Theme Editor's Introduction

Understanding Executive Functions:
What Helps or Hinders Them and How Executive Functions and Language Development Mutually Support One Another

by Adele Diamond

This special issue on executive functions (EFs) contains seven articles from five countries (Ecuador, the Netherlands, Switzerland, the United Kingdom, and the United States) and three continents (North and South America and Europe). EFs (also called *executive control* or *cognitive control*) refer to a family of top-down processes needed when you have to concentrate and pay attention, when "going on automatic" or relying on instinct or intuition would be ill-advised, insufficient, or impossible (Diamond, 2006, 2013; Espy, 2004; Hughes, 2005; Jacques & Marcovitch, 2010; Miller & Cohen, 2001; Zelazo, Carlson, & Kesek, 2008). Using EFs is effortful; it is easier to continue doing what you have been doing than to change or to put thought into what to do next, and it is easier to give into temptation than to resist it.

There is general agreement that there are three core executive functions (EFs): *inhibitory control*, *working memory*, and *cognitive flexibility* (Miyake, Emerson, & Freidman, 2000; Diamond, 2013; Lehto, Juujärvi, Kooistra, & Pulkkinen, 2003; Logue & Gould, 2013). From these, higher-order EFs are built, such as *reasoning*, *problem-solving*, and *planning* (Collins & Koechlin, 2012; Lunt et al., 2012).

Inhibitory Control

Inhibitory control (or inhibition) consists of the ability to control one's attention, behavior, thoughts, and emotions to override a strong internal predisposition or external lure, and instead do what is more appropriate or needed (Diamond, 2013; Levy & Wagner, 2011; Macdonald, Beauchamp, Crigan, & Anderson, 2013; Simpson et al., 2012; van den Wildenberg et al., 2010; Watson & Bell, 2013; Wiebe, Sheffield, & Espy, 2012). Having the presence of mind to wait before speaking or acting so we give a considered response rather than an impulsive one, can save us from making fools of ourselves and help us demonstrate the best of which we are capable. Self-control is the aspect of inhibitory control that involves resisting temptations and not acting impulsively. The temptation resisted might be to indulge in pleasures when one should not (e.g., eating sweets if you are trying to lose weight), to overindulge, or to stray from the straight and narrow (e.g., to cheat or steal). Alternatively, the temptation might be to impulsively react (e.g., reflexively striking back at someone who has hurt your feelings) or to do or take what you want without regard for social norms or the feelings of others (e.g., butting in line or grabbing another child's toy). Self-regulation overlaps to a large extent (but not completely) with inhibitory control (see Diamond, 2013).

Inhibitory control at the level of attention (selective attention) consists of staying focused on what you intend to focus on despite distractions (including distracting thoughts or distractions in the environment). Another aspect of inhibitory control is having the discipline to stay on task despite distractions and completing a task despite temptations to give up, to move on to more interesting work, or to have a good time instead. This involves making yourself do something or keep at something though you would rather be doing something else. It is related to a final aspect of self-control (delaying gratification (Mischel, Shoda, & Rodriguez, 1989)) making yourself forgo an immediate pleasure for a greater reward later. Without the discipline to complete what one started and delay gratification, no one would ever complete a long, time-consuming task such as writing a term paper, or later a dissertation, or running a marathon.

Without inhibitory control we would be at the mercy of impulse, old habits of thought or action and stimuli in the environment that pull us this way or that. Thus, inhibitory control makes it possible for us to change and choose how we react and how we behave rather than being unthinking creatures of habit. It does not make it easy. Indeed, we are usually creatures of habit and our behavior is under the control of environmental stimuli far more than we usually realize, but having the ability to exercise inhibitory control creates the possibility of choice and change.

Working Memory

Working memory (WM) involves holding information in mind and mentally working with it (Baddeley, 1992; Baddeley & Hitch, 1994; D'Esposito et al., 1995, 1998; Owen, Morris, Sahakian, Polkey, & Robbins, 1996; Smith & Jonides, 1999; Smith, Jonides, Marshuetz, & Koeppe, 1998). Translating instructions into action plans requires WM, as does updating your thinking or planning, mentally re-ordering a to-do list, considering alternatives, or relating one piece of information to another.

WM is critical for making sense of anything that unfolds over time, for that always requires holding in mind what happened earlier and relating that to what is happening now. Thus, WM is necessary for making sense of spoken or written language whether it is a sentence, a paragraph, or longer. The need for WM in oral language is most obvious because what was said earlier is no longer physically present, so relating that to what you are hearing now must be done in your head using WM. However, WM is also critical for understanding what you are reading because even at the level of a sentence it is rare to see all the words at once; so we use WM to relate what we read

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earlier to what we are reading now. Reasoning would not be possible without WM: WM is critical for mentally relating information to derive a general principle, to see relations between items or ideas, or to consider alternatives. WM is critical to our ability to see connections between seemingly unrelated things and to pull apart elements from an integrated whole—hence it is critical for creativity because creativity involves disassembling and recombining elements in new ways. WM also enables us to bring conceptual knowledge—not just perceptual input—to bear on our decisions and to consider our remembered past and hopes for the future in making plans and decisions.

