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Executive Function and Children's Development

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September 10, 2012

What is Executive Function?

Take a moment and think about the cognitive demands you encounter in a typical day. There are certainly innumerable tasks you need to accomplish in regards to work, family, etc., and you somehow need to find a way to balance exercise, hobbies, and social activities with these commitments. When the alarm rings, you need to inhibit the desire to stay in bed and motivate yourself to get up and start the day. Perhaps this involves going for a quick jog to energize yourself. You made plans to get together after work with friends, so you have made the decision to exercise now because you know you will not have time later. Once at work, you need to switch your attention from one task to another throughout the day, often making quick decisions about what to attend to immediately versus less time-sensitive issues that can be handled later. At home after dinner, your children, who are still learning to self-regulate, may resist doing homework and going to sleep, though they are slowly learning to adopt a routine (by example, of course).

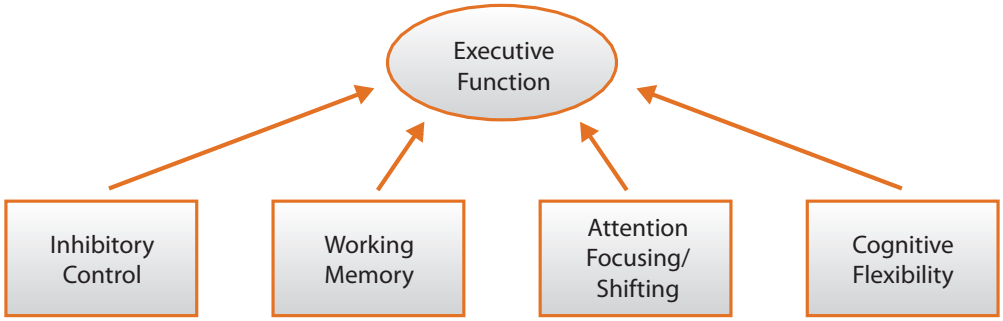
All of these challenges involve executive function. Executive function is involved in planning and represents our ability to think flexibly and regulate our behaviors. It is defined as the ability to engage in deliberate, goal-directed thought and action (Diamond, Barnett, Thomas, & Munro, 2007) through the use of inhibitory control (i.e., the ability to inhibit certain behaviors), attention focusing and shifting, cognitive flexibility, and memory (Zelazo, Craik, & Booth, 2004). Executive function is so named because it represents our ability to "delegate" goals to the rest of our cognitive system. Executive function is made up of the following components:

1. **Inhibitory control.** Inhibitory control is the ability to control one's behavior by inhibiting acting on one's immediate desires in favor of more adaptive and socially acceptable behaviors. For example, when you make the choice to not eat a cookie because you are dieting and want to avoid the unhealthy outcomes of overeating, you are engaging in inhibitory control.
2. **Working memory.** Working memory is the ability to actively hold information in mind. We use working memory to a great extent in reading and completing problems with multiple steps. If you were not able to hold information from the previous sentence in mind, reading comprehension would be quite difficult indeed!
3. **Attention focusing/shifting.** Attention focusing, as the name suggests, represents the ability to focus on relevant information. Attention shifting, a more complex skill, involves being able to shift attention from one task to another. For example, some children have trouble shifting from recess to the classroom environment, which may reflect on difficulties with perseveration (a point I will return to later).
4. **Cognitive flexibility.** Cognitive flexibility involves the skills described above, and is one of the most crucial components of executive function. It involves being able to change perspectives (i.e., see something from someone else's point of view), engage in flexible problem solving (i.e., seeing multiple ways to approach a problem), and change priorities if the situation calls for it.

While executive function consists of the specific components mentioned above, the components work together to create a hierarchy of goals and sub-goals that we use to plan our lives effectively (see Figure 1). In other words, it is the **coordination** of processes like inhibitory control, working memory, attention focusing and shifting, and cognitive flexibility that make up executive function. It is often helpful to think of executive function as the

conductor of an orchestra, with the rest of the orchestra consisting of all of the other cognitive processes in our brain.

