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Executive Functions: Insights Into Ways to Help More Children Thrive

Adele Diamond
University of British Columbia

ABSTRACT

Executive functions enable children to pay attention, follow instructions, apply what they have learned, have those "aha!" moments in which they grasp how multiple facts interrelate, think of creative solutions, obey social norms such as waiting their turn and not butting in line or jumping out of their seat, mentally construct a plan, hold in mind what they did so they can understand how that relates to later consequences, and much more. One would be hard pressed to think of an aspect of life in which executive functions are not important. In this article, I define and explain executive functions and provide examples of how these sophisticated abilities manifest themselves even in infants. Finally, I explore how to support, train, and improve these critical skills.

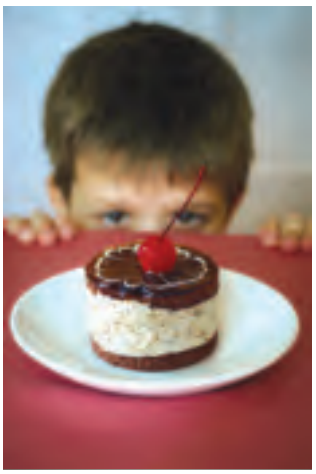
Executive functions are a set of mental processes needed when you have to concentrate and pay attention—when "going on automatic" or relying on instinct or intuition would be ill-advised, insufficient, or impossible (Diamond, 2006, 2013; Hughes, 2005; Jacques & Marcovitch, 2010; E. K. Miller & Cohen, 2001). Executive functions are so critical for so many aspects of life that it is no understatement to say that if you want Taylor to do well in school and in life, you need to care that Taylor develops healthy executive functions. Although executive functions take more than 2 decades to fully develop (Gogtay et al., 2004; Sowell, Thompson, Holmes, Jernigan, & Toga, 1999), even infants less than 1 year old are capable of demonstrating executive functions to some extent, and with training and practice, they can improve on them—just as anyone can at any age.

What Are Executive Functions?

There is general agreement that there are three core executive functions: *inhibitory control*, *working memory*, and *cognitive flexibility* (Diamond, 2013; Lehto, Juujärvi, Kooistra, & Pulkkinen, 2003; Logue & Gould, 2014; Miyake et al., 2000). From these, higher-order executive functions are built, such as *reasoning*, *problem solving*, and *planning* (Collins & Koechlin, 2012; Lunt et al., 2012).

INHIBITORY CONTROL (OR INHIBITION)

Inhibitory control involves being able to override a strong internal predisposition or external lure to do one thing and instead do what is more appropriate or needed (Diamond, 2013; Macdonald, Beauchamp, Crigan, & Anderson, 2014; Simpson et al., 2012; van den Wildenberg et al., 2010; Watson & Bell, 2013; Wiebe, Sheffield, & Espy, 2012). Inhibitory control makes it possible for people to resist acting on their first impulse so they do not do or say something they would regret. Inhibitory control also makes it possible for you and I to screen out (i.e., inhibit) what is irrelevant or distracting, making it possible for us to stay focused on the task at hand. *Self-regulation* overlaps to a large extent (but not completely) with inhibitory control (Diamond, 2013).



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A good synonym for much of what inhibitory control involves is *self-control*—resisting temptations and not acting impulsively.

A good synonym for much of what inhibitory control involves is *self-control*—resisting temptations and not acting impulsively. When Shawn goes looking for his favorite toy and sees that Sally has it, it will take inhibitory control for Shawn not to try to grab the toy from Sally. If Johnny has just said something that hurt Joey's feelings, it will take inhibitory control for Joey not to strike back. Standing in front of the cookie jar, it will take inhibitory control for Jill to obey the prohibition on eating cookies just before a meal. For adults, it takes inhibitory control to wait until their initial annoyance has subsided before pressing "send" on an e-mail message. It takes inhibitory control to "bite one's tongue" and

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not say the first thing that comes to mind when that would be something hurtful or inappropriate. A final aspect of self-control is delaying gratification (Mischel, Shoda, & Rodriguez, 1989), that is, having the discipline to forgo an immediate pleasure for a greater reward later.

