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Increasing the utility of EF assessment of executive function in children

Valorie Niloufar Salimpoor
McGill University
Mary Desrocher
York University

Executive functions (EF) are a group of interrelated complex mental abilities that are involved in planning and initiating goals and carrying them through despite interruptions. As these functions are typically higher-order and involved in integrating other, more basic, lower-order functions, they are difficult to assess directly, and executive dysfunction often goes unnoticed. This is a particular problem in children, as most tests of executive function are developed for adults and have not been properly standardized in children. The aim of this article is to introduce the methods typically used to assess EF in children, and discuss the challenges associated with assessment of EF in children and adults. Issues such as ecological validity, difficulty separating individual components of EF, problems with separating EF from other cognitive abilities, implications of the degree of complexity of assessment stimuli as well as task-dependent variables that may contribute to variability in performance will be discussed. These concerns will be discussed with implications for development of more standardized measures of EF assessment in children, as these abilities are important for maximizing potential for learning and academic achievement.

The frontal lobes of the brain are home to a group of distinct, but interrelated mental processes, commonly referred to as executive functions (EF; e.g., Stuss & Alexander, 2000). Under the umbrella term of EF, these processes are generally thought to be involved in maintaining "an appropriate problem-solving set for attainment of a future goal" (Welsh & Pennington, 1988, p. 201). More specifically, it is believed that these complex functions are collectively responsible for planning towards future goals, initiation and organization of relevant mental

resources, developing and carrying out strategies to achieve these goals, and incorporating feedback and making modifications along the way as required (Lezak, 1982, 1993; Lezak, Howieson, Loring, Hannay, & Fischer, 2004). These abilities are considered 'executive' because they are thought to subserve a supervisory role that involves integrating information stored elsewhere in the brain (Shallice, 2004; Stuss & Alexander, 2000), and can have the potential to affect the processing of other domains of cognition: learning, memory, language, and visual perception (see Kaufer & Lewis, 1999; Luria, 1966; Martinez, 1997; Minassian, Granholm, Verney, & Perry, 2005; Scanlan, 2004; Singer & Bashir, 1999). More specifically, it has been speculated that EF can involve relatively basic skills such as focusing and sustaining attention, to more complex processes such as integrating feedback and shifting mental sets accordingly, complex reasoning, and abstract thinking. Thus, these abilities are play a crucial role in the development and optimal functioning of other cognitive processes.

However, there are numerous challenges associated with assessment of EF dysfunction (EDF), particularly in children, potentially leading to inaccurate diagnoses and improper remediation. Since these abilities are important for ongoing social and cognitive development and academic achievement (Dennis, 1989), it is important to optimize methods of testing these skills in children, and pinpointing potential deficits to design appropriate remediation measures. The aim of this article is to review current methods of EF assessment and outline challenges associated with these measures, suggesting potential means of improving EF assessment in children.

Prevalence of Executive Dysfunction

Difficulty with executive functioning skills is common in various congenital or acquired conditions that affect children (for a review of EDF in children see Powell & Voeller, 2004). It is important to note that it is generally not believed that EDF *causes* these disorders or conditions; rather, EDF is displayed to various extents as a *symptom* accompanying many cases of these disorders or conditions. The cause for the high prevalence of EDF symptoms is likely due to damage to the frontal lobe

or any of the sources of input or output to this area. Since the prefrontal cortex has highly intricate connections with many different areas of the brain, damage to any of these complex connections can lead to EDF. Not surprisingly, there is often heterogeneity amongst the range and severity of EDF symptoms displayed in each condition or each individual case.