WM (holding information in mind and manipulating it) is distinct from short-term memory (just holding information in mind). They are linked to different neural sub-systems (D'Esposito, Postle, Ballard, & Lease, 1999; Eldreth et al., 2006; Smith & Jonides, 1999) and show different developmental progressions (short-term memory develops earlier and faster (Davidson, Amso, Anderson, & Diamond, 2006)).

Cognitive Flexibility

Cognitive flexibility (the third core EF) builds on the other two and comes in much later in development (Davidson et al., 2006; Garon, Bryson, & Smith, 2008). One aspect of cognitive flexibility is the ability to change perspectives—either spatially (e.g., "How would this look if viewed from a different direction?") or interpersonally (e.g., "Let me see if I can see this issue from your perspective."). To change perspectives, we need to inhibit (or de-activate) our previous perspective and load a different perspective into WM (i.e., or activate a different perspective). It is in this sense that cognitive flexibility requires and builds on inhibitory control and WM. Another aspect of cognitive flexibility involves changing how we think about something ("thinking outside the box"). For example, if one way of solving a problem isn't working, we can use cognitive flexibility to try to come up with a new way of attacking or conceiving of the problem.

Cognitive flexibility also involves being able to adjust to changed demands or priorities; take advantage of sudden, unexpected opportunities; overcome sudden, unexpected problems; or even admit you were wrong when you get new information. Suppose you were planning to do X, but an amazing opportunity arose to do Y: Do you have the flexibility to take advantage of serendipity? There is much overlap between cognitive flexibility and creativity, task switching, and set shifting. Cognitive flexibility is the opposite of rigidity.

As teachers, we can also use cognitive flexibility. When a student isn't grasping a concept, we often blame the student: "If only the student were brighter, he [or she] would have grasped what I'm trying to teach." We could consider a different perspective, however: "What might I do differently? How can I present the material differently, or word the question differently, so this student succeeds?"

Given what has been said above, it is hardly surprising that EFs are core skills critical for cognitive, social, and psychological development, mental and physical health, and success in school and in life. EFs are critical for *school readiness* (even more critical than IQ or entry-level reading or math; Blair, 2002; Blair & Razza, 2007; Carlson & Moses, 2001; Hughes & Ensor, 2008; Kochanska, Murray, & Coy, 1997; Morrison, Ponitz, & McClelland, 2010) *success in school from the earliest grades through university* (in both language arts and mathematics; Alloway & Alloway, 2010; Borella, Carretti, & Pelgrina, 2010; Duncan et al., 2007; Fiebach, Ricker, Friederici, & Jacobs, 2007; Hamre & Pianta, 2001; Loosli, Buschkuehl, Perrig, & Jaeggi, 2012; McClelland et al., 2007; Nicholson, 2007; Savage, Cornish, Manly, & Hollis, 2006; St Clair-Thompson & Gathercole, 2006), *career success* (Bailey, 2007), *making and keeping friends* (Hughes & Dunn, 1998), *marital harmony* (Eakin et al., 2004), and *good health* (Crescioni et al., 2011; Cserjési, Luminet, Poncelet, & Schafer, 2009; Hall, Crossley, & D'Arcy, 2010; Miller, Barnes, & Beaver, 2011; Moffitt et al., 2011; Perry et al., 2011; Riggs, Spruijt-Metz, Sakuma, Chou, & Pentz, 2010).

In This Issue

One article in this special issue focuses on inhibitory control (Borst & Houdé), two papers focus primarily on working memory (Gathercole & Holmes; Gordon-Pershey), and one focuses on cognitive flexibility (Huizinga, Smidts, & Ridderinkhof). Two articles in this special issue address how EFs can support early literacy (Roebers & Jäger; Raver & Blair). Two articles focus more on how language can support the early development of EFs (Gordon-Pershey; Tobar). Four of the articles in this issue offer clear, concrete suggestions for educators and parents (Tobar; Gordon-Pershey; Huizinga and colleagues; Gathercole and Holmes).

"The Relative Importance of Fine Motor Skills, Intelligence, and Executive Functions for First Graders' Reading and Spelling Skills" by Roebers and Jäger confirms what many early educators have noticed—that early motor skills, especially fine motor skills, are predictive of school readiness and a child's readiness to learn to read. What early educators had perhaps not recognized so readily and might be interested to learn from Roebers and Jäger is that a) the reason early fine motor skills appear to be predictive of readiness for the rigors of schooling and the demands of reading is that those require EFs (when EFs are entered into analyses, the relation between fine motor skills and academic achievement or cognitive skills drops out) and b) EFs and fine motor skills are even more predictive of early math achievement than early literacy achievement (see also Blair, Knipe, & Gamson, 2008; Blair & Razza, 2007; Bull & Lee, 2014; and Gilmore et al., 2013). Roebers and Jäger end with a call for appreciating the importance of physical activities and games for building EFs and aiding school achievement.