Another aspect of inhibitory control is *selective attention*—inhibiting attention to things that are irrelevant, keeping your attention focused despite distractions (Gomes, Duff, Barnhardt, Barrett, & Ritter, 2007; Posner & DiGirolamo, 1998; Stevens & Bavelier, 2012; Theeuwes, 2010; Wendelken, Baym, Gazzaley, & Bunge, 2011; Zanto, Hennigan, Östberg, Clapp, & Gazzaley, 2010). This ability is needed, for example, if your spouse is calling to you while you are on the phone, but you want to focus on what the person on the phone is saying. It is needed at a cocktail party when you want to screen out all voices but one. Inhibitory control of attention enables you and I to selectively attend, focusing on what we choose and suppressing attention to other things whether those are distracting thoughts or distractions in the environment.

Inhibitory control makes it possible for people to resist acting on their first impulse so that they do not do or say something they would regret.

Discipline and perseverance can be seen as aspects of inhibitory control because they involve inhibiting all the temptations not to be disciplined or persevere. It takes inhibitory control to see something through to completion despite having grown bored with it or frustrated with how difficult it has been, especially when there are any number of other things you would rather be doing. Staying on task and completing a task involves resisting all the temptations to move on to something more interesting, inhibiting distractions, and delaying gratification.

Without inhibitory control you and I 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 you and I to change, and to choose how we behave, rather than being "unthinking" creatures of habit. It does not make it easy, but it makes it possible. Think of all the trouble you would get in if you did not have inhibitory control—if you blurted out the first thing that came to mind; never said "no" to a tempting offer; took whatever you wanted without asking or paying; or acted in other inappropriate, hurtful, or self-destructive ways.

Inhibitory control is a much greater challenge for young children than adults often realize (Davidson, Amso, Anderson, & Diamond, 2006). Often an adult may think a child is intentionally misbehaving, when in fact the child really wants to do the right thing but does not have the inhibitory control to be able to do that. You can see videos of 3-year-old children who by all appearances would seem to know what they should do (because they can state the correct sorting rule every time they are asked) yet nevertheless persist in sorting the cards incorrectly on every trial (see the last two items in Learn More box). Note that although if you heard that they continued to sort the cards incorrectly despite knowing what they should do you might think the children were intentionally doing the wrong thing, when watching the video it seems clear that the children want very much to sort the cards correctly. (These are excerpts from sessions in which children were taught both sorting rules at the outset, then sorted six cards by one dimension and then were asked to sort six cards by the other dimension.)

Inhibitory control seems to be the executive function most predictive of long-term outcomes. For example, children with better inhibitory control (i.e., children who were more persistent, less impulsive, and had better attention regulation) when they became adolescents were less likely to smoke, have unplanned pregnancies, or drop out of school, and as adults (30 years later) had better health, higher incomes and better jobs, fewer run-ins with the law, and a better quality of life than those who as young children had worse inhibitory control—controlling for almost every variable imaginable. Those results are based on a study of 1,000 children who were born in the same city, in the same year, and who were followed for 32 years with a 96% retention rate (Moffitt et al., 2011). The authors of that study concluded that interventions that are able to improve inhibitory control in individuals—even just a little—could shift the entire distribution of outcomes in a beneficial direction and yield large improvements in health, wealth, and crime rate for an entire nation.

WORKING MEMORY

Working memory involves holding information in mind and mentally working with it (Baddeley, 1992; Baddeley & Hitch, 1994; D'Esposito et al., 1998, 1995; Smith & Jonides, 1999). Working memory is not just holding information in mind, but also mentally doing something with that information (e.g., mentally reordering a to-do list, doing mental math ["Did the store clerk give me the correct change?"], incorporating new information into your thinking or plans [updating], translating vague intentions into concrete action plans, considering alternatives, or relating one piece of information to another).

Working memory 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, it is necessary for making sense of anything that involves language. That is obvious for oral language because after something has been said it is no longer physically present—relating that to what you are hearing now must be done in your head using working memory. It is also true for written language because, even at the level of a sentence, all the words are rarely

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in view at the same time. It requires working memory to relate what you read earlier to what you are reading now.

Working memory also allows people to consider their remembered past and future hopes in making plans and decisions. Reasoning, problem solving, and creative thinking would not be possible without working memory because they involve holding information in mind, looking for connections often among seemingly unconnected things, and recombining elements in new ways—playing with facts and ideas in your head.