Typical symptoms of executive dysfunction (EDF) have been found in numerous congenital and acquired disorders and conditions that affect children, even after controlling for other factors which may influence performance on EF tasks, such as IQ. For example, despite controlling for level of IQ, EDF has been associated with numerous genetic disorders, such as Turner's Syndrome (Romans, 1997; Temple, Carney, & Mullarkey, 1996) , schizophrenia (Axelrod, Goldman, Tompkins, & Jiron, 1994; Beatty, Jocic, Monson, & Katzung, 1994), fragile X syndrome (Mazzocco, Pennington, & Hagerman, 1993), as well as acquired disorders, such as head injury (Sykes, Hoy, Bill, McClure, & et al., 1997), and frontal lobe lesions (Eslinger, Biddle, Pennington, & Page, 1999). Symptoms of EDF are also commonly found in developmental disorders, such as attention deficit hyperactivity disorder (Barkley, 1997; Chelune & Baer, 1986; Culbertson & Zillmer, 1998; Koziol & Stout, 1992; Mahone *et al.*, 2002), autism (Bishop, 1993; Lopez, 2001; Pennington & Ozonoff, 1996), obsessive-compulsive disorder (Head, Bolton, & Hymas, 1989), and in medical conditions, such as insulin dependent diabetes mellitus (Northam *et al.*, 2001). In children with these diagnoses, EDF decrements are shown to be greater than what would be expected from individuals with lower IQ. There are two important implications that arise from the high prevalence of EDF symptoms in conditions that affect children: (1) When assessing the presence or absence of EDF in a clinical group for research purposes, comparison groups should be chosen wisely, with careful consideration placed into matching individuals from the clinical group with individuals who are free from any conditions that may predispose them to EDF. Otherwise, the control group may also display EDF and differences between the two groups generalized to the typical clinical and control groups would be underestimated; (2) The presence of a dual-diagnosis of conditions that are associated with EDF may significantly increase the *range* and *severity* of EDF displayed by the individual.

Symptoms of Executive Dysfunction

Individuals with EDF often show difficulty in a number of skills. Difficulty with planning and organizing abilities have the potential to adversely affect the individual's ability to plan ahead and mentally organize the required steps to complete a task or goal (e.g., Prevost, Bronson, & Casey, 1995). Similarly, those who have difficulty with initiation often have trouble generating and implementing strategies and find it difficult to imagine abstract or multiple solutions to a problem (Ruff, Evans, & Marshall, 1986). Trouble with inhibition can lead to an inability to avoid distractions, and control or inhibit undesired impulsive responses or behavior (Diamond, Kirkham, & Amso, 2002). Poor mental flexibility or the ability to quickly shift between cognitive response sets or behavior, can cause individuals to perseverate on their answers and show cognitive inflexibility which required to switch from one task to another (Crone, Ridderinkhof, Worm, Somsen, & van der Molen, 2004). Overall, individuals with EDF also have difficulty monitoring or regulating their performance by integrating feedback (Lezak *et al.*, 2004).
Implications of Executive Dysfunction for Academic Achievement and Learning

Since EDF affects different types of information processing at various levels (Stuss & Knight, 2002), numerous cognitive abilities may be compromised. The implications of EDF in children are particularly important for learning and academic achievement. In an academic environment, difficulty with mental processes that directly or indirectly depend on EF can negatively affect school performance (Biederman *et al.*, 2004; Clark, Prior, & Kinsella, 2002; Gioia, Isquith, Kenworthy, & Barton, 2002a). Craik and Bialystok (2005) have proposed a theory that describes intelligence as comprising of two major elements: knowledge and control. The latter refers to the means by which an individual can use and apply stored knowledge. This theory underlines the importance of the role of executive functioning processes in using knowledge to the best adaptive advantage. The impact of EDF on learning and academic achievement can be discussed in light of this theory. In a school setting, although EF is separate from the student's academic knowledge in a particular subject, EDF can significantly affect achievement in that

subject by influencing various steps of information processing, organizing, and retrieval. For example, students who are not able to concentrate, inhibit distractions, and focus attention will likely have trouble with processing new information while listening to the class lesson. While solving a problem, some children with EDF may have an understanding of what is to be done, but have difficulty organizing their thoughts, mentally manipulating relevant information, and integrating information to solve the problem. Consistent with this notion is the finding that children with EDF display difficulty with solving mathematical problems, even though they know their math facts (Bull & Scerif, 2001; Espy *et al.*, 2004; Forrest, 2002; Swanson, 2004; Swanson & Beebe-Frankenberger, 2004). Other children with EDF may not be able to spontaneously come up with solutions or may get stuck on one method of solving a problem. In the case of children with a clinical diagnosis, these deficits may exacerbate other impairments already associated with their condition. Furthermore, since these dysfunctions are not readily visible (Stern & Prohaska, 1996), they may go unnoticed, decreasing the chance for remediation and cause a great deal of frustration for the affected child.