In her contribution to this issue, "The Influence of Sleep and Exercise, Emotions and Stress, and Language on the Development of Executive Functions: Implications for Parents and Early-Years Educators," Tobar briefly reviews factors that can aid or impede the development of, or ability to use, EFs. Oral language (talking to oneself) is an extremely important aid to fragile EFs. EFs might be fragile because they are still immature,

are deteriorating (as they do with aging), the brain has sustained an injury (say, in an accident or fall), or a person has not gotten enough sleep or exercise. As Tobar points out, physical, social, and emotional health are critical for cognitive health, especially good executive functioning. You may have noticed that you think less clearly and have weaker self-control when you are tired or stressed. If children's physical, emotional, or social needs are not met, their EFs and school performance will suffer. Tobar offers advice on the importance of addressing the different needs of each child and how to do it.

In Gordon-Pershey's contribution to this issue, "Executive Functioning and Language: A Complementary Relationship That Supports Learning," she points out that EFs and language skills have a recursive relation to one another: Each is important for and supports the other. EFs provide the cognitive foundation for the growth of language skills and language can be used to scaffold, support, and improve executive functioning. Gordon-Pershey provides a rich panoply of language-based strategies to help students succeed in academic contexts through exercising better EFs.

The Raver and Blair article , "At the Crossroads of Education and Developmental Neuroscience: Perspectives on Executive Function," highlights the key roles that EFs play in young children's opportunities for learning in school contexts. The authors then go on to discuss the evidence that children's EFs are shaped by social contexts, including neighborhood and family poverty, parents' and teachers' practices, and educational programs or policies. Family poverty with its associated stresses and strains has a powerful and negative impact on EFs. Home- and school-based interventions are promising approaches for supporting and improving children's EFs across early and middle childhood. Raver and Blair worry that such approaches are but bandages. They make a strong case that to make more than marginal inroads in the dramatic and devastating differences in EFs and school performance by social-economic status (SES) there is no getting around that we must alleviate the financial hardship experienced by economically strapped families by reducing poverty.

In their article, "Change of Mind: Cognitive Flexibility in the Classroom," Huizinga, Smidts, and Ridderinkhof focus on the EF component of cognitive flexibility. They provide an overview of a) the scientific research on cognitive flexibility, b) the importance of exercising cognitive flexibility in the classroom, c) the long developmental progression in children's ability to demonstrate better and better cognitive flexibility throughout childhood and adolescence, and d) practical guidelines and recommendations to help teachers and parents better support children who are suffering with problems with cognitive flexibility.

Susan Gathercole is one of the preeminent authorities on working memory (WM). In "Developmental Impairments of Working Memory: Profiles and Interventions" she and her co-author address WM impairments in a number of developmental disorders, such as specific language impairment. WM impairments are common in children and strongly predict problems in learning and academic progress. WM impairments take a variety of forms. Different profiles of WM impairments are described that partially overlap and are partially distinct. What looks like a WM impairment might actually be a problem in a different function, such as perception. Gathercole and Holmes point out that identifying the cause of WM problems is therefore critical and requires a broad assessment of functions, including, but not limited to, WM. Finally, Gathercole and Holmes discuss multiple, diverse methods for improving academic outcomes in children with WM challenges.

Last but not least, in "Inhibitory Control As a Core Mechanism for Cognitive Development and Learning at School," Borst and Houdé focus on the EF component called *inhibitory control*. Many teachers and educators assume that if children know what they should do, they will do it. Therefore, not solving a problem correctly or not behaving properly is thought to indicate either ignorance and lack of understanding or willful misbehavior and defiance. Thus, for example, Piaget assumed that young children did not understand the principles of number conservation and class inclusion because they failed his tests of those principles. However, as Borst and Houdé demonstrate, often Piaget's measures of cognitive abilities required inhibitory control abilities that are still immature in young children. Young children failed the tests, not because they did not understand the concepts, but because they lacked the inhibitory control to demonstrate their understanding on those tests.

The Borst and Houdé article underscores two general points of considerable importance. One, any test or assessment is only an imperfect indicator of the underlying ability or knowledge it is intended to measure. A child may know much more than he or she can show on a particular test. Queried a different way, a child may be capable of much more sophisticated understanding and advanced ability. Two, development proceeds both by the **acquisition** of knowledge and skills **and** by the increasing ability to **inhibit** inappropriate reactions that can get in the way of demonstrating what is already known. Between knowing the right answer or knowing what correct behavior entails and demonstrating that in one's behavior, another step, long ignored, is often needed. When a strong competing response is present, that response needs to be inhibited. It is not enough to know what is right and to want very much to act accordingly, you must do it, and sometimes an inability to inhibit an inappropriate inclination gets in the way. Adults may not appreciate how inordinately difficult inhibitory control can be for young children because it is so much less difficult for us grown-ups (Wright & Diamond, 2014).

It is hoped that readers will come away from this issue with a better understanding of what EFs are, why people who care about children's ability to read and succeed in school should care about EFs, what factors facilitate or impede EF development, and how EFs not only aid language development but how using language skills can aid EF development.

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