Working memory and inhibitory control are more strongly associated with school readiness than are IQ or entry-level reading or math (Blair & Razza, 2007; Espy et al., 2004; McClelland et al., 2007; F. J. Morrison, Ponitz, & McClelland, 2010). Working memory and inhibitory control each independently predict math and reading competence from the earliest grades through university, sometimes even better than does IQ (Alloway & Alloway, 2010; Bull & Scerif, 2001; Dumontheil & Klingberg, 2012; Gathercole, Pickering, Knight, & Stegmann, 2004; McClelland & Cameron, 2011; Nicholson, 2007; Passolunghi, Vercelloni, & Schadee, 2007; Savage, Cornish, Manly, & Hollis, 2006; St Clair-Thompson & Gathercole, 2006; Swanson, 2014).

COGNITIVE FLEXIBILITY

Cognitive flexibility (the third core executive function) involves, in part, being able to creatively think outside the box to come up with fresh ways of attacking a problem and being able to see things from different angles and perspectives. For example, if one way of solving a problem is not working, can you come up with a new way of attacking it or conceiving of it? Or, can you empathize with someone by seeing things from that person's perspective?

Cognitive flexibility also involves the flexibility to (a) quickly change course when appropriate or needed, (b) adjust to changed demands or priorities, or (c) admit you were wrong when you get more information. Perhaps a sudden opportunity has just arisen; do you have the flexibility to take advantage of serendipity? Perhaps you are encountering problems, obstacles, or challenges you had not expected; do you have the flexibility to make adjustments so you can still succeed? There is much overlap between cognitive flexibility and creativity, task switching, and set shifting. Cognitive flexibility is the opposite of rigidity. Alexander Graham Bell provided an excellent example of poor cognitive flexibility when he said the following: "When one door closes, another door opens; but we often look so long and so regretfully upon the closed door, that we do not see the ones which open for us."

Cognitive flexibility builds on the other two core executive functions (Davidson et al., 2006; Diamond, 2013; Garon, Bryson, & Smith, 2008). For example, to change perspectives, you need to inhibit your previous perspective and load into working memory a different perspective.

When a student is not grasping a concept, instead of blaming the student—"If only the student were brighter, he or she would have grasped what I'm trying to teach"— you or I can exercise cognitive flexibility and consider a different perspective: "What might I do differently? How can I present the material differently or word the question differently so this student can succeed?"

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Storytelling (listening to the oral telling of stories) is great for challenging attention span.

How can you and I stop ourselves from getting really upset when a child misbehaves? What we usually get upset about is the intent we think is behind an action. However, we might be wrong about the intent and need flexibility to see the behavior in a different light: A child might be acting in the most awful manner because he has been terribly hurt and is afraid of being hurt again, so he will push you away before you have a chance to reject him, or he will test you to see if you are really someone he can feel safe with. If you and I see the misbehavior as coming from hurt, we can react completely differently.

It should come as no surprise that executive functions play critical roles in cognitive, social, and psychological development; mental and physical health; and success in school and in life. Besides being critical for school readiness and school success (as noted earlier), executive functions play important roles in career success (Bailey, 2007), making and keeping friends (Hughes & Dunn, 1998), marital harmony (Eakin et al., 2004), and good health (Cserjési, Luminet, Poncelet, & Schafer, 2009; Hall, Crossley, & D'Arcy, 2010; H. V. Miller, Barnes, & Beaver, 2011; Moffitt et al., 2011; Perry et al., 2011). For example, poor executive functions can contribute to obesity, overeating, poor food choices, substance abuse, and poor sustained adherence to doctors' orders (McAuley et al., 2011; Riggs, Spruijt-Metz, Sakuma, Chou, & Pentz, 2010). In a large sample of more than 14,000 teenagers, H. V. Miller et al. (2011) found that youths with poorer self-control were exponentially more likely to suffer from nine of the 10 adverse health conditions they examined.

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Examples of Executive Functions in Infants Less Than 1 Year Old

Infants 2–4 months old can show what is called *sticky fixation*, in which they keep looking at something after their interest in it has faded (Hood & Atkinson, 1993; Romero, 2007). It is as if their attention gets "stuck" or captured by what they are looking at. Beginning at about 4–5 months, however, infants can inhibit that and look away (Diamond, 1995; Romero, 2007).