Executive Dysfunction in Everyday Behavior

Executive deficits often extend far beyond cognitive deficits into other aspects of a child's life, such as the home and other environments, affecting not only academic but everyday functioning as well (Stern & Prohaska, 1996). Previous studies have linked EDF with social and behavioral problems (Donders, 2002; Flaherty, 1999; Gioia & Isquith, 2004; Gioia, Isquith, Guy, & Kenworthy, 2000; Gioia *et al.*, 2002a; Gioia, Isquith, Retzlaff, & Espy, 2002b; Grigsby, Kaye, & Robbins, 1995; McEvoy, Rogers, & Pennington, 1993; Morgan & Lilienfeld, 2000; Quamma, 1997; Snell, 1998). Symptoms of EDF in everyday behavior can present themselves in tasks that require skills involving planning a sequence of events towards a goal, initiation of thoughts or strategies to complete a goal, inhibition of inappropriate behavior, and the ability to quickly switch from one task to another as situational demands change (Donders, 2002; Gioia *et al.*, 2000; Isquith, Gioia, & Espy, 2004). Thus, a child who has trouble with inhibition may have a hard time inhibiting a

prepotent response that is inappropriate in a particular social situation. Not surprisingly, children displaying EDF generally also tend to show socially inappropriate behavior and can have poor interpersonal skills (Gioia *et al.*, 2000; Gioia *et al.*, 2002a; Gioia *et al.*, 2002b). Furthermore, various deficits in adaptive behavior, such as communication, play, and social relationships have also been associated with EDF (Gilotty, Kenworthy, Sirian, Black, & Wagner, 2002). Although such deficits in everyday behavior would not be surprising given the potentially wide-ranging adverse effects of EDF, the exact relationship between EDF and social behavior is not yet clear and more research is required before any conclusions can be drawn. Nonetheless, due to the covert nature of executive impairments, they are often either missed or overlooked, or mistaken for lack of motivation, laziness, or impulsivity (Stern & Prohaska, 1996). However subtle, these skills seem to be crucial for social and cognitive development, and academic achievement.

Neural Basis of EF

It has been established through brain imaging and lesion studies that the frontal lobes of the brain are the neural basis of executive functions (for a review of such studies see Fassbender *et al.*, 2004; Scheibel *et al.*, 2003). The frontal lobes are an ideal location for high-level supervisory control, as they constitute about half of the entire cerebral cortex (Brodmann, 1909) and have intricate connections with numerous other brain regions, receiving and transmitting information through complex circuits to the posterior cortices, brainstem, limbic structures (i.e., hippocampus and amygdala), thalamus, basal ganglia, striatum, and cerebellum (Barbas & Hilgetag, 2002; Ciccia, 2003; Cummings, 1993; Goldman-Rakic, 1995; Goldman-Rakic & Leung, 2002; Kaufer & Lewis, 1999; Petrides, 2000, 2002; Petrides & Pandya, 2002; Robbins, 1997; Zald & Kim, 2001). In light of the rich connections between the frontal lobes and other regions of the brain, it is not surprising that the impact of early frontal lobe damage has the potential to be wide reaching, typically resulting in a range of cognitive and behavioral deficits (for a review see V. Anderson, Levin, & Jacobs, 2002). Furthermore, interruptions to maturation of neural circuits early in life may underlie the inability of the immature prefrontal cortex to mediate cognitive and social demands later in development. Since

