your head requires this, as does reasoning, because it involves holding bits of information in mind and seeing how they relate. As Nelson et al. note in Chapter 3 of this volume, the ability to hold information in mind develops very early and even extremely young children can hold one or two things in mind for quite a long time. Indeed, infants of only 9 to 12 months can update the contents of their working memory, as seen on tasks such as A-not-B (Diamond, 1985; see also Chapter 7, this volume). However, being able to hold many things in mind or do any kind of mental manipulation (e.g., reordering mental representations of objects in order of size) is far slower to develop and shows a prolonged developmental progression (Bachevalier, 1990; Barrouillet, Gavens, Vergauwe, Gaillard, & Camos, 2009; Cowan, Saults, & Elliott, 2002; Luciana, Conklin, Hooper, & Yarger, 2005; Schleepen & Jonkman, 2009).

Holding a piece of information in mind for some seconds could just as correctly be described as keeping your attention focused on a piece of information for some seconds. Indeed, the distinction between these aspects of memory and attention appears to be arbitrary. They are similar in many ways including in their neural bases. The same prefrontal system that enables you to selectively remain focused on the information you want to hold in mind also helps you selectively attend to stimuli in your environment, tuning out irrelevant stimuli. Hence it is virtually impossible to try to hold something in mind that is at odds with what you are trying to keep your attention focused on in the environment (Awh & Jonides, 2001; Awh, Vogel, & Oh, 2006; Gazzaley, 2011; Gazzaley & Nobre, 2012; Zanto et al., 2011).

The other core EF skill is inhibitory control, which is more heterogeneous than working memory. It includes inhibition of attention (selective or focused attention), which is often referred to as interference control and involves inhibiting (or suppressing) attention to other things in the environment (distracters) so you can stay focused on what you want. Inhibitory control also includes inhibition of action (motor responses, including verbal ones), which includes several subtypes. Most of the subtypes are aspects of self-control: (a) inhibiting the impulse to respond or react immediately—making yourself wait or giving yourself time to give a wiser, more considered response (e.g., not sending off a blistering email, but waiting until you are calmer; giving yourself time to acquire more information before jumping to a conclusion); (b) delaying gratification—making yourself wait, forgoing an immediate pleasure for a greater reward later (often termed *delay discounting* by neuroscientists and learning theorists; Louie & Glimcher, 2010; Rachlin, Raineri, & Cross, 1991); (c) inhibiting your first inclination and substituting a more appropriate response (e.g., not butting in line but going to the end of the line, not blurting out something that could offend but saying something more considerate instead, or not giving the more natural response to a stimulus when instructed to give a different response instead); (d) holding up on making a response that had almost reached response threshold (e.g., a batter checking his or her swing); (e) resisting temptations (e.g., temptations such as eating foods that are not good for you, overindulging, trying forbidden substances, or taking something you are addicted to). The other subtypes of inhibitory control are aspects of discipline: (f) staying on task, including (f.1) finishing one's work though it might be tedious or difficult, inhibiting temptations to do something more fun, and (f.2) sustaining your attention on something for several long minutes despite distractions even if the task seems boring and pointless.

You are in good company if you think (a) and (c)—or (b), (e), and (f)—are so related as to perhaps be the same thing, or if you think the above list is so long and diverse that a single construct (inhibitory control) does not do justice to the heterogeneity or that surely the neural basis for all of these aspects of inhibitory control (e.g., inhibition at the level of attention or action, or inhibition when motivation is high [hot situations] and inhibition when motivation is minimal [cool situations]) could not possibly be the same (Dempster, 1993; Harnishfeger, 1995; Kerr & Zelazo, 2004; Nigg, 2000). Those are among the many debates concerning EFs. It is interesting that some confirmatory factor analyses find that inhibition of attention (resistance to distracter interference) and inhibition of action (inhibiting a prepotent response) are highly related and form a single factor (Friedman & Miyake, 2004). Moreover, when required to exert one type of self-control (e.g., resisting sweets) and then required immediately after to exert a second type of self-control (e.g., the Stop-Signal task), people are consistently found to be more impaired on the second task than if they did a different difficult task first that did not require self-control (e.g., math calculations; Muraven & Baumeister, 2000). One group reports that all the diverse types of self-control appear to rely on substantially similar neural bases (Cohen, Berkman, & Lieberman, 2013). However, many studies have found that interference control (inhibiting extraneous thoughts or inhibiting attention to environmental distraction) is much more strongly linked to working memory than to other forms of inhibitory control (e.g., response inhibition). In particular, selective attention and working memory appear to be very tightly linked (see above as well as Awh & Jonides, 2001; Gazzaley, 2011). Working memory and inhibition are highly interrelated. A situation might place a higher demand on one than the other, and two conditions of a task might differ more in their working memory demands or their inhibitory demands, but rarely if ever are either of these exercised in the absence of the other. How can you know what to inhibit unless you maintain your goal in working memory? How can you stay focused on the relevant information in working memory if you do not inhibit (suppress) environmental distractions and mental distractions, such as irrelevant thoughts?

Different theories of EFs postulate inhibitory control (Barkley, 2001), working memory (Cepeda & Munakata, 2007; Cohen, Dunbar, & McClelland, 1990; Morton & Munakata, 2002; Pennington, 1994), or attention (Garon, Bryson, & Smith, 2008; Rothbart & Posner, 2001) as primary. As Nelson et al. outline in Chapter 3 (this volume), early in development, working memory and inhibitory control appear to be relatively undifferentiated behaviorally, consistent with intellectual skills developing from a relatively unified, general ability in childhood to more differentiated, specific cognitive abilities with age (Garrett, 1946; Werner, 1957). There was already evidence that this characterized the development of working memory and inhibition from 4 to 14 years of age (e.g., Shing, Lindenberger, Diamond, Li, & Davidson, 2010). Willoughby and Blair (Willoughby, Blair, Wirth, & Greenberg, 2010; see also Chapter 4, this volume) and Espy and colleagues (Wiebe et al., 2011; see also Chapter 3, this volume) provided evidence that, consistent with this relative nondifferentiation early in development, working memory and inhibitory control fall along a single factor in children 3 to 5 years of age. It has also been known for some time that progressive differentiation occurs at the neural level from childhood to adolescence, with first many brain regions being recruited to exercise EFs followed by progressive fine-tuning of neural activation to prefrontal cortex and other members of the EF neural network (Durston et al., 2006). In Chapter 7 of this volume, Bell and Cuevas present new data showing that this progressive fine-tuning of neural activation also characterizes changes from infancy to the preschool period.

More Advanced Executive Functions

To shift mental sets or see something from different perspectives, you need to activate and maintain a new set or perspective in working memory and you need to inhibit the set or perspective that was just being used. Thus cognitive flexibility (also called *set shifting*) the third core EF, builds upon and requires working memory and inhibitory control (Diamond, 2010; Morasch, Raj, & Bell, 2013; see Figure 1.1). Whereas factor analyses of EFs in adults routinely come up with three factors (working memory, inhibitory control, and cognitive flexibility; Lehto, Juujärvi, Kooistra, & Pulkkinen, 2003; Miyake et al., 2000), factor analyses with children are more likely to find only two factors (working memory and inhibitory control; Hughes, Ensor, Wilson, & Graham, 2009; St Clair-Thompson & Gathercole, 2006; Wiebe et al., 2011). Not surprisingly, cognitive flexibility emerges later than working memory or inhibitory control (Cepeda, Kramer, & Gonzalez de Sather, 2001; Davidson, Amso, Anderson, & Diamond, 2006; Garon et al., 2008). Being able to flexibly switch between two rules or two ways of sorting cards on a trial-by-trial basis is utterly beyond the ability of most preschoolers, and before they are 2.5 or 3 years old there is little or no evidence that children can make a switch between blocks of trials (using one rule for all trials in one block, and a different rule for all trials in the next block; Marcovitch & Zelazo, 2009). Still more advanced EFs that build upon working memory, inhibitory control, and cognitive flexibility include reasoning, problem solving, and planning (Collins & Koechlin, 2012; Daniels, Toth, & Jacoby, 2006; Niendam et al., 2012).

DIFFERENCES AND SIMILARITIES BETWEEN EXECUTIVE FUNCTIONS AND RELATED TERMS

Self-regulation refers to processes that enable people to maintain optimal levels of emotional, motivational, and cognitive arousal (Liew, 2011). Eisenberg, Hofer, and Vaughan (2007) define emotion-related self-regulation as "processes used to manage and change if, when, and how (e.g., how intensely) one experiences emotions and emotion-related motivation and physiological states, as well as how emotions are expressed behaviorally"

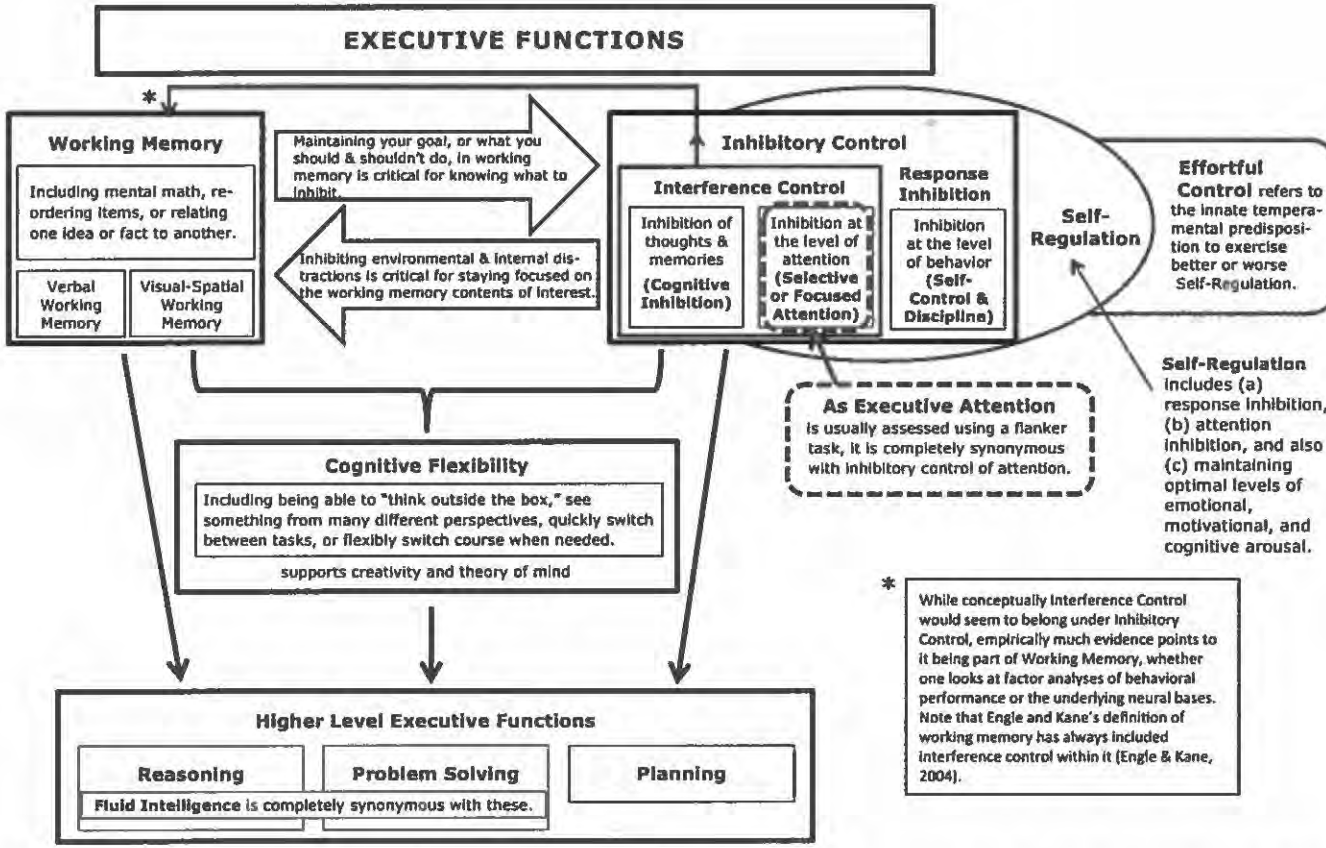

Figure 1.1. The components that together comprise executive functions (EFs) and the relation of executive functions to other related concepts. The two primary EFs are working memory and inhibitory control. Those together make cognitive flexibility possible. From those three core EFs, the higher order EFs of reasoning, problem solving, and planning are built.