Infants 5–8 months old, who can see an object they want inside a transparent container, will try to reach through the side of the container they are looking through, despite repeatedly hitting a solid, impenetrable surface (Diamond, 1990, 1991a). Over the period of 8–12 months old, they go through a fascinating series of stages in being able to inhibit the pull to reach directly for what they see, flexibly considering alternative routes, and using working memory to hold in mind what they saw when they looked along the line of reach so they can integrate reaching through the open side of a transparent container while looking through a closed side (Diamond 1991a, 1991b). The active, creative problem solving of infants on the task is a great joy to behold.

Inhibitory control seems to be the executive function that is most predictive of long-term outcomes.

To uncover a hidden object, an infant needs to hold in mind what is hidden and where, over sometimes many seconds, and then act on the covering material to reveal the hidden reward. When (a) there is distraction between seeing the hidden object and when the infant can reach, (b) one or more covers that look the same, and (c) the reward has sometimes been hidden under one cover and sometimes under another, all three core executive functions (inhibitory control, working memory, and cognitive flexibility) are needed to succeed (Bell, 1998; Cuevas, Swingler, Bell, Marcovitch, & Calkins, 2012; Diamond 1991a, 1991b).

How to Scaffold and Improve Executive Functions

Scaffolding executive functions enables children to practice executive-function skills they are not yet able to exercise on their own unaided.

You and I can support our own executive functions, reducing the amount of effort that we have to exert to remember or inhibit by, for example, writing ourselves notes so we do not have to hold everything in mind and by keeping temptations out of sight. You and I can also do things that reduce the effort young children need to exert to exercise executive functions. For the little girl in front of the cookie jar trying to obey the injunction not to eat sweets before dinner, the cookies could be placed in an opaque jar rather than a transparent one. Preschoolers who succeed at Mischel's delay of gratification task (waiting an undisclosed length of time to get two marshmallows or getting only one marshmallow if they cannot wait; Mischel, Shoda, & Rodriguez, 1992) typically do so by reducing the demand on their inhibitory control by looking away from the luscious marshmallow or finding something else to occupy their attention.

The Providing Alternative THinking Strategies (PATHS) program (Domitrovich, Greenberg, Cortes, & Kusché, 2005; Kusché & Greenberg, 2001; Riggs, Greenberg, Kusché, & Pentz, 2006) teaches a very clever and effective strategy to aid young children in inhibiting lashing out at someone when they get upset. Children are taught that when they get upset they should get into the "turtle" position (cross their arms and wrap them around their body, hugging themselves tightly), and take a deep breath before starting to plan how they will respond. This strategy is far more effective than asking young children to wait before responding. Young children are no good at waiting; asking them to wait is asking them to do something that is beyond their developmental level. PATHS gives children something to do while waiting (they get into the turtle position). Doing this accomplishes two very important things: (a) it allows time to pass between the upsetting moment and when the child responds, permitting the intensity of the annoyance to subside, and (b) what it asks children to do happens to help reduce the intensity of the child's emotions. Children, who have learned to do turtle at school when they get upset, will call out to a parent when they see the parent getting progressively more upset at someone at home, "Do turtle!"

The Tools of the Mind preschool and kindergarten curriculum (Bodrova & Leong, 2007) uses a simple memory aid to help children remember to inhibit speaking and wait their turn. In an activity called "Buddy Reading," the teacher instructs children to each choose a picture book, pair up with another child, and take turns telling the story that goes with the pictures in their books. With everyone all excited to tell the story, no one wants to be the listener. The teacher gives one child in each pair a simple line drawing of an ear and explains that "ears don't talk; ears listen." With that concrete reminder, the child is able to listen. Without it, most 4- or 5-year-olds would not be able to listen. After a few months, the children do not need the scaffold of the picture of the ear anymore; the children have internalized it.