many of the complex EF skills do not fully emerge until later in development, impairments may not be immediately apparent, or may appear when more complex functioning is necessitated (Ackerly & Benton, 1947; Price, Daffner, Stowe, & Mesulam, 1990). This has important implications for understanding the scope of additional deficits that may later accompany a clinical diagnosis early in childhood. In other words, additional symptoms may emerge when environmental cognitive and behavior demands become greater, but go unnoticed as they were not initially apparent at the time of diagnosis. As expected, numerous lesion studies have demonstrated moderate to severe cognitive, behavioral, and social deficits in individuals who experienced an interruption to typical maturation of the frontal cortex early in life (e.g., Anderson, Damasio, Tranel, & Damasio, 2000; Eslinger, Grattan, Damasio, & Damasio, 1992). Interestingly, some research on neural plasticity has found that due to the more diffuse organization of the female brain, girls may be better able to cope with early brain damage resulting from various conditions that may negatively affect neural integrity than boys (Kolb, Gibb, & Gorny, 2000). Whether this translates into a sex difference in frontally mediated functions remains to be seen.

Conceptualizing EF

Despite tremendous interest within the scientific community, conceptualzation of EF has been late-emerging in the literature. Based on various sources of evidence (i.e., neuroimaging, neurophysiological, and lesion studies), researchers have attempted to conceptualize and operationalize these complex processes (for a review, see Smidts, 2003). Unfortunately, there has been little consensus amongst these theories and a unified theory of EF remains to be conceptualized. However, there is general agreement that executive functions include *at least* the following basic abilities: (1) Planning ahead and goal-setting, (2) generation of ideas and initiation of a mental set required to perform a task, (3) inhibition of impulsive behavior, (4) cognitive flexibility, or the ability to quickly switch between mental sets without perseverative behavior, and (5) working memory, or the ability to hold new information in mind long enough to manipulate it for the purpose of solving a problem or accomplishing a task (Ahluvalia *et al.*, 2002; Donders, 2002; Espy *et al.*, 2002; Gioia *et al.*, 2000; Gioia *et al.*, 2002a; Gioia

et al., 2002b; Griffith, Pennington, Wehner, & Rogers, 1999; Hill, 2004; Ozonoff, 1998a; Pennington, Bennetto, McAleer, & Roberts, 1996; Robbins, 1998; Stern & Prohaska, 1996). Although theories of EF typically denote many other subcomponents and abilities (i.e., metacognition, reasoning, abstract concept formation, decision-making, judgment, self-monitoring, and self-regulation), the focus of this paper will be only on those abilities listed, as they are generally agreed upon and testable. Each of these domains will be defined individually and an overview of the most widely used assessment techniques will be presented.

Methods of EF Assessment

Planning and Goal-Setting

Planning refers to an individual's ability to set goals and develop the appropriate and necessary steps to carry out a task or activity (Gioia *et al.*, 2000; Klahr, 1978; Klahr & Robinson, 1981; Richard, 1982). Planning and goal-setting involve imagining or developing an end state and then determining the most effective method or steps to attain that goal, while identifying and sequencing the steps, skills, and materials needed to achieve the goal (Gioia *et al.*, 2000; Ozonoff, 1998b). This cognitive skill also involves anticipating problems, generating alternative courses of action, and making choices among alternatives (Lezak *et al.*, 2004). The ability to plan and organize information underlies many aspects of our daily lives, such as accomplishment of daily tasks in a timely manner, or establishing an alternative to a routine that may be unexpectedly interrupted.

Neuropsychological tests that measure planning deficits often require individuals to take steps towards achieving a predefined goal. Such measures of planning include the widely-used Towers Tests, such as the Tower of London (Shallice, 1982) and the Tower of Hanoi (Boyrs, Spitz, & Dorans, 1982; Welsh & Huizinga, 2001). Other assessment techniques with children include completion of mazes, such as the Porteus Mazes (Krikorian & Bartok, 1998; Porteus, 1959). Performance on these tasks is measured by accuracy and efficiency. For example, the Towers tests

require participants to move a number of rings from a starting peg to a goal peg, in as few moves as possible, without ever placing a larger object on top of a smaller one. Since the goal is to reach the end-state with the fewest number of moves possible, the moves must be planned out in advance, and successful completion of these tasks requires significant planning ability (Krikorian, Bartok, & Gay, 1994; Stern & Prohaska, 1996).