(p. 288). These processes include effortfully "managing the perception of stimuli and manipulating cognitions and behavior associated with emotion, generally in the service of biological or social adaptation and/or accomplishing goals" (Eisenberg & Zhou, Chapter 5, this volume, p. 118).

Self-regulation does not include a working memory component (unlike EFs), but it overlaps substantially with the inhibitory control component of EFs (see Figure 1.1). Self-regulation refers primarily to control and regulation of one's emotions (Eisenberg, Spinrad, & Eggum, 2010; Mischel & Ayduk, 2002; Raver, 2004; Rothbart & Jones, 1998). EF researchers have historically focused more on the control of thoughts, attention, and actions; only recently have they included control of one's emotions. Whereas EF researchers have addressed emotions only as troublesome things to be inhibited, self-regulation also embraces the importance of motivation and interest as emotional responses that can be critical to the achievement of one's goals (Blair & Diamond, 2008). Historically, self-regulation has been assessed through (a) adult ratings of children's behavior, observed over the course of time in real-world settings such as home or school, and (b) observation of children's behavior when they have to delay gratification in an emotionally laden, hot situation (Mischel, Shoda, & Rodriguez, 1989) or in a frustrating situation (Kochanska, Philibert, & Barry, 2009). Historically, EFs have been assessed directly from children's performance on arbitrary laboratory-based tests far removed from the real world in fairly emotionally neutral, cool situations. Finally, EF researchers have historically focused on the brain bases for component EFs, whereas self-regulation researchers have focused more on the peripheral, autonomic nervous system, using measures such as heart rate variability or respiratory sinus arrhythmia as indices of parasympathetic nervous system activity (Porges, Doussard-Roosevelt, & Maiti, 1994). For a more thorough discussion of what self-regulation is and how it compares to EFs, see Chapter 5, this volume.

Effortful control (Rothbart & Bates, 2006) refers to an aspect of temperament, a largely innate predisposition, which involves a tendency to exercise self-regulation with ease (e.g., easily able to slow down or lower one's voice), perhaps even being too regulated (lacking in spontaneity) versus finding regulation harder or less natural. It is usually measured by parental report (Goldsmith, 1996; Rothbart, Ahadi, Hershey, & Fisher, 2001).

Executive attention (Fan, McCandliss, Sommer, Raz, & Posner, 2002; Posner & DiGirolamo, 1998; Rueda, Posner, & Rothbart, 2005) refers to the top-down regulation of attention as opposed to alerting (maintaining a state of high readiness to attend to potential stimuli) or orienting (exogenous attention—being pulled by a stimulus to attend to it). As the name and definition imply, it sounds synonymous with inhibitory control of attention. Indeed, it is usually assessed using measures of selective attention such as the flanker task (Fan et al., 2002; Rueda et al., 2005). Much confusion has been engendered by the overly broad use of the term *executive attention* to apply to such skills as working memory capacity (Engle, 2002; Erickson, 2008) and response inhibition, which is also known as the resolution of response conflict (e.g., whether to press on the left or right on a Simon-type task; Gerardi-Caulton, 2000; Jones, Rothbart, & Posner, 2003).

Fluid intelligence is the ability to reason, problem solve, and see patterns or relations among items (Cattell, 1963). It is synonymous with the reasoning and problem-solving subcomponents of EFs. No surprise then that measures of fluid intelligence (e.g., Raven's Matrices; Raven, Raven, & Court, 2004) are very highly correlated with independent measures of EFs (Boone, 1999; Conway, Kane, & Engle, 2003; Duncan, Emslie, Williams, Johnson, & Freer, 1996; Duncan et al., 2008; Engle, Tuholski, Laughlin, & Conway, 1999; Roca et al., 2010).

Working memory is often referred to as a subcomponent of EFs, although many working-memory researchers use the term *working memory* more broadly. For example, Kane and Engle define working memory as the ability to (a) maintain selected information in an active, easily retrievable state while (b) inhibiting (blocking) distracters or interference, such as from other information that might otherwise enter that active state (i.e., memory maintenance + interference control, which seems consistent with the close empirical tie between these two skills; Conway & Engle, 1994; Kane & Engle, 2000, 2002). Hasher and Zacks (1988; Zacks & Hasher, 2006) also insert interference control components into their definition of working memory: (a) gating out irrelevant information from the working-memory workspace and (b) deleting no-longer-relevant information from that limited-capacity workspace. Functions of the central executive in Baddeley's working-memory model (Baddeley, 1992; Baddeley & Hitch, 1994) include inhibitory control and cognitive flexibility: (a) multitasking, (b) shifting between tasks or retrieval strategies, and (c) the capacity to attend and inhibit in a selective manner. Working-memory researchers often use complex span tasks (also called working memory span tasks; Bailey, Dunlosky, & Kane, 2008; Barrouillet et al., 2009; Chein & Morrison, 2010; Conway et al., 2005; Pardo-Vázquez & Fernández-Rey, 2008; Unsworth, Redick, Heitz, Broadway, & Engle, 2009) to study what they call working memory but what EF researchers would call EFs (because these tasks require more subcomponents of EFs than just holding information in mind and manipulating it). It would probably cause less confusion if they were called EF tasks.

EVIDENCE OF THE IMPORTANCE OF EFs

EFs are critical for success in school. EF skills have been repeatedly found to be more important for school readiness than IQ or entry-level reading or math (e.g., Blair, 2002, 2003; Blair & Razza, 2007; Normandeau & Guay, 1998). EFs continue to be critical for school success from preschool through university, even controlling for initial achievement levels and IQ. Working memory and inhibitory control each independently predict both math and reading competence throughout the school years, and often do so much better than IQ (e.g., Alloway & Alloway, 2010; Borella, Carretti, & Pelegrina, 2010; Duckworth & Seligman, 2005; Duncan et al., 2007; Gathercole, Pickering, Knight, & Stegmann, 2004; see also Chapter 10, this volume).

EFs are also critical for job success. Poor EFs lead to poor productivity and difficulty finding and keeping a job (Bailey, 2007). EFs are important for marital harmony because people with poor EFs are more difficult to get along with, less dependable, and more likely to act on impulse (Eakin et al., 2004). Poor EFs can lead to social problems such as aggression, emotional outbursts, and crime (Broidy et al., 2003; Denson, Pedersen, Friese, Hahm, & Roberts, 2011; Moffitt et al., 2011; Saarni, 1999; Winstok, 2009). EFs are impaired in many mental health disorders (such as addictions, attention-deficit/hyperactivity disorder, obsessive–compulsive disorder, depression, conduct disorder, and schizophrenia; Baler & Volkow, 2006; Barch, 2005; Diamond, 2005; Lui & Tannock, 2007; Miller, Barnes, & Beaver, 2011; Penadés et al., 2007; Taylor Tavares et al., 2007; Verdejo-García, Bechara, Recknor, & Pérez-García, 2006). Such disorders are increasing at alarming rates (Moffitt et al., 2010; Robison, Sclar, Skaer, & Galin, 1999) and account for more lost years of life and productivity than any other illness including cancer (Prince et al., 2007). Not surprisingly, given all of these findings, poorer EFs are associated with a poorer quality of life (Davis, Marra, Najafzadeh, & Liu-Ambrose, 2010; Moffitt, 2012).

In general, these associations are particularly true for the inhibitory control component of EFs. For example, Moffitt et al. (2011) found that children, who at ages 3 through 11 had worse inhibitory control (were less persistent, more impulsive, and had poorer selective attention), as adults 30 years later had worse health (were more likely to be overweight and have substance abuse problems), earned less, committed more crimes, and were less happy than those with better inhibitory control as children, controlling for IQ, gender, social class, and their home lives and family circumstances growing up. This finding is based on a sample of 1,000 children born in the same city in the same year followed for 32 years with a 96% retention rate.

Inhibitory control is also disproportionately difficult for young children. For example, the difference in both speed and accuracy of children at all ages from 4 through 9 for always responding on the same side as a stimulus versus inhibiting that impulse and always responding on the side opposite a stimulus is greater than the difference in either their speed or accuracy for holding two associations in mind versus six (Davidson et al., 2006). This is true whether or not the same-side trials come before or after the opposite-side ones (Wright & Diamond, 2014). The opposite is true for adults: It is far harder to hold six associations in mind than two but it is no harder to always respond on the side opposite a stimulus than to always respond on the same side as a stimulus (adults' speed and accuracy for each are equivalent; Davidson et al., 2006; Lu & Proctor, 1995). Preschool and early elementary school programs that target EFs have thus wisely focused on improving inhibitory control (focused attention, self-control, and discipline; Bodrova & Leong, 2007; Kusché & Greenberg, 1994; Raver et al., 2008; Webster-Stratton & Reid, 2004). Inhibitory control is by no means fully mature by age 9; indeed, it continues to improve throughout adolescence (Bedard et al., 2002; Christakou, Brammer, & Rubia, 2011; Klein, Foerster, Hartnegg, & Fischer, 2005; Leon-Carrion, García-Orza, & Pérez-Santamaría, 2004; Luna, 2009; Olson et al., 2009; Rubia, Smith, Taylor, & Brammer, 2007; Steinberg et al., 2009).

BENEFITS OF EARLY IMPROVEMENTS OF EFs

EFs can be improved. That is true throughout life from infancy through old age (Bryck & Fisher, 2012; Diamond & Lee, 2011; Greenberg & Harris, 2012; Klingberg, 2010; Kovács & Mehler, 2009; Morrison & Chein, 2011; Muraven, 2010; Wass, Porayska-Pomsta, & Johnson, 2011). Why bother to try to improve EFs early if (a) those with poorer EFs might just be slower maturers and might catch up and (b) EFs can be improved later if the children do not catch up on their own? The early gap between those with better and worse EFs often does not disappear on its own but can grow larger over time (O'Shaughnessy, Lane, Gresham, & Beebe-Frankenberger, 2003; Riggs, Blair, & Greenberg, 2004) and EF problems (especially inhibitory control problems) in early childhood predict EF problems years later (Eigsti et al., 2006; Friedman et al., 2007; Moffitt et al., 2011; Shoda, Mischel, & Peake, 1990). Similarly, children's school readiness (which depends heavily on children's EFs) strongly predicts academic performance years later in middle school through college (Entwisle, Alexander, & Olson, 2005; McClelland, Acock, Piccinin, Rhea, & Stallings, 2013; O'Shaughnessy et al., 2003; Petit, Courtney, Maisog, Ungerleider, & Haxby, 1997; see also Chapter 12, this volume).

Prefrontal cortex is not fully mature until early adulthood (one's mid-20s; Gogtay et al., 2004; Paus et al., 1999). Some people have asked, therefore, "Isn't it nonsense to try to improve EFs in preschoolers? There isn't enough of a biological substrate to work with; wait until prefrontal cortex is more mature." In response, I think it is helpful to consider an analogy. Certainly toddlers' legs are not at their full adult extent, and they probably will not be for another 15 years or so, but with those immature legs toddlers can walk and even run. That is to say that even though the prefrontal cortex is immature, it is able to subserve EFs to some extent (not at the full adult level, but to some extent) and with training and practice, that immature prefrontal cortex can probably subserve EFs at a higher level of proficiency.