If adults tell young children to try to exercise executive functions but do not provide supports (scaffolding), children fail, feel embarrassed, and get reprimanded. If teachers or parents eliminate the need for children to exercise executive functions, children miss out on the practice that helps their executive functions to improve. By providing scaffolds to help children exercise executive functions, children get practice, which helps their executive functions improve, and children have the pride of having succeeded (of being a good listener, for example) and increased confidence that they will be able to do that in the future.

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Improving Executive Functions

Executive functions need to be continually challenged to see improvements—not just used, but challenged.

ACTIVITIES TO IMPROVE EXECUTIVE FUNCTIONS IN THE EARLY YEARS

Storytelling (listening to the oral telling of stories) is great for challenging attention span. It requires sustained attention and concentration as well as working memory to keep track of what has already happened, relating that to what is or might happen in the story, and remembering who is who in the story. It taxes executive functions more than a video, which has visual images that grab the viewer's attention, or than reading with a child when the child can look at the pictures. Youngsters can be mesmerized by a great storyteller, but you do not need a professional; even parents can read from a book with the pages turned toward them, reading with drama and enthusiasm if they can, looking up often to maintain eye contact with their child. It is great exercise for executive functions. An added bonus is that it allows the child to imagine what the characters and scenes in the story look like, so he can imagine that the brave knight looks like him or she can imagine that the beautiful princess looks like her.

Vygotsky emphasized the importance of social pretend play (e.g., playing doctor and patient) for the early development of executive functions, and that is an important component of the Tools of the Mind program (Bodrova & Leong, 2007), which has been shown to improve executive functions (Diamond, Barnett, Thomas, & Munro, 2007). During social pretend play, children

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Articles

Is EF the New IQ?
W. Herbert (2008, June 10) *Newsweek*
www.newsweek.com/id/139885

Beyond IQ: Youngsters Who Can Focus on the Task at Hand Do Better in Math
C. Nicholson (2007, March 26) *Scientific American*
www.scientificamerican.com/article/beyond-iq-kids-who-can-focus-on-task-do-better-math/

Helping Kids Who Struggle With Executive Functions
R. Ehmke (2012, August) *Child Mind Institute*
www.childmind.org/en/posts/articles/2012-8-20-helping-kids-executive-functions-organization

Executive Function Skills Predict Children's Success in Life and in School
E. Galinsky (2012, June) *The Blog (Huffington Post)*
www.huffingtonpost.com/ellen-galinsky/executive-function-skills_1_b_1613422.html?utm_hp_ref=education

Teaching Children to Train Their Minds
LearnNow.org website
www.learnnow.org/topics/attention/teaching-children-train-their-minds

The following articles can be downloaded for free from www.devcogneuro.com/AdeleDiamond.html#Pubs

- **Want to Optimize Executive Functions and Academic Outcomes? Simple, Just Nourish the Human Spirit**
  A. Diamond (2014) *Minnesota Symposia on Child Psychology, 37*, 203–230
- **Executive Functions**
  A. Diamond (2013) *Annual Review of Psychology, 64*, 135–168
- **Activities and Programs That Improve Children's Executive Functions**
  A. Diamond (2012) *Current Directions in Psychological Science, 21*, 335–341
- **The Evidence Base for Improving School Outcomes by Addressing the Whole Child and by Addressing Skills and Attitudes, Not Just Content**
  A. Diamond (2010) *Early Education and Development, 21*, 780–793

Books

Mind in the Making
E. Galinsky (2010) New York, NY: William Morrow

NurtureShock: New Thinking About Children
P. Bronson and A. Merryman (2009) New York, NY: Twelve

Videos

InBrief: Executive Function: Skills for Life and Learning
www.youtube.com/watch?v=efCq_vHUMqs&list=PLTMQncsWPsq0AWUDtitolyokayUJ0-04I

What Are Executive Functions?
www.youtube.com/watch?v=8cCNhKqQXOM

Child Development and the Brain: Insights to Help Every Child Thrive
A. Diamond (2012, June 12) Invited talk, Garrison Institute Board of Trustees Luncheon, New York, NY
www.youtube.com/watch?v=MQ_j1mjGLow

AboutKidsHealth: Trusted Answers From The Hospital for Sick Children (posted August 4, 2011)
www.aboutkidshealth.ca/En/News/Video/PsychologyVideos/Pages/default.aspx