Figure 1: Components of Executive Function



Executive function has often been compared with fluid intelligence, which involves our knowledge of how to solve problems, as opposed to crystalized intelligence, which consists of the facts and information we know (e.g., when the Declaration of Independence was signed). Children who are able to be flexible in their use of strategies when encountering problems, both in school and in social situations, are at an advantage because they are better able to see multiple ways of approaching a problem and are more equipped to be creative and innovative – skills highly valued in American society (Star & Seifert, 2006). Executive function is also involved in our ability to engage in something called self-regulation, meaning that we can manage our emotions and behavior in a way consistent with our goals (Blair & Diamond, 2008). Educators, parents, and researchers have begun to notice that it takes more than general intelligence to succeed in school and engage in effective social interaction. Students who have trouble with motivation are no longer automatically labeled as lazy because parents, researchers, and educators understand that they may be having trouble with executive function. Therefore, recently there has been a great deal of attention devoted to understanding executive function and how it relates to children's cognitive, social, and academic competence.

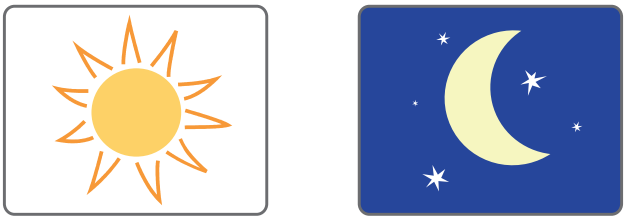
How is executive function measured?

Although executive function is involved in everyday tasks, psychologists and educators need to find ways to measure executive function in children that are consistent across large samples. Therefore, there are several different types of tasks that researchers use to measure executive function. One common measure is called the Go/No Go task. There are several variations of this task, but generally it involves showing a child a series of pictures and instructing him or her to press a button whenever he or she sees a certain series of pictures (Go), and to refrain from pressing a button when he or she sees a different picture (No Go). It is generally considered a measure of inhibitory control, meaning that if the child is able to inhibit the prepotent or "natural" response to hit a button when the "No Go" picture is shown, he or she has demonstrated good inhibitory control. This measure is considered a good stand-in for real-life inhibitory control, as performance on this task is correlated with parental report of children's ability to inhibit desires.

Another common task that measures inhibitory control is the Stroop task. One of the common ones used with children is called the Day/Night Stroop which requires the child to say "day"

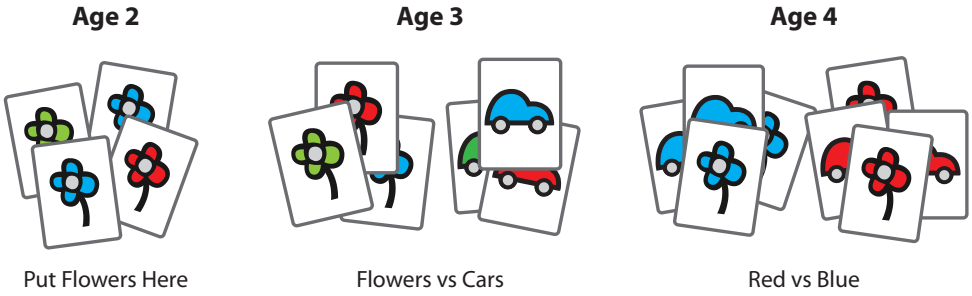
when shown a picture of a moon and stars and "night" when shown a picture of the sun (see Figure 2). The prepotent response is to say the word consistent with the picture, but the child must inhibit this response.

Figure 2. Day/Night Stroop Task



Another set of laboratory tasks that is used to measure executive function involves more than just inhibition, but also the ability to shift attention and flexibly switch between different sets of rules. One such task is called the Dimensional Card Sort Task (see Figure 3), in which the child learns one set of rules (e.g., sort these cards into flowers v. cars), and on subsequent trials learns a different set of rules (e.g., sort these cards by color). Younger children (around age 3) often do something called perseverate, in which they have difficulty switching from one rule to another. However, by age 4 or 5, they are better at flexible rule switching. This cognitive flexibility involves several components or skills involved in executive functioning, including inhibition, attention focusing, and shifting.