Initiation

Cognitive functioning requires the ability to initiate a mental set or a course of action, inhibit distractions, and shift a mental set when required by external demands (Stern & Prohaska, 1996). Initiation refers to the generation of ideas and alternatives to produce mental sets. This component of executive functioning involves the ability to begin a task or activity and independently generate ideas, responses, or problem-solving strategies (Gioia *et al.*, 2000; Turner, 1997).

Formation of response sets is often assessed by tests of fluency, by measuring an individual's ability and speed of generating verbal or nonverbal responses. These tests include verbal fluency tasks – such as the Controlled Oral Word Association task (COWA) – that require the production of words, and design fluency tasks – such as the Ruff Figural Fluency (Vik & Ruff, 1988) – that require the production of designs. The former measures children's ability to generate words that begin with a certain letter, and the latter requires the production of novel designs.
Inhibition

Once a mental set is formed, inhibition refers to the ability to inhibit irrelevant distractions and maintain the current mental set. Inhibition may involve the ability to resist or not act on an impulse, stop one's behavior at the appropriate time, or control the urge to pursue a prepotent response (Bialystok & Martin, 2004; Gioia *et al.*, 2000; Levin, Hanten, Zhang, Swank, & Hunter, 2004).

Tests that measure inhibition include the Go/No-Go Test (Milner & Ettlinger, 1972) and the Stroop Test (Stroop, 1935). In the Stroop Test

participants are presented with a list of color names that are printed in different color (e.g., the word 'green' is printed in blue ink), and instructed to say the ink colors that the word is printed in without reading the word, thereby inhibiting the automatic urge to response in a prepotent manner. Participants' response reaction times on the congruent conditions are subtracted from their reaction times on the incongruent conditions to obtain an estimate of their inhibition abilities. The Go/ No-Go task requires individuals to perform an action or say a word during the "Go" condition, but resist the impulsive urge to perform that action or say that word during the "No-Go" condition. There are numerous variations of the Stroop and the Go/No-Go tasks, with varying degrees of complexity and difficulty, and geared towards different age groups.

Shifting

After behavior has been initiated and maintained, perseveration, or difficulty shifting attention and behavior to a different task, may result. Although maintenance of a mental set is important, the ability to flexibly shift from one mental set to another and move freely from one situation, activity, or aspect of a problem to another as required by changes in the environment is also a crucial component of cognitive function (Gioia *et al.*, 2000; Husband & Miles, 1927; Tinker, Imm, & Swanson, 1932). This construct measures the ability to integrate feedback as the rules and requirements of tasks often change, and a shift in mental set is required. Thus, shifting involves monitoring cues from the environment, incorporating feedback, making transitions, switching or alternating attention, changing focus from one mindset to another, and altering behavior accordingly (Steven W. Anderson, Damasio, Jones, & Tranel, 1991; Gioia *et al.*, 2000; Rothke, 1986; van der Sluis, de Jong, & van der Leij, 2004). Mild deficits in shifting ability can compromise the efficiency of problem solving (Goldstein & Green, 1995; Korkman, 2000). More severe difficulties are evident through perseveration, the inappropriate repetition of previously correct behavior, or concrete, rigid approaches to problem-solving (Gioia *et al.*, 2000; Spreen & Strauss, 1998; Stuss & Benson, 1984). Tests of flexibility require participants to shift their

thought process or behavior to conform to changing demands of a situation (Lezak, 1995; Spreen & Strauss, 1998).