Being able to improve EFs early in a child's life may be absolutely critical because it affects the trajectory (the negative or positive feedback loop) on which a child gets launched. Children who start school with relatively poor inhibitory control tend to blurt out the answer, jump out of their seats, take things from other children, and have difficulty paying attention and completing their assignments. They are always getting scolded and get poor grades. Teachers come to expect poor performance from them and the children come to expect the same from themselves. A downward spiral of self-doubt, low expectations, and not wanting to be in school begins. Contrast that with the self-reinforcing positive feedback loop that develops when children start off with better EFs. They are able to pay attention, complete their assignments, and not misbehave. They are often praised, get good grades, and enjoy school. Teachers come to expect them to succeed and the children come to expect the same. Improving EF skills early gets children started on a trajectory for success. Conversely, letting children start school behind on EF skills is letting them get started on a negative trajectory that can be extremely difficult and expensive to reverse. It can be astonishingly difficult to change self-perceptions, self-expectations, and the expectations of others and of an institution for you once those have been formed.

The need to intervene early is probably particularly critical for children at risk because of social or economic disadvantage. They enter school with poorer EFs (Evans & Rosenbaum, 2008; Evans & Schamberg, 2009; Hackman & Farah, 2009; Lengua, Honorado, & Bush, 2007; Noble, McCandliss, & Farah, 2007; Noble, Norman, & Farah, 2005; Raizada & Kishiyama, 2010; Sektnan, McClelland, Acock, & Morrison, 2010; see also Chapter 12, this volume). Those early differences increase with time. Disadvantaged children fall progressively farther behind each school year (O'Shaughnessy et al., 2003). They also become progressively more vulnerable to mental and physical health problems (Adler & Newman, 2002; Gianaros, 2011). A small difference between at-risk and more-advantaged children in EFs early can lead to a gap in achievement and mental health that grows ever wider each passing year. Reducing or erasing that gap at the outset could nip that dynamic in the bud. Intervening early thus has enormous potential to reduce inequalities in health and its determinants.

Indeed, there is already evidence that improving EFs early improves academic achievement. The Chicago School Readiness Project (CSRP) found that children's EFs (inhibitory control of attention and action) improved significantly more in those preschool classes where Head Start teachers had been trained on CSRP than in comparison classes (Raver et al., 2011). CSRP children also improved in vocabulary, letter-naming, and math significantly more than did controls. CSRP's improvement of academic skills was mediated largely via its improvement of EFs. EFs in the spring of preschool predicted achievement 3 years later in math and reading. Thus disadvantaged children who were lucky enough to have been randomly assigned to a CSRP class tended to continue to perform better in school 3 years later, and that was primarily mediated through their improved EFs (Li-Grining, Raver, & Pess, 2011).

MECHANISMS BY WHICH SOCIAL AND ECONOMIC DISADVANTAGE CAN IMPAIR EF DEVELOPMENT

The flip side of the neural plasticity that makes possible improvements in EFs due to environmental influences such as school curricula is that EFs are also particularly vulnerable to impairment by disadvantageous environmental influences. Growing up in poverty, in a community characterized by violence, moving often, having divorced parents, being removed from one's parents, or being a member of a minority that is discriminated against each increases one's stress (e.g., Blair et al., 2011; Bradley & Corwyn, 2002; Evans, 2004; Goodman, McEwen, Dolan, Schafer-Kalkhoff, & Adler, 2005). A plethora of evidence shows that stress impairs EFs and that EFs are exceptionally vulnerable to stress. When a person is stressed, prefrontal cortex gets flooded with too much dopamine (Arnsten, 2000; Cerqueira, Mailliet, Almeida, Jay, & Sousa, 2007; Roth, Tam, Ida, Yang, & Deutch, 1988) and the activity of the neural circuit that includes prefrontal cortex becomes less synchronized (Liston, McEwen, & Casey, 2009). One cannot think clearly and the ability to exercise self-control is weakened (Arnsten, 1998; Liston et al., 2009; Mueller et al., 2010; Oaten & Cheng, 2005; Steinhauser, Maier, & Hübner, 2007). Stressful life circumstances not only directly affect a child growing up in such circumstances, but also affect his or her parents and their ability to think clearly and be caring role models. Not only is their stress detrimental to their ability to be good parents but their child will pick up on their stress, which will increase the stress the child feels.

Another way that social or economic disadvantage can get inside the brain and affect prefrontal cortex and EFs is via parenting. For example, parents who are too fearful and overly protective or too controlling, coercive, or harsh tend to have children with worse EFs than do parents who are more supportive of their child's developing autonomy (Bernier, Carlson, & Whipple, 2010; Eddy, Leve, & Fagot, 2001; Karreman, van Tuijl, van Aken, & Dekovic, 2006; Matte-Gagné & Bernier, 2011). Homes with a richer oral language environment (especially where utterances are more elaborated and conceptually rich, where parents ask open-ended questions and model how to problem solve out loud while their child is working on a problem, and where children are encouraged to think out loud and ask questions) tend to produce children with better EFs (Hackman & Farah, 2009; Hart & Risley, 1992; Matte-Gagné & Bernier, 2011; Vallotton & Ayoub, 2011). Parents can also aid their child's development of EFs by scaffolding or supporting their child's attempts at problem solving or exercising self-control so their child can succeed when, without their help, their child would not (Bernier et al., 2010; Bibok, Carpendale, & Müller, 2009; Hughes & Ensor, 2009; Landry, Smith, Swank, Assel, & Vellet, 2001). This assistance can take the form of guiding questions; helping their child stay on task; helping their child wait rather than giving the immediate, impulsive response; making critical features more salient for their child; helping their child handle frustration and keep going; reducing the number of possible options for problem solution; and so on, thus bootstrapping a process by which children can gradually come to solve problems and exercise self-control on their own (Bibok et al., 2009). One way that scaffolding and a rich verbal environment might aid EF development is through improving the child's verbal ability, which in turn then supports EF development (Landry et al., 2001; Matte-Gagné & Bernier, 2011; Vygotsky, 1978).

Sensitive and responsive parenting and secure attachment can buffer children against the negative effects of environmental risk on EFs (Bernier, Carlson, Deschênes, & Matte-Gagné, 2012; Bernier et al., 2010; Kochanska, Murray, & Harlan, 2000; Landry et al., 2001; Matte-Gagné & Bernier, 2011; Rhoades, Greenberg, Lanza, & Blair, 2011; Robinson, Burns, & Davis, in press; see also Chapter 11, this volume). Such fostering of better EF development translates directly into better grades in school (Sektnan et al., 2010) and better resiliency in general (Obradović, 2010). For a more extended discussion of the mechanisms by which socioeconomic disadvantage can impair EFs, and how this can be minimized, see the chapters in Part III of this volume, especially Chapters 10 and 11.

MEASUREMENT TOOLS FOR ASSESSING EF DEVELOPMENT

To investigate the factors mediating and moderating the effects of environmental risk on EFs and to investigate the causal relations between EFs and academic performance, tools for measuring EFs that can be used over a broad age range and that are valid not only for middle-class, European American children but also for children at social or economic disadvantage are needed. Zelazo has been working with others on the National Institutes of Health Toolbox to develop brief EF measures for use with people ages 3 through 85 (Weintraub et al., 2010). Diamond and colleagues have EF measures that can be used with people ages 4 through 85, but each takes about 10 to 12 minutes to administer (Davidson et al., 2006; Diamond, Barnett, Thomas, & Munro, 2007).

There are many EF tasks appropriate for the 3- to 5-year-old age range, including the Dimensional Change Card Sort (DCCS), Day-Night (Gerstadt, Hong, & Diamond, 1994), Tapping (Diamond & Taylor, 1996; also called the Hands task [Hughes, 1996]), Appearance-Reality (Flavell, 1986, 1993), Ambiguous Figures (Gopnik & Rosati, 2001), False Belief (Perner, Leekam, & Wimmer, 1987), Matrix Classification (Inhelder & Piaget, 1959/1964), and Go/No-Go (Livesey & Morgan, 1991). It has been hard to find EF tasks on which children of only 2.5 or 3 years can succeed, however. Carlson and colleagues (e.g., see Chapter 2, this volume) have been at the forefront of efforts to devise measures that can be used for children 2 through 5 years of age. The combined work of several people in the field seems to have produced one progression of performance on very similar tasks from 2 to 5 years of age (see Table 1.1): By roughly 2.5 years of age, children can do intradimensional switching (reversal tasks: e.g., first putting trucks with trucks, and stars with stars, and then switching to put trucks with stars, and stars with trucks; Brooks, Hanauer, Padowska, & Rosman, 2003; Perner & Lang, 2002). By roughly 3.5 years of age, children can do extradimensional switching (switch between dimensions) from one block of trials to another but only if the dimensions are physically separated on the stimulus cards (e.g., color is a property of background rather than of the stimuli themselves, thus instead of white cards with a red truck or blue star, the front of the cards are

TABLE 1.1
Developmental Progression in the Age at Which Children Can First Switch Rules When Sorting Cards

Tasks that require switching rules	Age in years at which most children can first succeed
Intradimensional switch: Reversal Tasks[a]	2½
Extradimensional switches (sort by 1 dimension and then by another):	
DCCS With Separated Dimensions[b]	3½
DCCS (Standard)—Integrated Dimensions[c]	4½
DCCS–Mixed Block (switching dimensions randomly across trials)[d]	7½

Note. DCCS = Dimensional Change Card Sorting task.
[a]On Reversal Tasks, first stimuli of Type 1 (say, cars) go in the left bin (stimuli of Type 2 [say, animals] go in the right bin); then when the rules reverse, stimuli of Type 1 go in the right bin and Type 2 stimuli go in the left bin. [b]For DCCS with Separated Dimensions, the stimulus on the card is always black or white with a black outline, and color appears elsewhere on the card (either as the background or as a color patch on the other side of the card). [c]For DCCS (standard), the stimuli themselves are colored and the rest of the card is white. First, the participant sorts by one dimension for some trials and then there is a single switch to sorting by the other dimension for a block of trials. In other words, there are two single-task blocks. [d]For DCCS–Mixed Block, there are several switches of sorting by one dimension and then the other. These occur randomly over trials often after only 1, 2, or 3 trials. This is called a mixed-task block. Note how much longer it takes most children to master this.

red or blue and the trucks and stars are drawn entirely in black; Diamond, Carlson, & Beck, 2005; Kloo & Perner, 2005). By roughly 4.5 years of age, children can switch between dimensions from one block of trials to another, even when both dimensions are properties of the same objects (DCCS; Zelazo, Reznick, & Piñon, 1995). It is not until about 7.5 years of age, however, that children can flexibly switch between dimensions on a trial-by-trial basis (Cohen, Bixenman, Meiran, & Diamond, 2001), and not until about 10.5 years of age that they can begin to perform well on the Wisconsin Card Sorting Task (Chelune & Baer, 1986; Welsh, Pennington, & Groisser, 1991).

There is a dearth of research on the early development of EFs among low-income children, children living in sparsely populated rural areas, children who are not of European American descent, and especially among children who are both poor and members of ethnic minorities (the children at greatest risk for school failure and for mental and physical health problems). Work such as that by Caughy et al. (see Chapter 12, this volume) and Willoughby and Blair (see Chapter 4, this volume) is starting to fill that gap but much more work is needed. The timetable of EF development among monolingual North American children of European descent cannot be assumed to be true of all children. There is already evidence that, at least during early childhood, EFs develop faster in East Asian children (Lewis et al., 2009; Oh & Lewis, 2008; Sabbagh, Xu, Carlson, Moses, & Lee, 2006) and in children who are bilingual (Bialystok & Martin, 2004; Kovács & Mehler, 2009).