A set of six brief videos of Dr. Diamond on the website

- Early Childhood Support and Education
- Multiple Types of ADHD
- Babies and Abstract Reasoning
- The Importance of Child's Play
- Prefrontal Cortex
- The Psychology of Effective Education

Cultivating the Mind
A. Diamond (2013, May 10) Invited talk, Heart–Mind Conference 2013: Helping Children Thrive, Vancouver, British Columbia, Canada
http://dalailamacenter.org/heart-mind-2013-helping-children-thrive/heart-mind-2013-presenters/adele-diamond

Card Sorting—Switching to Sorting by Shape
www.devcogneuro.com/videos/cardsort.mpg

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Repeated practice allows skills to become second nature or automatic.

must inhibit acting out of character, hold in mind the role they have chosen and those of their friends, and flexibly adjust in real time as their friends take the play scenario in directions they never imagined. Thus, social pretend play exercises and challenges all three core executive functions.

Many traditional games—such as Simon Says; Red Light, Green Light; and Mother May I—challenge and thus help to develop inhibitory control. Children can practice motor control and focused attention by walking on a line (an activity in Montessori classrooms, another curriculum shown to improve executive functions; Lillard & Else-Quest, 2006). It is as difficult for a young child to walk on a line on the ground as it is for an adult to walk on a balance beam. As children improve, it can be made more difficult by, for example, walking faster, carrying something on their head, or carrying an egg in a spoon. To make it into a game that is in essence a form of walking meditation, one only needs old-fashioned bells with a handle. Each game participant gets one (adults included). In the game, everyone follows a leader, trying to stay on the line with the goal of having no bell make a sound. This is terrific for settling children down after recess or before bedtime.

It is terribly important to realize that if a child is stressed; sad; lonely; or not getting enough sleep, exercise, or proper nutrition that child will show impaired executive-function performance. The child will appear to have an executive-function disorder (e.g., attention-deficit/hyperactivity disorder [ADHD]) when that is not the case. The child will not be doing nearly as well as possible in school as he could—not because the child is not bright or is incapable of excellent executive functions—but because the child is not able to show what he is capable of because of unmet emotional, social, or physical needs (Diamond, 2010, 2013, 2014). Because executive functions are critical for academic achievement, a society that wants its children to excel needs to take seriously that the different parts of the human being are inextricably interrelated (Diamond, 2007).

ACTIVITIES TO IMPROVE EXECUTIVE FUNCTIONS IN OLDER CHILDREN AND ADULTS

Many different activities have at least one published study showing that they can improve executive functions, including computerized training, games, aerobic exercise, martial arts, mindfulness, and certain school curricula (e.g., Tools of the Mind, Montessori, PATHS, and the Chicago School Readiness Program; for reviews, see Bryck & Fisher, 2012; Burke, 2010; Diamond, 2012; Diamond & Lee, 2011; Howard-Jones, 2014; Melby-Lervåg & Hulme, 2012; A. B. Morrison & Chein, 2011; Rabiner, Murray, Skinner, & Malone, 2010; Rabipour, & Raz, 2012; Riccio & Gomes, 2013; Sedlmeier et al., 2012; Spierer, Chavan, & Manuel, 2013).

Regardless of the method or approach to improving executive functions, the most fundamental principle is that whether executive-function gains are seen depends on the amount of time spent practicing, working on these skills, and pushing oneself to improve. If participants are not challenged to keep improving, but simply continue doing what is easy, minimal benefit is seen. This principle has been known for a very long time and applies to all skills at all ages. Ericsson spent his career studying what makes an expert across all manner of fields and endeavors. He found the answer was always the same: many thousands of hours of practice trying to master what is just beyond your current level of competence and comfort (Ericsson, Nandagopal, & Roring, 2009), what Vygotsky (1978) termed the zone of proximal development.

Repeated practice enables skills to become second nature or automatic. A child may know intellectually that he should not hit another, but in the heat of the moment if that knowledge has not become automatic, the child will hit another (though if asked, he knows perfectly well he should not do that). It is the difference between knowing something at an intellectual level and having it be second nature or automatic. The only way something becomes automatic is through repeated action; nothing else will do. When you are struggling to exercise an executive function, you are using prefrontal cortex, but when it has become easy and second nature (and you are much better at it) you are not using prefrontal cortex as much or at all (Chein & Schneider, 2005; Diamond, 2013; Garavan, Kelley, Rosen, Rao, & Stein, 2000). Years ago, a book called *Zen in the Art of Archery* (Herrigel, 1999) captured what I am talking about here.