Tests of shifting mental sets have long included tasks that require sorting cards based on various criteria (Berg & Grant, 1948; Brody, 1948; Husband & Miles, 1927; Jones & Grant, 1948; Tinker *et al.*, 1932). There have been numerous versions of card and object sorting tasks (Caffarra, Vezzadini, Dieci, Zonato, & Venneri, 2004; Grant, 1950, 1951; Grant & Cost, 1954; Kucera-Thompson, 2003; Nelson, 1976; Osmon & Suchy, 1996; Smith, 1995). Another task that measures set-switching abilities includes the Trail Making "B" (Army Individual Test Battery, 1944). One of the most frequently used EF measures is the Wisconsin Card Sorting Task (WCST; Berg & Grant, 1948), a task generally considered to tap cognitive shifting ability (Cicerone, Lazar, & Shapiro, 1983; Ozonoff, 1998a). This task measures flexibility by requiring individuals to shift from a prepotent, previously reinforced cognitive set to a new strategy that the individual must generate (Heaton, Chelune, Talley, Kay, & Curtiss, 1981). In this task, individuals are required to sort a set of cards based on three possible dimensions – color, shape, and number. The criteria for matching cards change after a certain number of correct responses without any warning to the participant. As the rules change, perseveration is measured by an inability to adapt to the new rule, evident in reverting back to previous rules for card sorting.

Working Memory

Working memory refers to the ability to hold information in mind for the purpose of completing a task and the ability to apply it for problem solving (Ahluvalia *et al.*, 2002; Gioia *et al.*, 2000; Kimberg, 1996; Pennington, 1994). This cognitive skill is required to carryout multi-step activities and follow complex instructions. The Working Memory component of EF measures the ability to remember the rules governing a specific task, not losing track of responses already given on a task which requires multiple answers, and mentally manipulating information (i.e., repeating digits in reverse order) (Gioia *et al.*, 2000).

Working memory is typically assessed through tasks that require participants to maintain information in mind long enough to manipulate and apply it to the task at hand (Spreen & Strauss, 1998). One method of assessing working memory verbally is the Digit Span task, a subtest of the Wechsler Intelligence Scales (Wechsler, 1939, 1941, 1949, 1958) that requires individuals to repeat a string of numbers forwards, then backwards. A measure of spatial working memory is the Self-Ordered Pointing Task (Petrides & Milner, 1982), which requires individuals to point to one picture on a page in a series of pages, ensuring that they do not point to the same picture more than once.

Challenges with EF Assessment

In assessing EF in children, there are numerous issues that must be taken into consideration. As EF abilities have traditionally been thought of as more mature skills, there have been few standardized tests developed to assess these cognitive functions in children. Although that has certainly changed in the past decade, there still remain many challenges to validly assess these abilities, some of which can be generalized to assessment in adults as well. The two most prominent concerns are low levels of ecological validity, and difficulty in separately assessing each component of EF. Other concerns include challenges in separating out deficits in other cognitive functions from EDF, and designing tasks tap into abilities at different levels of complexity with various modes of presentation. Ideally, comprehensive EF measures would tap into assessment across a range of daily situations (i.e., social, behavioral, academic), would include a range of complexity, and assess abilities in different modes of presentation (e.g., verbal and non-verbal, etc.).

Ecological Validity

Ecological validity refers to the level to which test results can be generalized to naturally occurring events in the real world (Brunswick, 1955). Tests administered in a well-structured setting with minimal distractions may not approximate real-world demands and are not necessarily representative of other environments in a child's life (Sbordone, 2000). It is likely that a child may not display deficits with a