To test rural children, especially those of low income, the commonly used computerized tests of EFs are not always practical. Willoughby and colleagues (Willoughby & Blair, 2011; Willoughby et al., 2010; see also Chapter 4, this volume) have developed a flip-book version of EF measures, free of technological or electrical requirements. The flip-book version has its own drawbacks, however. One must forgo the collection of reaction-time data, which is often more sensitive than percentage of correct responses (e.g., Durston, Thomas, Worden, Yang, & Casey, 2002; Simpson & Riggs, 2005). Even with training and clear instructions, there is considerable room for between-tester differences in tone of voice, pacing, and other aspects of task administration. For example, although testers are instructed to flip pages at the rate of one page every 2 seconds, there is almost surely more between-tester variability in rate than if a computer controls the timing. A computer takes away much of the opportunity for intertester variations in task administration and reduces opportunities for human error. A final drawback is that the flip-book battery is labor and time intensive; it requires the presence of two staff persons per test administration (increasing labor costs) and it takes 2 hours. The pros and cons of each EF measure and method of administration need to be carefully considered as was indicated above when asking adults for their subjective assessments of children's behavior in real-world settings (as is often done by self-regulation researchers) was contrasted with obtaining objective assessments of children's actual behavior on decontextualized, arbitrary laboratory tasks.

Researchers often assume that a measure labeled an EF measure is (a) really assessing EFs and (b) dependent on frontal cortex and interconnected brain regions thought to subserve EFs. Often those assumptions go untested. Any task requires multiple abilities, and children may have difficulty with a task not because of the ability the researcher was targeting but because of some other requirement of the task. Prefrontal cortex is late maturing; it is not impossible that earlier maturing brain regions subserve EF abilities in very young children. In Chapter 7 (this volume), Bell and Cuevas present initial electroencephalogram evidence of frontal activation during EF performance in preschoolers. Preschoolers exhibited task-related increases in medial frontal power and medial frontal-posterior coherence. (Medial frontal cortex is just behind prefrontal cortex.)

SUMMARY

One of the most critical societal needs is to develop effective, scalable, sustainable, and affordable strategies for supporting children from the youngest age possible, their parents, and their early child-care providers to get children started with good EFs when they first enter school, thereby launching them on a promising, positive trajectory, improving their life prospects and preventing problems, rather than trying to treat problems after they have been allowed to develop. To be able to determine whether a strategy is successful or not, sensitive and valid measures of EFs that can be administered longitudinally are absolutely essential.

REFERENCES

Adler, N. E., & Newman, K. (2002). Socioeconomic disparities in health: Pathways and policies. *Health Affairs, 21*, 60–76. http://dx.doi.org/10.1377/hlthaff.21.2.60

Alloway, T. P., & Alloway, R. G. (2010). Investigating the predictive roles of working memory and IQ in academic attainment. *Journal of Experimental Child Psychology, 106*, 20–29. http://dx.doi.org/10.1016/j.jecp.2009.11.003

Arnsten, A. F. T. (1998). The biology of being frazzled. *Science, 280*, 1711–1712. http://dx.doi.org/10.1126/science.280.5370.1711

Arnsten, A. F. T. (2000). Stress impairs prefrontal cortical function in rats and monkeys: Role of dopamine D1 and norepinephrine alpha-1 receptor mechanisms. *Progress in Brain Research, 126*, 183–192. http://dx.doi.org/10.1016/S0079-6123(00)26014-7

Aron, A. R., Behrens, T. E., Smith, S., Frank, M. J., & Poldrack, R. A. (2007). Triangulating a cognitive control network using diffusion-weighted magnetic resonance imaging (MRI) and functional MRI. *Journal of Neuroscience, 27*, 3743–3752. http://dx.doi.org/10.1523/JNEUROSCI.0519-07.2007

Awh, E., & Jonides, J. (2001). Overlapping mechanisms of attention and spatial working memory. *Trends in Cognitive Sciences, 5*, 119–126. http://dx.doi.org/10.1016/S1364-6613(00)01593-X

Awh, E., Vogel, E. K., & Oh, S. H. (2006). Interactions between attention and working memory. *Neuroscience, 139*, 201–208. http://dx.doi.org/10.1016/j.neuroscience.2005.08.023

Bachevalier, J. (1990). Ontogenetic development of habit and memory formation in primates. *Annals of the New York Academy of Sciences*, 608, 457–484. http://dx.doi.org/10.1111/j.1749-6632.1990.tb48906.x

Baddeley, A. (1992). Working memory. *Science, 255*, 556–559. http://dx.doi.org/10.1126/science.1736359

Baddeley, A. D., & Hitch, G. J. (1994). Developments in the concept of working memory. *Neuropsychology*, 8, 485–493. http://dx.doi.org/10.1037/0894-4105.8.4.485

Bailey, C. E. (2007). Cognitive accuracy and intelligent executive function in the brain and in business. *Annals of the New York Academy of Sciences, 1118*, 122–141. http://dx.doi.org/10.1196/annals.1412.011

Bailey, H., Dunlosky, J., & Kane, M. J. (2008). Why does working memory span predict complex cognition? Testing the strategy affordance hypothesis. *Memory & Cognition*, 36, 1383–1390. http://dx.doi.org/10.3758/MC.36.8.1383

Baler, R. D., & Volkow, N. D. (2006). Drug addiction: The neurobiology of disrupted self-control. *Trends in Molecular Medicine, 12*, 559–566. http://dx.doi.org/10.1016/j.molmed.2006.10.005

Barch, D. M. (2005). The cognitive neuroscience of schizophrenia. *Annual Review of Clinical Psychology, 1*, 321–353. http://dx.doi.org/10.1146/annurev.clinpsy.1.102803.143959

Barkley, R. A. (2001). The inattentive type of ADHD as a distinct disorder: What remains to be done. *Clinical Psychology: Science and Practice*, 8, 489–493. http://dx.doi.org/10.1093/clipsy.8.4.489

Barrouillet, P., Gavens, N., Vergauwe, E., Gaillard, V., & Camos, V. (2009). Working memory span development: A time-based resource-sharing model account. *Developmental Psychology*, 45, 477–490. http://dx.doi.org/10.1037/a0014615

Bedard, A.-C., Nichols, S., Barbosa, J. A., Schachar, R., Logan, G. D., & Tannock, R. (2002). The development of selective inhibitory control across the life span. *Developmental Neuropsychology, 21*, 93–111. http://dx.doi.org/10.1207/S15326942DN2101_5

Bernier, A., Carlson, S. M., Deschênes, M., & Matte-Gagné, C. (2012). Social factors in the development of early executive functioning: A closer look at the care-giving environment. *Developmental Science, 15*, 12–24. http://dx.doi.org/10.1111/j.1467-7687.2011.01093.x

Bernier, A., Carlson, S. M., & Whipple, N. (2010). From external regulation to self-regulation: Early parenting precursors of young children's executive functioning. *Child Development, 81*, 326–339. http://dx.doi.org/10.1111/j.1467-8624.2009.01397.x

Bialystok, E., & Martin, M. M. (2004). Attention and inhibition in bilingual children: Evidence from the dimensional change card sort task. *Developmental Science, 7*, 325–339. http://dx.doi.org/10.1111/j.1467-7687.2004.00351.x

Bibok, M. B., Carpendale, J. I. M., & Müller, U. (2009). Parental scaffolding and the development of executive function. *New Directions for Child and Adolescent Development, 2009*, 17–34. http://dx.doi.org/10.1002/cd.233

Blair, C. (2002). School readiness. Integrating cognition and emotion in a neurobiological conceptualization of children's functioning at school entry. *American Psychologist, 57*, 111–127. http://dx.doi.org/10.1037/0003-066X.57.2.111

Blair, C. (2003). *Self-regulation and school readiness*. Champaign, IL: ERIC Clearinghouse on Elementary and Early Childhood Education.

Blair, C., & Diamond, A. (2008). Biological processes in prevention and intervention: The promotion of self-regulation as a means of preventing school failure. *Development and Psychopathology, 20*, 899–911. http://dx.doi.org/10.1017/S0954579408000436

Blair, C., Granger, D. A., Willoughby, M., Mills-Koonce, R., Cox, M., Greenberg, M. T., . . . the FLP Investigators. (2011). Salivary cortisol mediates effects of poverty and parenting on executive functions in early childhood. *Child Development, 82*, 1970–1984. http://dx.doi.org/10.1111/j.1467-8624.2011.01643.x

Blair, C., & Razza, R. P. (2007). Relating effortful control, executive function, and false belief understanding to emerging math and literacy ability in kindergarten. *Child Development, 78*, 647–663. http://dx.doi.org/10.1111/j.1467-8624.2007.01019.x

Bodrova, E., & Leong, D. J. (2007). *Tools of the mind: The Vygotskian approach to early childhood education* (2nd ed.). New York, NY: Merrill/Prentice Hall.

Boone, K. B. (1999). Neuropsychological assessment of executive functions: Impact of age, education, gender, intellectual level, and vascular status on executive test scores. In B. R. Miller & J. L. Cummings (Eds.), *The human frontal lobes: Functions and disorders* (pp. 247–260). New York, NY: Guilford Press.

Borella, E., Carretti, B., & Pelegrina, S. (2010). The specific role of inhibition in reading comprehension in good and poor comprehenders. *Journal of Learning Disabilities, 43*, 541–552. http://dx.doi.org/10.1177/0022219410371676

Bradley, R. H., & Corwyn, R. F. (2002). Socioeconomic status and child development. *Annual Review of Psychology, 53*, 371–399. http://dx.doi.org/10.1146/annurev.psych.53.100901.135233

Braver, T. S., Cohen, J. D., & Barch, D. M. (2002). The role of the prefrontal cortex in normal and disordered cognitive control: A cognitive neuroscience perspective. In D. T. Stuss & R. T. Knight (Eds.), *Principles of frontal lobe function* (pp. 428–447). Oxford, England: Oxford University Press. http://dx.doi.org/10.1093/acprof:oso/9780195134971.003.0027

Broidy, L. M., Nagin, D. S., Tremblay, R. E., Bates, J. E., Brame, B., Dodge, K. A., . . . Vitaro, F. (2003). Developmental trajectories of childhood disruptive behaviors and adolescent delinquency: A six-site, cross-national study. *Developmental Psychology*, 39, 222–245.