A second important principle is that people improve on the executive-function skills they practice and that improvement transfers to other contexts in which those same skills are needed (that is called *narrow transfer*); however, people only improve on the skills they practice. Consistently across all intervention approaches and executive functions targeted, the benefits from any approach are narrow and focused. Wide transfer does not occur; on the rare occasions when it has been found, those findings have not been replicated (reviews include Baltes & Lindenberger, 1988; Diamond & Lee, 2011; Melby-Lervåg & Hulme, 2012; Noack, Lövdén, Schmiedek, & Lindenberger, 2009; Park, Gutchess, Meade, & Stine-Morrow, 2007). For example,

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training working memory improves working memory, but it does not improve inhibitory control or cognitive flexibility.

To see widespread benefits, individuals need to practice diverse skills. Because of that, real-world activities, such as martial arts and school curricula (that train diverse executive-function skills), have shown more widespread cognitive benefits than targeted computerized training. Several review articles have touted the benefits of aerobic exercise for improving executive functions. The evidence for that is actually quite weak. Just exercising (e.g., running, lifting weights, or riding a stationary bicycle) without a cognitive component improves recall and recognition memory, but there is not much evidence that it improves executive functions. The evidence is stronger for exercise-plus-character-development (e.g., traditional martial arts) or exercise-plus-mindfulness (e.g., yoga).

I predict that many activities not yet studied might well improve executive functions. The activities should require executive functions and keep challenging those skills at ever greater levels of difficulty. The activity should be something the child really wants to do so she will spend a lot of time at it, pushing to improve. Those activities that most successfully improve executive functions, I predict, will be those that not only directly train and challenge executive functions but those that also indirectly support executive functions by providing joy and pride, a sense of belonging and social support, and physical exercise. What activities do that? Some of the activities that do that best are precisely the ones being cut back in so many schools—activities such as music-making, dance, and positive sports. They address people's cognitive, emotional, social, and physical needs. They challenge executive functions (requiring focused concentration, quickly adjusting to changed circumstances, etc.); require hard work, discipline, and perseverance; build self-confidence and engender joy and feelings of pride; involve working together toward a shared goal; are often characterized by close mentoring relationships with caring adults; and whip the body into shape.

Music, dance, positive sports, and programs such as El Sistema Orchestra, National Dance Institute, Youth Circus, Free the Children, True Sport, and so many others should improve executive functions because they have all the prerequisites. Certainly there are testimonials galore about how such activities have improved executive functions and academic performance and transformed children's lives. There are no studies that have shown this, however—none. There are studies showing correlations (e.g., showing that children in band or sports do better in school), but in those studies there is no way of knowing whether children who chose band or sports already possessed qualities for school success or would have developed them anyway. The studies have not been done because of lack of interest in doing them (my colleagues and I have applied more than once for such funding) but rather because reviewers have been unwilling to approve funding for rigorous studies on these less traditional topics (whereas our grant applications on traditional research topics easily sail through funding review). It is time to broaden the scope of research to more fully understand what most helps different children to thrive and why.

Adele Diamond, PhD, FRSC, is the Tier 1 Canada Research Chair Professor of Developmental Cognitive Neuroscience at the University of British Columbia in Vancouver, British Columbia, Canada. She is one of the founders of the field of developmental cognitive neuroscience, a leader in two fields (psychology and neuroscience), and at the forefront of research on executive functions. Her lab specializes in examining fundamental questions about how executive functions are affected by biological factors (e.g., genes and neurochemistry) and by environmental factors (e.g., stress or creative interventions). Her work has improved medical treatment for two disorders (phenylketonuria and attention-deficit/hyperactivity disorder) and has impacted early education. Recently, Dr. Diamond has turned her attention to the possible roles of traditional activities, such as music and dance, in improving executive functions. Her many awards include election to the Royal Society of Canada, being named one of the "2,000 Outstanding Women of the 20th Century," and being named one of the 15 most influential neuroscientists alive today.

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