Figure 3. Dimensional Card Sort Task



Tasks that are similar to more real-life challenges children face with regards to planning and executive function have been developed as well. A famous study conducted by psychologist Walter Mischel and his colleagues at Stanford University in the 1970s involved leaving children alone in a room with a marshmallow. The children were told that if they did not eat the marshmallow and waited until an adult came back into the room, they would receive two marshmallows. Researchers then recorded how long the children were able to wait, and what kinds of distraction strategies they used. Amazingly, children who were able to resist the temptation of eating the marshmallow were less likely as adults to end up in jail, and were more likely to be described as competent adults. (Mischel, Shoda, & Peake, 1988).

Why Is Executive Function Important?

Executive function affects not only learning and cognitive skills, but also social and emotional competencies – and these are related to one another. In order for children to learn to engage

in the classroom in activities such as reading and organized games, they must first learn to regulate their emotions and inhibit some behaviors, such as shouting out without raising their hands. Children who enter the highly structured environment of grade school who are unable to sustain attention on a task and control their behavior are more likely than their better-regulated peers to struggle in school, both socially and academically (Denham et al., 2003; Rimm-Kaufman, La Paro, Downer, & Pianta, 2005). In addition, children who are able to regulate their behavior develop better teacher-student relationships, which has been consistently shown to be related to positive school outcomes (e.g., Reddy, Rhodes, & Mulhall, 2003). In addition, while intelligence (the kind measured in IQ tests) is important for academic success, some research has shown that executive function has distinct effects, apart from IQ, on academic achievement (Blair & Razza, 2007). Executive function and the ability to self-regulate have been shown to predict academic achievement among children even several years later (e.g., Valiente et al., 2011; Zhou, Main & Wang, 2010).

Executive function has been shown to be associated with fewer internalizing problems (e.g., depression and anxiety) and externalizing problems (e.g., aggression) in children (Zhou et al., 2008). Executive function has also been shown to be related to positive outcomes in children, such as empathy (Eisenberg et al., 2007) and social competence (Razza & Blair, 2009). Children with ADHD in particular tend to have problems regulating their behavior, and they tend to perform worse on executive functioning tasks (Pennington & Ozonoff, 1996).

Individuals who have problems with executive function often have difficulty managing many different kinds of life tasks. For instance, they are often disorganized, have trouble organizing projects, experience difficulty managing their emotions, have difficulty planning for the future, have trouble working through complex problems that require flexible thinking, and lack motivation. Moffitt (2012) found that preschool and school-aged children who had poorer inhibitory control than their peers had poorer health, lower incomes, were less happy, and committed more crimes 30 years later, even when taking into consideration their IQ, gender, social class, and family environment when they were children.

Deficits in executive function are involved in several psychological disorders that affect both children and adults. Attention Deficit Hyperactivity Disorder (ADHD) involves difficulty with focusing and sustaining attention on tasks, in addition to problems with impulsivity. Indeed, children with ADHD perform more poorly than their peers on laboratory tests of executive function (Willcutt, Doyle, Nigg, Faraone, & Pennington, 2005). Another set of disorders affecting children that involves executive function is Autism Spectrum Disorders (ASD). Researchers believe that children with different forms of ASD may have difficulty with Theory of Mind. Theory of Mind is a term used in Psychology to explain how we understand that others may have thoughts and feelings that are different from our own – a skill that is underdeveloped among children and adults diagnosed with ASD.

How Does Executive Function Develop?

Executive function begins developing very early in life. Infants' ability to orient their attention toward different objects and being able to follow the gaze of a caregiver begins to develop during the first year of life, and the ability to sustain attention develops rapidly during the second and third years (Jones, Rothbart, & Posner, 2003). However, complex planning involves more than sustaining attention on a task. Even adults can find planning to be quite difficult! Executive function develops quite slowly over the course of development. This is evident in

research on the brain, which shows that the prefrontal cortex, often referred to as the "brain's CEO" (see Figure 4), the part of our brain responsible for planning and the "higher-order" thinking that separates humans from other species, develops last, showing changes well into young adulthood. Between ages 2 and 5, there are rapid changes in the prefrontal cortex, and these changes coincide with changes one can observe in children's ability to succeed on executive functioning tasks (Diamond, in press).

Figure 4: Prefrontal Cortex

Different components of executive function develop at different times. For instance, working memory and inhibition develop earlier than cognitive flexibility, which although it is not at adult levels, is relatively mature by age 13. This is because there is a rapid period of growth in the prefrontal cortex during early adolescence, around age 11 or 12 (Dawson & Guare, 2010). Because the prefrontal cortex takes so long to mature, and this coincides with increasing demands in school on planning and other tasks involving executive function, many children who were once wonderful students in elementary school begin to fall off the wagon in middle school.