Brooks, P. J., Hanauer, J. B., Padowska, B., & Rosman, H. (2003). The role of selective attention in preschoolers' rule use in a novel dimensional card sort. *Cognitive Development*, *18*, 195–215. http://dx.doi.org/10.1016/S0885-2014(03)00020-0

Bryck, R. L., & Fisher, P. A. (2012). Training the brain: Practical applications of neural plasticity from the intersection of cognitive neuroscience, developmental psychology, and prevention science. *American Psychologist*, *67*, 87–100. http://dx.doi.org/10.1037/a0024657

Cattell, R. B. (1963). Theory of fluid and crystallized intelligence: A critical experiment. *Journal of Educational Psychology*, 54(1), 1–22. http://dx.doi.org/10.1037/h0046743

Cepeda, N. J., Kramer, A. F., & Gonzalez de Sather, J. C. (2001). Changes in executive control across the life span: Examination of task-switching performance. *Developmental Psychology*, *37*, 715–730. http://dx.doi.org/10.1037/0012-1649.37.5.715

Cepeda, N. J., & Munakata, Y. (2007). Why do children perseverate when they seem to know better: Graded working memory, or directed inhibition? *Psychonomic Bulletin & Review*, *14*, 1058–1065. http://dx.doi.org/10.3758/BF03193091

Cerqueira, J. J., Mailliet, F., Almeida, O. F. X., Jay, T. M., & Sousa, N. (2007). The prefrontal cortex as a key target of the maladaptive response to stress. *The Journal of Neuroscience*, *27*, 2781–2787. http://dx.doi.org/10.1523/JNEUROSCI.4372-06.2007

Chein, J. M., & Morrison, A. B. (2010). Expanding the mind's workspace: Training and transfer effects with a complex working memory span task. *Psychonomic Bulletin & Review*, *17*, 193–199. http://dx.doi.org/10.3758/PBR.17.2.193

Chelune, G. J., & Baer, R. A. (1986). Developmental norms for the Wisconsin Card Sorting test. *Journal of Clinical and Experimental Neuropsychology*, 8, 219–228. http://dx.doi.org/10.1080/01688638608401314

Christakou, A., Brammer, M., & Rubia, K. (2011). Maturation of limbic corticostriatal activation and connectivity associated with developmental changes in temporal discounting. *NeuroImage*, *54*, 1344–1354. http://dx.doi.org/10.1016/j.neuroimage.2010.08.067

Cohen, J. D., Dunbar, K., & McClelland, J. L. (1990). On the control of automatic processes: A parallel distributed processing account of the Stroop effect. *Psychological Review*, 97, 332–361. http://dx.doi.org/10.1037/0033-295X.97.3.332

Cohen, J. R., Berkman, E. T., & Lieberman, M. D. (2013). Intentional and incidental self-control in ventrolateral PFC. In D. T. Stuss & R. T. Knight (Eds.), *Principles of frontal lobe function* (2nd ed., pp. 417–440). New York, NY: Oxford University Press.

Cohen, S., Bixenman, M., Meiran, N., & Diamond, A. (2001, May). *Task switching in children*. Paper presented at the South Carolina Bicentennial Symposium on Attention, University of South Carolina, Columbia, SC.

Collins, A., & Koechlin, E. (2012). Reasoning, learning, and creativity: Frontal lobe function and human decision-making. *PLoS Biology, 10*(3), e1001293. http://dx.doi.org/10.1371/journal.pbio.1001293

Conway, A. R. A., & Engle, R. W. (1994). Working memory and retrieval: A resource-dependent inhibition model. *Journal of Experimental Psychology: General, 123*, 354–373. http://dx.doi.org/10.1037/0096-3445.123.4.354

Conway, A. R. A., Kane, M. J., Bunting, M. F., Hambrick, D. Z., Wilhelm, O., & Engle, R. W. (2005). Working memory span tasks: A methodological review and user's guide. *Psychonomic Bulletin & Review, 12*, 769–786. http://dx.doi.org/10.3758/BF03196772

Conway, A. R. A., Kane, M. J., & Engle, R. W. (2003). Working memory capacity and its relation to general intelligence. *Trends in Cognitive Sciences, 7*, 547–552. http://dx.doi.org/10.1016/j.tics.2003.10.005

Cowan, N., Saults, J. S., & Elliott, E. M. (2002). The search for what is fundamental in the development of working memory. *Advances in Child Development and Behavior, 29*, 1–49. http://dx.doi.org/10.1016/S0065-2407(02)80050-7

Daniels, K. A., Toth, J. P., & Jacoby, L. L. (2006). The aging of executive functions. In F. I. M. Craik & E. Bialystok (Eds.), *Lifespan cognition: Mechanisms of change* (pp. 9–11). London, England: Oxford University Press.

Davidson, M. C., Amso, D., Anderson, L. C., & 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*, 2037–2078. http://dx.doi.org/10.1016/j.neuropsychologia.2006.02.006

Davis, J. C., Marra, C. A., Najafzadeh, M., & Liu-Ambrose, T. (2010). The independent contribution of executive functions to health related quality of life in older women. *BMC Geriatrics, 10*(1), 16–23. http://dx.doi.org/10.1186/1471-2318-10-16

Dempster, F. N. (1993). Resistance to interference: Developmental changes in a basic processing mechanism. In M. L. Howe & R. Rasnak (Eds.), *Emerging themes in cognitive development: Vol. 1. Foundations* (pp. 3–27). New York, NY: Springer-Verlag.

Denson, T. F., Pedersen, W. C., Friese, M., Hahm, A., & Roberts, L. (2011). Understanding impulsive aggression: Angry rumination and reduced self-control capacity are mechanisms underlying the provocation–aggression relationship. *Personality and Social Psychology Bulletin, 37*, 850–862. http://dx.doi.org/10.1177/0146167211401420

Diamond, A. (1985). Development of the ability to use recall to guide action, as indicated by infants' performance on AB. *Child Development, 56*, 868–883. http://dx.doi.org/10.2307/1130099

Diamond, A. (2005). Attention-deficit disorder (attention-deficit/hyperactivity disorder without hyperactivity): A neurobiologically and behaviorally distinct disorder from attention-deficit/hyperactivity disorder (with hyperactivity). *Development and Psychopathology, 17*, 807–825. http://dx.doi.org/10.1017/S0954579405050388

Diamond, A. (2010). The evidence base for improving school outcomes by addressing the whole child and by addressing skills and attitudes, not just content. *Early Education and Development, 21*, 780–793. http://dx.doi.org/10.1080/10409289.2010.514522

Diamond, A., Barnett, W. S., Thomas, J., & Munro, S. (2007). Preschool program improves cognitive control. *Science, 318*, 1387–1388. http://dx.doi.org/10.1126/science.1151148

Diamond, A., Carlson, S. M., & Beck, D. M. (2005). Preschool children's performance in task switching on the dimensional change card sort task: Separating the dimensions aids the ability to switch. *Developmental Neuropsychology, 28*, 689–729. http://dx.doi.org/10.1207/s15326942dn2802_7

Diamond, A., & Lee, K. (2011). Interventions shown to aid executive function development in children 4 to 12 years old. [Research Support, N.I.H., Extramural Review]. *Science, 333*, 959–964. http://dx.doi.org/10.1126/science.1204529

Diamond, A., & Taylor, C. (1996). Development of an aspect of executive control: Development of the abilities to remember what I said and to "do as I say, not as I do." *Developmental Psychobiology, 29*, 315–334. http://dx.doi.org/10.1002/(SICI)1098-2302(199605)29:4<315::AID-DEV2>3.0.CO;2-T

Duckworth, A. L., & Seligman, M. E. P. (2005). Self-discipline outdoes IQ in predicting academic performance of adolescents. *Psychological Science, 16*, 939–944. http://dx.doi.org/10.1111/j.1467-9280.2005.01641.x

Duncan, G. J., Dowsett, C. J., Claessens, A., Magnuson, K., Huston, A. C., Klebanov, P., . . . Japel, C. (2007). School readiness and later achievement. *Developmental Psychology, 43*, 1428–1446. http://dx.doi.org/10.1037/0012-1649.43.6.1428

Duncan, J., Emslie, H., Williams, P., Johnson, R., & Freer, C. (1996). Intelligence and the frontal lobe: The organization of goal-directed behavior. *Cognitive Psychology, 30*, 257–303. http://dx.doi.org/10.1006/cogp.1996.0008

Duncan, J., Parr, A., Woolgar, A., Thompson, R., Bright, P., Cox, S., . . . Nimmo-Smith, I. (2008). Goal neglect and Spearman's g: Competing parts of a complex task. *Journal of Experimental Psychology: General, 137*, 131–148. http://dx.doi.org/10.1037/0096-3445.137.1.131

Durston, S., Davidson, M. C., Tottenham, N., Galvan, A., Spicer, J., Fossella, J. A., & Casey, B. J. (2006). A shift from diffuse to focal cortical activity with development. *Developmental Science, 9*, 1–8. http://dx.doi.org/10.1111/j.1467-7687.2005.00454.x

Durston, S., Thomas, K. M., Worden, M. S., Yang, Y., & Casey, B. J. (2002). The effect of preceding context on inhibition: An event-related fMRI study. *NeuroImage, 16*, 449–453. http://dx.doi.org/10.1006/nimg.2002.1074

Eakin, L., Minde, K., Hechtman, L., Ochs, E., Krane, E., Bouffard, R., . . . Looper, K. (2004). The marital and family functioning of adults with ADHD and their spouses. *Journal of Attention Disorders, 8*, 1–10. http://dx.doi.org/10.1177/108705470400800101

Eddy, J. M., Leve, L. D., & Fagot, B. I. (2001). Coercive family processes: A replication and extension of Patterson's coercion model. *Aggressive Behavior, 27*, 14–25. http://dx.doi.org/10.1002/1098-2337(20010101/31)27:1<14::AID-AB2>3.0.CO;2-2

Eigsti, I. M., Zayas, V., Mischel, W., Shoda, Y., Ayduk, O., Dadlani, M. B., . . . Casey, B. J. (2006). Predicting cognitive control from preschool to late adolescence and young adulthood. *Psychological Science, 17*, 478–484. http://dx.doi.org/10.1111/j.1467-9280.2006.01732.x

Eisenberg, D. P., & Berman, K. F. (2010). Executive function, neural circuitry, and genetic mechanisms in schizophrenia. *Neuropsychopharmacology, 35*, 258–277. http://dx.doi.org/10.1038/npp.2009.11

Eisenberg, N., Hofer, J., & Vaughan, C. (2007). Effortful control and its socioemotional consequences, *Handbook of emotion regulation* (pp. 287–306). New York, NY: Guilford Press.

Eisenberg, N., Spinrad, T. L., & Eggum, N. D. (2010). Emotion-related self-regulation and its relation to children's maladjustment. *Annual Review of Clinical Psychology, 6*, 495–525. http://dx.doi.org/10.1146/annurev.clinpsy.121208.131208

Engle, R. W. (2002). Working memory capacity as executive attention. *Current Directions in Psychological Science, 11*, 19–23. http://dx.doi.org/10.1111/1467-8721.00160

Engle, R. W., Tuholski, S. W., Laughlin, J. E., & Conway, A. R. (1999). Working memory, short-term memory, and general fluid intelligence: A latent-variable approach. *Journal of Experimental Psychology: General, 128*, 309–331. http://dx.doi.org/10.1037/0096-3445.128.3.309

Entwisle, D. R., Alexander, K. L., & Olson, L. S. (2005). First grade and educational attainment by age 22: A new story. *American Journal of Sociology, 110*, 1458–1502. http://dx.doi.org/10.1086/428444

Erickson, M. A. (2008). Executive attention and task switching in category learning: Evidence for stimulus-dependent representation. *Memory & Cognition, 36*, 749–761. http://dx.doi.org/10.3758/MC.36.4.749

Evans, G. W. (2004). The environment of childhood poverty. *American Psychologist, 59*, 77–92. http://dx.doi.org/10.1037/0003-066X.59.2.77

Evans, G. W., & Rosenbaum, J. (2008). Self-regulation and the income achievement gap. *Early Childhood Research Quarterly, 23*, 504–514. http://dx.doi.org/10.1016/j.ecresq.2008.07.002

Evans, G. W., & Schamberg, M. A. (2009). Childhood poverty, chronic stress, and adult working memory. *Proceedings of the National Academy of Sciences of the United States of America, 106*, 6545–6549. http://dx.doi.org/10.1073/pnas.0811910106

Fan, J., McCandliss, B. D., Sommer, T., Raz, A., & Posner, M. I. (2002). Testing the efficiency and independence of attentional networks. *Journal of Cognitive Neuroscience, 14*, 340–347. http://dx.doi.org/10.1162/089892902317361886

Flavell, J. H. (1986). The development of children's knowledge about the appearance-reality distinction. *American Psychologist, 41*, 418–425. http://dx.doi.org/10.1037/0003-066X.41.4.418

Flavell, J. H. (1993). The development of children's understanding of false belief and the appearance-reality distinction. *International Journal of Psychology, 28*, 595–604. http://dx.doi.org/10.1080/00207599308246944