How can Executive Function be Strengthened in Children?

If you are a parent or educator who is reading this, you are taking crucial steps toward educating yourself as to how to foster your child's or student's executive functioning development. However, you are probably already doing many things to help stimulate your child's or student's executive function without even realizing it. The skills children learn from their parents that will help them succeed in school and get along with their peers will also help the development of their executive function. Parents who verbally stimulate their children by talking and reading with them, are warm and responsive to their children's needs, and help direct their children's attention when they are getting off task have children who tend to have better executive functioning compared with their peers (Kochanska, Murray, & Harlan, 2000). However, it is important to keep in mind that parents do not have complete control over their children's executive functioning development, in the same way they can't control their grades or what career path they choose. Factors such as children's temperament (i.e., different sensitivities to reward or discomfort) can affect children's ability to delay and control behaviors and hold information in mind – key components of executive function. In addition, children with anxiety problems have been shown to have problems with working memory when they are feeling stressed (Eysenck, Derakshan, Santos, & Calvo, 2007).

Executive function is relatively plastic, meaning it can be changed, and formal training of children's executive function can begin as early as age 4 or 5 (Diamond, in press). Some interventions that have been implemented involve computer programs that help children practice executive function skills, such as attention focusing/shifting and inhibitory control. One training program targeting children's working memory (both spatial and verbal), inhibitory control, and complex reasoning abilities improved executive functioning in children with ADHD (Klingberg, Forssberg, & Westerberg, 2002). Children's executive functioning can begin to improve after only 5 days of participating in these types of training programs (Rueda, Posner, & Rothbart, 2005). However, a key question is whether these types of training programs can affect children's real-life academic and social achievement.

There have been several successful intervention programs in classrooms that have been shown to improve children's executive functioning and in turn, improve their social and academic competencies. The studies supporting these programs all use random assignment (meaning that children were randomly chosen to be a part of the intervention), measured children's performance before and after the intervention, and found improvements in children's executive functioning on tasks in which the children were not explicitly trained (Diamond, in press). These studies have been conducted in university settings, in schools, with special education programs, and internationally. These interventions typically involve teaching children skills such as how to take turns, take others' perspectives, and monitor both themselves and their peers, in addition to the use of computerized tasks specifically designed to improve attention, inhibition, and flexible rule use (Ursache, Blair, & Raver, 2012). Children enrolled in these programs have been shown to demonstrate fewer behavioral problems and academic achievement improvement compared with their peers (see Blakemore & Bunge, 2012, Diamond, in press, and Klingberg, 2010 for reviews of executive function training programs). One such program is the Fast ForWord family of products that focuses on enhancing children's reading through training skills such as attention and information processing (Gillam, 1999; Temple et al., 2003). Studies have shown that following training (typically lasting six weeks), children's phonological skills improve, and brain regions associated with phonological processing are more involved during phonological tasks (Stevens, Fanning, Coch, Sanders, & Neville, 2008). These results have been shown with typically-developing children and children with language impairments.

There are strategies that parents and teachers can try with students to help foster their executive function development. These strategies mainly involve helping children be more organized and more effective planners. The following strategies may help children (and adults!) who have difficulty with executive function:

1. Use visual aids (e.g., writing out schedules and instructions)
2. Use step-by-step guides
3. Estimate how long it will take to complete tasks
4. Keep work space organized and separate from spaces used for other activities
5. Use checklists

The strategies listed above may not work for all children, and it is crucial that adults working with children with deficits in executive function be flexible and responsive to a particular child's needs.

Beyond the individual child, interventions such as the ones described above can contribute to a more positive classroom environment, which can lessen teachers' stress, and thereby make teachers feel more able to deal with behavioral problems of individual students. Therefore, executive function training not only can contribute to the social and academic success of a particular child, but can also contribute to a more effective learning environment for all students (Ursache et al., 2012). Therefore, a curriculum that involves both direct executive functioning training as well as overall classroom stress management and team building will likely help children with self-regulation, and contribute to a more positive learning environment.

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