Friedman, N. P., Haberstick, B. C., Willcutt, E. G., Miyake, A., Young, S. E., Corley, R. P., & Hewitt, J. K. (2007). Greater attention problems during childhood predict poorer executive functioning in late adolescence. *Psychological Science, 18*, 893–900. http://dx.doi.org/10.1111/j.1467-9280.2007.01997.x

Friedman, N. P., & Miyake, A. (2004). The relations among inhibition and interference control functions: A latent-variable analysis. *Journal of Experimental Psychology: General, 133*, 101–135. http://dx.doi.org/10.1037/0096-3445.133.1.101

Garon, N., Bryson, S. E., & Smith, I. M. (2008). Executive function in preschoolers: A review using an integrative framework. *Psychological Bulletin, 134*, 31–60. http://dx.doi.org/10.1037/0033-2909.134.1.31

Garrett, H. E. (1946). A developmental theory of intelligence. *American Psychologist, 1*, 372–378. http://dx.doi.org/10.1037/h0056380

Gathercole, S. E., Pickering, S. J., Knight, C., & Stegmann, Z. (2004). Working memory skills and educational attainment: Evidence from National Curriculum assessments at 7 and 14 years of age. *Applied Cognitive Psychology, 18*, 1–16. http://dx.doi.org/10.1002/acp.934

Gazzaley, A. (2011). Influence of early attentional modulation on working memory. *Neuropsychologia, 49*, 1410–1424. http://dx.doi.org/10.1016/j.neuropsychologia.2010.12.022

Gazzaley, A., & Nobre, A. C. (2012). Top-down modulation: Bridging selective attention and working memory. *Trends in Cognitive Sciences, 16*, 129–135. http://dx.doi.org/10.1016/j.tics.2011.11.014

Gerardi-Caulton, G. (2000). Sensitivity to spatial conflict and the development of self-regulation in children 24–36 months of age. *Developmental Science, 3*, 397–404. http://dx.doi.org/10.1111/1467-7687.00134

Gerstadt, C. L., Hong, Y. J., & Diamond, A. (1994). The relationship between cognition and action: Performance of children 3½–7 years old on a Stroop-like day–night test. *Cognition, 53*, 129–153. http://dx.doi.org/10.1016/0010-0277(94)90068-X

Gianaros, P. J. (2011, January). Socioeconomic health disparities: A health neuroscience and lifecourse perspective. *Psychological Science Agenda, 25*(1). Retrieved from http://www.apa.org/science/about/psa/2011/01/health-disparities.aspx

Gogtay, N., Giedd, J. N., Lusk, L., Hayashi, K. M., Greenstein, D., Vaituzis, A. C., . . . Thompson, P. M. (2004). Dynamic mapping of human cortical development during childhood through early adulthood. *Proceedings of the National Academy of Sciences of the United States of America, 101*, 8174–8179. http://dx.doi.org/10.1073/pnas.0402680101

Goldsmith, H. H. (1996). Studying temperament via construction of the Toddler Behavior Assessment Questionnaire. *Child Development, 67*, 218–235. http://dx.doi.org/10.2307/1131697

Goodman, E., McEwen, B. S., Dolan, L. M., Schafer-Kalkhoff, T., & Adler, N. E. (2005). Social disadvantage and adolescent stress. *Journal of Adolescent Health, 37*, 484–492. http://dx.doi.org/10.1016/j.jadohealth.2004.11.126

Gopnik, A., & Rosati, A. (2001). Duck or rabbit? Reversing ambiguous figures and understanding ambiguous representations. *Developmental Science, 4*, 175–183. http://dx.doi.org/10.1111/1467-7687.00163

Greenberg, M. T., & Harris, A. R. (2012). Nurturing mindfulness in children and youth: Current state of research. *Child Development Perspectives*, *6*, 161–166. http://dx.doi.org/10.1111/j.1750-8606.2011.00215.x

Hackman, D. A., & Farah, M. J. (2009). Socioeconomic status and the developing brain. *Trends in Cognitive Sciences*, *13*, 65–73. http://dx.doi.org/10.1016/j.tics.2008.11.003

Harnishfeger, K. K. (1995). The development of cognitive inhibition: Theories, definitions, and research evidence. In F. N. Dempster & C. J. Brainerd (Eds.), *New perspective on interference and inhibition in cognition* (pp. 175–204). San Diego, CA: Academic Press. http://dx.doi.org/10.1016/B978-012208930-5/50007-6

Hart, B., & Risley, T. R. (1992). American parenting of language-learning children: Persisting differences in family-child interactions observed in natural home environments. *Developmental Psychology*, *28*, 1096–1105. http://dx.doi.org/10.1037/0012-1649.28.6.1096

Hasher, L., & Zacks, R. T. (1988). Working memory, comprehension, and aging: A review and a new view. In G. H. Bower (Ed.), *The psychology of learning and motivation: Advances in research and theory* (Vol. 22, pp. 193–225). San Diego, CA: Academic Press.

Hughes, C. (1996). Control of action and thought: Normal development and dysfunction in autism: A research note. *Journal of Child Psychology and Psychiatry*, *37*, 229–236. http://dx.doi.org/10.1111/j.1469-7610.1996.tb01396.x

Hughes, C. H., & Ensor, R. A. (2009). How do families help or hinder the emergence of early executive function? *New Directions for Child and Adolescent Development*, *2009*, 35–50. http://dx.doi.org/10.1002/cd.234

Hughes, C. H., Ensor, R. A., Wilson, A., & Graham, A. (2009). Tracking executive function across the transition to school: A latent variable approach. *Developmental Neuropsychology*, *35*, 20–36. http://dx.doi.org/10.1080/87565640903325691

Inhelder, B., & Piaget, J. (1964). *The early growth of logic in the child: Classification and seriation* (E. A. Lunzer & D. Papert, Trans.). New York, NY: Harper & Row. (Original work published 1959)

Jones, L. B., Rothbart, M. K., & Posner, M. I. (2003). Development of executive attention in preschool children. *Developmental Science*, *6*, 498–504. http://dx.doi.org/10.1111/1467-7687.00307

Kane, M. J., & Engle, R. W. (2000). Working-memory capacity, proactive interference, and divided attention: Limits on long-term memory retrieval. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *26*, 336–358. http://dx.doi.org/10.1037/0278-7393.26.2.336

Kane, M. J., & 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 & Review*, *9*, 637–671. http://dx.doi.org/10.3758/BF03196323

Karreman, A., van Tuijl, C., van Aken, M. A. G., & Dekovic, M. (2006). Parenting and self-regulation in preschoolers: A meta-analysis. *Infant and Child Development*, *15*, 561–579. http://dx.doi.org/10.1002/icd.478

Kerr, A., & Zelazo, P. D. (2004). Development of "hot" executive function: The children's gambling task. *Brain and Cognition*, *55*, 148–157. http://dx.doi.org/10.1016/S0278-2626(03)00275-6

Klein, C., Foerster, F., Hartnegg, K., & Fischer, B. (2005). Lifespan development of pro- and anti-saccades: Multiple regression models for point estimates. *Developmental Brain Research*, *160*, 113–123. http://dx.doi.org/10.1016/j.devbrainres.2005.06.011

Klingberg, T. (2010). Training and plasticity of working memory. *Trends in Cognitive Sciences*, *14*, 317–324. http://dx.doi.org/10.1016/j.tics.2010.05.002

Kloo, D., & Perner, J. (2005). Disentangling dimensions in the Dimensional Change Card Sorting task. *Developmental Science*, *8*, 44–56.

Kochanska, G., Murray, K. T., & Harlan, E. T. (2000). Effortful control in early childhood: Continuity and change, antecedents, and implications for social development. *Developmental Psychology*, *36*, 220–232.

Kochanska, G., Philibert, R. A., & Barry, R. A. (2009). Interplay of genes and early mother–child relationship in the development of self-regulation from toddler to preschool age. *Journal of Child Psychology and Psychiatry*, *50*, 1331–1338. http://dx.doi.org/10.1111/j.1469-7610.2008.02050.x

Kovács, A. M., & Mehler, J. (2009). Flexible learning of multiple speech structures in bilingual infants. *Science*, *325*, 611–612. http://dx.doi.org/10.1126/science.1173947

Kusché, C. A., & Greenberg, M. T. (1994). *The PATHS Curriculum*. Seattle, WA: Developmental Research and Programs.

Landry, S. H., Smith, K. E., Swank, P. R., Assel, M. A., & Vellet, S. (2001). Does early responsive parenting have a special importance for children's development or is consistency across early childhood necessary? *Developmental Psychology*, *37*, 387–403. http://dx.doi.org/10.1037/0012-1649.37.3.387

Leh, S. E., Petrides, M., & Strafella, A. P. (2010). The neural circuitry of executive functions in healthy subjects and Parkinson's Disease. *Neuropsychopharmacology*, *35*, 70–85. http://dx.doi.org/10.1038/npp.2009.88

Lehto, J. E., Juujärvi, P., Kooistra, L., & Pulkkinen, L. (2003). Dimensions of executive functioning: Evidence from children. *British Journal of Developmental Psychology*, *21*, 59–80. http://dx.doi.org/10.1348/026151003321164627

Lengua, L. J., Honorado, E., & Bush, N. R. (2007). Contextual risk and parenting as predictors of effortful control and social competence in preschool children. *Journal of Applied Developmental Psychology*, *28*(1), 40–55. http://dx.doi.org/10.1016/j.appdev.2006.10.001

Leon-Carrion, J., García-Orza, J., & Pérez-Santamaría, F. J. (2004). Development of the inhibitory component of the executive functions in children and adolescents. *International Journal of Neuroscience*, *114*, 1291–1311. http://dx.doi.org/10.1080/00207450490476066

Lewis, C., Koyasu, M., Oh, S., Ogawa, A., Short, B., & Huang, Z. (2009). Culture, executive function, and social understanding. *New Directions for Child and Adolescent Development*, *2009*(123), 69–85. http://dx.doi.org/10.1002/cd.236

Liew, J. (2011). Effortful control, executive functions, and education: Bringing self-regulatory and social–emotional competencies to the table. *Child Development Perspectives*, 6, 105–111. http://dx.doi.org/10.1111/j.1750-8606.2011.00196.x

Li-Grining, C. P., Raver, C. C., & Pess, R. A. (2011, April). *Academic impacts of the Chicago School Readiness Project: Testing for evidence in elementary school*. Paper presented at the Society for Research in Child Development Biennial Meeting, Montreal, Quebec, Canada.

Liston, C., McEwen, B. S., & Casey, B. J. (2009). Psychosocial stress reversibly disrupts prefrontal processing and attentional control. *Proceedings of the National Academy of Sciences of the United States of America*, *106*, 912–917. http://dx.doi.org/10.1073/pnas.0807041106

Livesey, D. J., & Morgan, G. A. (1991). The development of response inhibition in 4- and 5-year-old children. *Australian Journal of Psychology*, *43*, 133–137. http://dx.doi.org/10.1080/00049539108260137

Louie, K., & Glimcher, P. W. (2010). Separating value from choice: Delay discounting activity in the lateral intraparietal area. *The Journal of Neuroscience*, *30*, 5498–5507. http://dx.doi.org/10.1523/JNEUROSCI.5742-09.2010

Lu, C. H., & Proctor, R. W. (1995). The influence of irrelevant location information on performance: A review of the Simon and spatial Stroop effects. *Psychonomic Bulletin & Review*, 2, 174–207. http://dx.doi.org/10.3758/BF03210959

Luciana, M., Conklin, H. M., Hooper, C. J., & Yarger, R. S. (2005). The development of nonverbal working memory and executive control processes in adolescents. *Child Development*, *76*, 697–712. http://dx.doi.org/10.1111/j.1467-8624.2005.00872.x

Lui, M., & Tannock, R. (2007). Working memory and inattentive behavior in a community sample of children. *Behavioral and Brain Functions*, 3, 12. http://dx.doi.org/10.1186/1744-9081-3-12

Luna, B. (2009). Developmental changes in cognitive control through adolescence. *Advances in Child Development and Behavior*, *37*, 233–278. http://dx.doi.org/10.1016/S0065-2407(09)03706-9

Marcovitch, S., & Zelazo, P. D. (2009). A hierarchical competing systems model of the emergence and early development of executive function. *Developmental Science*, *12*, 1–18. http://dx.doi.org/10.1111/j.1467-7687.2008.00754.x

Matte-Gagné, C., & Bernier, A. (2011). Prospective relations between maternal autonomy support and child executive functioning: Investigating the mediating role of child language ability. *Journal of Experimental Child Psychology*, *110*, 611–625. http://dx.doi.org/10.1016/j.jecp.2011.06.006

McClelland, M. M., Acock, A. C., Piccinin, A., Rhea, S. A., & Stallings, M. C. (2013). Relations between preschool attention span-persistence and age 25 educational outcomes. *Early Childhood Research Quarterly*, *28*, 314–324.

Miller, H. V., Barnes, J. C., & Beaver, K. M. (2011). Self-control and health outcomes in a nationally representative sample. *American Journal of Health Behavior*, 35, 15–27. http://dx.doi.org/10.5993/AJHB.35.1.2

Mischel, W., & Ayduk, O. (2002). Self-regulation in a cognitive–affective personality system: Attentional control in the service of the self. *Self and Identity, 1*, 113–120. http://dx.doi.org/10.1080/152988602317319285

Mischel, W., Shoda, Y., & Rodriguez, M. I. (1989). Delay of gratification in children. *Science, 244*, 933–938. http://dx.doi.org/10.1126/science.2658056

Miyake, A., Friedman, N. P., Emerson, M. J., Witzki, A. H., Howerter, A., & 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*, 49–100. http://dx.doi.org/10.1006/cogp.1999.0734

Moffitt, T. E. (2012, January). Childhood self-control predicts adult health, wealth, and crime. *Multi-disciplinary symposium improving the well-being of children and youth*. Copenhagen, Denmark.

Moffitt, T. E., Arseneault, L., Belsky, D., Dickson, N., Hancox, R. J., Harrington, H., . . . 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*, 2693–2698. http://dx.doi.org/10.1073/pnas.1010076108

Moffitt, T. E., Caspi, A., Taylor, A., Kokaua, J., Milne, B. J., Polanczyk, G., & Poulton, R. (2010). How common are common mental disorders? Evidence that lifetime prevalence rates are doubled by prospective versus retrospective ascertainment. *Psychological Medicine, 40*, 899–909. http://dx.doi.org/10.1017/S0033291709991036

Morasch, K. C., Raj, V. R., & Bell, M. A. (2013). The development of cognitive control from infancy through childhood. In D. Resiberg (Ed.), *Oxford handbook of cognitive psychology* (pp. 989–999). New York, NY: Oxford University Press. http://dx.doi.org/10.1093/oxfordhb/9780195376746.013.0062

Morrison, A. B., & Chein, J. M. (2011). Does working memory training work? The promise and challenges of enhancing cognition by training working memory. *Psychonomic Bulletin & Review, 18*, 46–60. http://dx.doi.org/10.3758/s13423-010-0034-0

Morton, J. B., & Munakata, Y. (2002). Active versus latent representations: A neural network model of perseveration, dissociation, and decalage. *Developmental Psychobiology, 40*, 255–265. http://dx.doi.org/10.1002/dev.10033

Mueller, S. C., Maheu, F. S., Dozier, M., Peloso, E., Mandell, D., Leibenluft, E., . . . Ernst, M. (2010). Early-life stress is associated with impairment in cognitive control in adolescence: An fMRI study. *Neuropsychologia, 48*, 3037–3044. http://dx.doi.org/10.1016/j.neuropsychologia.2010.06.013

Muraven, M. (2010). Building self-control strength: Practicing self-control leads to improved self-control performance. *Journal of Experimental Social Psychology, 46*, 465–468. http://dx.doi.org/10.1016/j.jesp.2009.12.011

Muraven, M., & Baumeister, R. F. (2000). Self-regulation and depletion of limited resources: Does self-control resemble a muscle? *Psychological Bulletin, 126*, 247–259. http://dx.doi.org/10.1037/0033-2909.126.2.247

Niendam, T. A., Laird, A. R., Ray, K. L., Dean, Y. M., Glahn, D. C., & Carter, C. S. (2012). Meta-analytic evidence for a superordinate cognitive control network subserving diverse executive functions. *Cognitive, Affective & Behavioral Neuroscience, 12*, 241–268. http://dx.doi.org/10.3758/s13415-011-0083-5

Nigg, J. T. (2000). On inhibition/disinhibition in developmental psychopathology: Views from cognitive and personality psychology and a working inhibition taxonomy. *Psychological Bulletin, 126*, 220–246. http://dx.doi.org/10.1037/0033-2909.126.2.220

Noble, K. G., McCandliss, B. D., & Farah, M. J. (2007). Socioeconomic gradients predict individual differences in neurocognitive abilities. *Developmental Science, 10*, 464–480. http://dx.doi.org/10.1111/j.1467-7687.2007.00600.x

Noble, K. G., Norman, M. F., & Farah, M. J. (2005). Neurocognitive correlates of socioeconomic status in kindergarten children. *Developmental Science, 8*, 74–87. http://dx.doi.org/10.1111/j.1467-7687.2005.00394.x

Normandeau, S., & Guay, F. (1998). Preschool behavior and first-grade school achievement: The mediational role of cognitive self-control. *Journal of Educational Psychology, 90*, 111–121. http://dx.doi.org/10.1037/0022-0663.90.1.111

Oaten, M., & Cheng, K. (2005). Academic examination stress impairs self-control. *Journal of Social and Clinical Psychology, 24*, 254–279. http://dx.doi.org/10.1521/jscp.24.2.254.62276

Obradović, J. (2010). Effortful control and adaptive functioning of homeless children: Variable-focused and person-focused analyses. *Journal of Applied Developmental Psychology, 31*, 109–117. http://dx.doi.org/10.1016/j.appdev.2009.09.004

Oh, S., & Lewis, C. (2008). Korean preschoolers' advanced inhibitory control and its relation to other executive skills and mental state understanding. *Child Development, 79*, 80–99. http://dx.doi.org/10.1111/j.1467-8624.2007.01112.x

Olson, E. A., Collins, P. F., Hooper, C. J., Muetzel, R., Lim, K. O., & Luciana, M. (2009). White matter integrity predicts delay discounting behavior in 9- to 23-year-olds: A diffusion tensor imaging study. *Journal of Cognitive Neuroscience, 21*, 1406–1421. http://dx.doi.org/10.1162/jocn.2009.21107

O'Shaughnessy, T., Lane, K. L., Gresham, F. M., & Beebe-Frankenberger, M. (2003). Children placed at risk for learning and behavioral difficulties: Implementing a school-wide system of early identification and prevention. *Remedial and Special Education, 24*, 27–35. http://dx.doi.org/10.1177/074193250302400103

Pardo-Vázquez, J. L., & Fernández-Rey, J. (2008). External validation of the computerized, group administrable adaptation of the "operation span task." *Behavior Research Methods, 40*, 46–54. http://dx.doi.org/10.3758/BRM.40.1.46

Paus, T., Zijdenbos, A., Worsley, K., Collins, D. L., Blumenthal, J., Giedd, J. N., . . . Evans, A. C. (1999). Structural maturation of neural pathways in children and adolescents: In vivo study. *Science, 283*, 1908–1911. http://dx.doi.org/10.1126/science.283.5409.1908

Penadés, R., Catalán, R., Rubia, K., Andrés, S., Salamero, M., & Gastó, C. (2007). Impaired response inhibition in obsessive compulsive disorder. *European Psychiatry*, 22, 404–410. http://dx.doi.org/10.1016/j.eurpsy.2006.05.001

Pennington, B. F. (1994). The working memory function of the prefrontal cortices: Implications for developmental and individual differences in cognition. In M. M. Haith, J. Benson, R. Roberts, & B. F. Pennington (Eds.), *The development of future oriented processes* (pp. 243–289). Chicago, IL: University of Chicago Press.

Perner, J., & Lang, B. (2002). What causes 3-year-olds' difficulty on the dimensional change card sorting task? *Infant and Child Development*, 11, 93–105. http://dx.doi.org/10.1002/icd.299

Perner, J., Leekam, S. R., & Wimmer, H. (1987). Three-year-olds' difficulty with false belief: The case for a conceptual deficit. *British Journal of Developmental Psychology*, 5, 125–137. http://dx.doi.org/10.1111/j.2044-835X.1987.tb01048.x

Petit, L., Courtney, S. M., Maisog, J. M., Ungerleider, L. G., & Haxby, J. V. (1997). Frontal spatial working memory areas anterior to the frontal and supplementary eye fields studied with fMRI in humans. *Society for Neuroscience Abstracts*, 23, 1679.

Porges, S. W., Doussard-Roosevelt, J. A., & Maiti, A. K. (1994). Vagal tone and the physiological regulation of emotion. *Monographs of the Society for Research in Child Development*, 59(2–3), 167–186. http://dx.doi.org/10.1111/j.1540-5834.1994.tb01283.x

Posner, M. I., & DiGirolamo, G. J. (1998). Executive attention: Conflict, target detection, and cognitive control. In R. Parasuraman (Ed.), *The attentive brain* (pp. 401–423). Cambridge, MA: MIT Press.

Prince, M., Patel, V., Saxena, S., Mmaj, M., Maselko, J., Phillips, M., & Rahman, A. (2007). No health without mental health. *The Lancet*, 370, 859–877.

Rachlin, H., Raineri, A., & Cross, D. (1991). Subjective probability and delay. *Journal of the Experimental Analysis of Behavior*, 55, 233–244. http://dx.doi.org/10.1901/jeab.1991.55-233

Raizada, R. D., & Kishiyama, M. M. (2010). Effects of socioeconomic status on brain development, and how cognitive neuroscience may contribute to levelling the playing field. *Frontiers in Human Neuroscience*, 4, 1–11.

Raven, J., Raven, J. C., & Court, J. H. (2004). *Manual for Raven's Progressive Matrices and Vocabulary Scales*. San Antonio, TX: Pearson Assessment.

Raver, C. C. (2004). Placing emotional self-regulation in sociocultural and socioeconomic contexts. *Child Development*, 75, 346–353. http://dx.doi.org/10.1111/j.1467-8624.2004.00676.x

Raver, C. C., Jones, S. M., Li-Grining, C. P., Metzger, M., Smallwood, K., & Sardin, L. (2008). Improving preschool classroom processes: Preliminary findings from a randomized trial implemented in Head Start settings. *Early Childhood Research Quarterly*, 63, 253–255.

Raver, C. C., Jones, S. M., Li-Grining, C., Zhai, F., Bub, K., & Pressler, E. (2011). CSRP's impact on low-income preschoolers' preacademic skills: Self-regulation as a mediating mechanism. *Child Development*, 82, 362–378.

Rhoades, B. L., Greenberg, M. T., Lanza, S. T., & Blair, C. (2011). Demographic and familial predictors of early executive function development: Contribution of a person-centered perspective. *Journal of Experimental Child Psychology, 108*, 638–662. http://dx.doi.org/10.1016/j.jecp.2010.08.004

Riggs, N. R., Blair, C. B., & Greenberg, M. T. (2004). Concurrent and 2-year longitudinal relations between executive function and the behavior of 1st and 2nd grade children. *Child Neuropsychology, 9*, 267–276. http://dx.doi.org/10.1076/chin.9.4.267.23513

Robinson, J. B., Burns, B. M., & Davis, D. W. (in press). Maternal scaffolding and attention regulation in children living in poverty. *Journal of Applied Developmental Psychology*.

Robison, L. M., Sclar, D. A., Skaer, T. L., & Galin, R. S. (1999). National trends in the prevalence of attention-deficit/hyperactivity disorder and the prescribing of methylphenidate among school-age children: 1990–1995. *Clinical Pediatrics, 38*, 209–217. http://dx.doi.org/10.1177/000992289903800402

Roca, M., Parr, A., Thompson, R., Woolgar, A., Torralva, T., Antoun, N., . . . Duncan, J. (2010). Executive function and fluid intelligence after frontal lobe lesions. *Brain: A Journal of Neurology, 133*, 234–247. http://dx.doi.org/10.1093/brain/awp269

Roth, R. H., Tam, S. Y., Ida, Y., Yang, J. X., & Deutch, A. Y. (1988). Stress and the mesocorticolimbic dopamine systems. *Annals of the New York Academy of Sciences, 537*, 138–147. http://dx.doi.org/10.1111/j.1749-6632.1988.tb42102.x

Rothbart, M. K., Ahadi, S. A., Hershey, K. L., & Fisher, P. (2001). Investigations of temperament at three to seven years: The Children's Behavior Questionnaire. *Child Development, 72*, 1394–1408. http://dx.doi.org/10.1111/1467-8624.00355

Rothbart, M. K., & Bates, J. E. (2006). Temperament. In W. Damon & N. Eisenberg (Eds.), *Handbook of child psychology: Vol. 3. Social, emotional, and personality development* (pp. 105–176). New York, NY: Wiley.

Rothbart, M. K., & Jones, L. B. (1998). Temperament, self-regulation, and education. *School Psychology Review, 27*, 479–491.

Rothbart, M. K., & Posner, M. I. (2001). Mechanism and variation in the development of attentional networks. In C. A. Nelson & M. Luciana (Eds.), *Handbook of developmental cognitive neuroscience* (pp. 353–363). Cambridge, MA: MIT Press.

Rubia, K., Smith, A. B., Taylor, E., & Brammer, M. (2007). Linear age-correlated functional development of right inferior fronto-striato-cerebellar networks during response inhibition and anterior cingulate during error-related processes. *Human Brain Mapping, 28*, 1163–1177. http://dx.doi.org/10.1002/hbm.20347

Rueda, M. R., Posner, M. I., & Rothbart, M. K. (2005). The development of executive attention: Contributions to the emergence of self-regulation. *Developmental Neuropsychology, 28*, 573–594. http://dx.doi.org/10.1207/s15326942dn2802_2

Saarni, C. (1999). *The development of emotional competence*. New York, NY: Guilford Press.

Sabbagh, M. A., Xu, F., Carlson, S. M., Moses, L. J., & Lee, K. (2006). The development of executive functioning and theory of mind. A comparison of Chinese and U.S. preschoolers. *Psychological Science, 17*, 74–81. http://dx.doi.org/10.1111/j.1467-9280.2005.01667.x

Schleepen, T. M., & Jonkman, L. M. (2009). The development of non-spatial working memory capacity during childhood and adolescence and the role of interference control: An N-back task study. *Developmental Neuropsychology, 35*, 37–56. http://dx.doi.org/10.1080/87565640903325733

Sektnan, M., McClelland, M. M., Acock, A., & Morrison, F. J. (2010). Relations between early family risk, children's behavioral regulation, and academic achievement. *Early Childhood Research Quarterly, 25*, 464–479. http://dx.doi.org/10.1016/j.ecresq.2010.02.005

Shing, Y. L., Lindenberger, U., Diamond, A., Li, S. C., & Davidson, M. C. (2010). Memory maintenance and inhibitory control differentiate from early childhood to adolescence. *Developmental Neuropsychology, 35*, 679–697. http://dx.doi.org/10.1080/87565641.2010.508546

Shoda, Y., Mischel, W., & Peake, P. K. (1990). Predicting adolescent cognitive and self-regulatory competencies from preschool delay of gratification: Identifying diagnostic conditions. *Developmental Psychology, 26*, 978–986. http://dx.doi.org/10.1037/0012-1649.26.6.978

Simpson, A., & Riggs, K. J. (2005). Inhibitory and working memory demands of the day–night task in children. *British Journal of Developmental Psychology, 10*, 1–17.

St Clair-Thompson, H. L., & Gathercole, S. E. (2006). Executive functions and achievements in school: Shifting, updating, inhibition, and working memory. *The Quarterly Journal of Experimental Psychology, 59*, 745–759. http://dx.doi.org/10.1080/17470210500162854

Steinberg, L., Graham, S., O'Brien, L., Woolard, J., Cauffman, E., & Banich, M. (2009). Age differences in future orientation and delay discounting. *Child Development, 80*, 28–44. http://dx.doi.org/10.1111/j.1467-8624.2008.01244.x

Steinhauser, M., Maier, M., & Hübner, R. (2007). Cognitive control under stress: How stress affects strategies of task-set reconfiguration. *Psychological Science, 18*, 540–545. http://dx.doi.org/10.1111/j.1467-9280.2007.01935.x

Taylor Tavares, J. V., Clark, L., Cannon, D. M., Erickson, K., Drevets, W. C., & Sahakian, B. J. (2007). Distinct profiles of neurocognitive function in unmedicated unipolar depression and bipolar II depression. *Biological Psychiatry, 62*, 917–924. http://dx.doi.org/10.1016/j.biopsych.2007.05.034

Unsworth, N., Redick, T. S., Heitz, R. P., Broadway, J. M., & Engle, R. W. (2009). Complex working memory span tasks and higher-order cognition: A latent-variable analysis of the relationship between processing and storage. *Memory, 17*, 635–654. http://dx.doi.org/10.1080/09658210902998047

Vallotton, C., & Ayoub, C. (2011). Use your words: The role of language in the development of toddlers' self-regulation. *Early Childhood Research Quarterly, 26*, 169–181. http://dx.doi.org/10.1016/j.ecresq.2010.09.002

Verdejo-García, A., Bechara, A., Recknor, E. C., & Pérez-García, M. (2006). Executive dysfunction in substance dependent individuals during drug use and abstinence: An examination of the behavioral, cognitive, and emotional correlates of addiction. *Journal of the International Neuropsychological Society, 12*, 405–415. http://dx.doi.org/10.1017/S1355617706060486

Vygotsky, L. S. (1978). *Mind in society: The development of higher psychological processes*. Cambridge, MA: Harvard University Press.

Wass, S., Porayska-Pomsta, K., & Johnson, M. H. (2011). Training attentional control in infancy. *Current Biology, 21*, 1543–1547. http://dx.doi.org/10.1016/j.cub.2011.08.004

Webster-Stratton, C., & Reid, M. J. (2004). Strengthening social and emotional competence in young children: The foundation for early school readiness and success. *Infants and Young Children, 17*, 96–113. http://dx.doi.org/10.1097/00001163-200404000-00002

Weintraub, S., Tulksy, D., Dikmen, S., Heaton, R., Havlik, R., Fox, N., & Borosh, B. (2010). *The NIH Toolbox for assessment of neurological and behavioral function: The cognition team experience*. Evanston, IL: Center on Education Research and Outcomes, Evanston Northwestern Healthcare.

Welsh, M. C., Pennington, B. F., & Groisser, D. B. (1991). A normative–developmental study of executive function: A window on prefrontal function in children. *Developmental Neuropsychology, 7*, 131–149. http://dx.doi.org/10.1080/87565649109540483

Werner, H. (1957). The concept of development from a comparative and organismic point of view. In D. B. Harris (Ed.), *The concept of development: An issue in the study of human behaviour* (pp. 125–148). Minneapolis, MN: Jones Press.

Wiebe, S. A., Sheffield, T., Nelson, J. M., Clark, C. A., Chevalier, N., & Espy, K. A. (2011). The structure of executive function in 3-year-olds. *Journal of Experimental Child Psychology, 108*, 436–452. http://dx.doi.org/10.1016/j.jecp.2010.08.008

Willoughby, M. T., & Blair, C. B. (2011). Test–retest reliability of a new executive function battery for use in early childhood. *Child Neuropsychology, 17*, 564–579. http://dx.doi.org/10.1080/09297049.2011.554390

Willoughby, M. T., Blair, C. B., Wirth, R. J., & Greenberg, M. (2010). The measurement of executive function at age 3 years: Psychometric properties and criterion validity of a new battery of tasks. *Psychological Assessment, 22*, 306–317. http://dx.doi.org/10.1037/a0018708

Winstok, Z. (2009). From self-control capabilities and the need to control others to proactive and reactive aggression among adolescents. *Journal of Adolescence, 32*, 455–466. http://dx.doi.org/10.1016/j.adolescence.2008.08.006

Wright, A., & Diamond, A. (2014). An effect of inhibitory load in children while keeping working memory load constant. [Special issue on Development of Executive Function during Childhood]. *Frontiers in Psychology, 5*, 213. http://dx.doi.org/10.3389/fpsyg.2014.00213

Zacks, R. T., & Hasher, L. (2006). Aging and long-term memory: Deficits are not inevitable. In E. Bialystock & F. I. M. Craik (Eds.), *Lifespan cognition: Mechanisms of change* (pp. 162–177). New York, NY: Oxford University Press. http://dx.doi.org/10.1093/acprof:oso/9780195169539.003.0011

Zanto, T. P., Rubens, M. T., Thangavel, A., & Gazzaley, A. (2011). Causal role of the prefrontal cortex in top-down modulation of visual processing and working memory. *Nature Neuroscience, 14*, 656–661. http://dx.doi.org/10.1038/nn.2773

Zelazo, P. D., Reznick, J. S., & Piñon, D. E. (1995). Response control and the execution of verbal rules. *Developmental Psychology, 31*, 508–517. http://dx.doi.org/10.1037/0012-1649.31.3.508

Executive Function in Preschool-Age Children

INTEGRATING MEASUREMENT, NEURODEVELOPMENT, AND TRANSLATIONAL RESEARCH

Edited by James A. Griffin, Peggy McCardle, and Lisa S. Freund

American Psychological Association • Washington, DC

Published by
American Psychological Association
750 First Street, NE
Washington, DC 20002
www.apa.org

To order
APA Order Department
P.O. Box 92984
Washington, DC 20090-2984
Tel: (800) 374-2721; Direct: (202) 336-5510
Fax: (202) 336-5502; TDD/TTY: (202) 336-6123
Online: www.apa.org/pubs/books
E-mail: order@apa.org

In the U.K., Europe, Africa, and the Middle East, copies may be ordered from
American Psychological Association
3 Henrietta Street
Covent Garden, London
WC2E 8LU England

Typeset in Goudy by Circle Graphics, Inc., Columbia, MD

Printer: Sheridan Books, Ann Arbor, MI
Cover Designer: Mercury Publishing Services, Inc., Rockville, MD

Library of Congress Cataloging-in-Publication Data

Executive function in preschool-age children : integrating measurement, neurodevelopment, and translational research / [edited by] James A. Griffin, Peggy McCardle, and Lisa S. Freund. — First edition.
pages cm
Includes bibliographical references and index.
ISBN 978-1-4338-1826-4 — ISBN 1-4338-1826-4 1. Executive functions (Neuropsychology) 2. Cognition in children. 3. Control (Psychology) in children. 4. Child psychology. 5. Preschool children. I. Griffin, James Alan, 1963- II. McCardle, Peggy D. III. Freund, Lisa S.
BF723.C5E985 2016
155.42'3—dc23

2015019980

British Library Cataloguing-in-Publication Data
A CIP record is available from the British Library.

Printed in the United States of America
First Edition

http://dx.doi.org/10.1037/14797-000

CONTENTS