test of shifting ability in a structured clinical session, but demonstrate significant difficulty with disengaging from one behavior and switching to another in a social situation. Not surprisingly, there are often inconsistencies between performance on EF measures and real life application of executive abilities (Eslinger & Damasio, 1985; Levine *et al.*, 1998). Thus, a comprehensive assessment of EF abilities in a child should also take into consideration behavior in social settings. This can be accomplished by incorporating questionnaires and other qualitative observation techniques that tap into children's everyday functioning. The Behavioral Rating Inventory of Executive Function (BRIEF; Gioia et al., 2000) is an example of a rating scale that can be a useful adjunct to neuropsychological assessment to provide a more comprehensive assessment of EF in various domains. This rating scale consists of items tapping into children's executive functioning in everyday settings at home and at school, typically completed by a child's parent and teacher. Indeed, studies have found modest agreement between scores on the BRIEF and tests of EF administered in clinical settings (Anderson, Anderson, Northam, Jacobs, & Mikiewicz, 2002), suggesting that this behavioral inventory provides unique information about a child's behavior in various settings.

Separating Different Components of EF

Challenges with conceptualzing the different components of EF are most likely due to the fact that many of these components under the umbrella of EF are highly interrelated. As such, it is difficult to define and assess these components separately. For example, the Towers tests are intended to measure planning abilities, but performance on these tasks also involves working memory, as participants must remember the rules of the task and the sequence of their moves actively in mind while manipulating the consequences of their decisions. Thus, it is difficult to determine whether any difficulties that children display on this task are actually due to planning or working memory deficits. One method of overcoming this obstacle is to administer more than one test that taps into each ability. For example, in the case of the Towers Tests, if children are also administered other measures of working memory, and do not

display deficits on these tests, per se, it is likely that deficits displayed on the Towers Tests will not be due to a working memory deficits.

Separating EF from other Cognitive Abilities

It is not only difficult to separate the various components of executive functioning from one another, but also from other cognitive functions. Since EF abilities are complicated and intricate mental processes, it is difficult to separate these skills from simpler, more fundamental skills during assessment. For example, it may be difficult to determine whether deficits are actually due to impairments in EF, or primary attention deficits. For example, if a child is having trouble focusing attention on a given task, this may be misinterpreted as an inability to initiate or maintain a mental set. Such deficits in attention can undermine the integrity of higher-order multicomponent executive functions, thereby making it difficult to separate EDF from more fundamental attention deficits. To account for these deficits, one possibility is to include simple tests of attention (tapping into selective and sustained attention) along with EF tasks in future studies, in order to rule out baseline attention deficits.

Level of Difficulty and Complexity of EF Tasks

When assessing EF in children, the choice of tasks that are used can introduce significant variability. Whereas some tasks may only tap into simple EF skills; others may require complex abilities. The former might not be powerful enough to detect actual impairments and lead to the incorrect assumption that such skills are intact, when in fact they may be significantly impaired in more complex tasks. Thus, EF tasks of various levels of complexity should be used to fully assess executive functioning and allow measurement of subtle differences.

Task-Dependent Variables

Other important factors that may contribute to variability in results is task presentation and type of response that is required. For example, stimulus presentation may be auditory (e.g., Digit Span) or visual (e.g.,

Trail Making Task), responses maybe verbal (e.g., Verbal Fluency) or nonverbal (e.g., Figural Fluency), and the presented stimuli maybe in the form of numbers (e.g., Digits Span), words (e.g., Verbal Fluency), colors (e.g., Stroop Task), or images (e.g., Self-Ordered Pointing Task, Wisconsin Card Sorting Task). It may be the case that although some children have difficulty within one modality, they may not show deficits within a different modality. For example, some children may show deficits with the verbal working memory task, but not the non-verbal working memory task. Such a circumstance may have important implications for intervention, as strengths in one area may be reinforced to compensate for deficits in another. Discovering the fundamental roots of EDF can be important step in designing intervention programs.

Summary and Conclusions

In summary, the subcomponents of EF represent a heterogeneous group of cognitive processes that are important for planning, initiation, inhibition, shifting, and working memory, in addition to certain aspects of other more complex functions, such as reasoning, abstract concept formation, self-monitoring, and metacognition. Deficits with these functions may occur as a result of focal lesions or immature or damaged neural circuitry in the prefrontal regions, with the potential for cascading effects on the integrity of other neural circuits, and can have wide-ranging negative sequelae for individuals in the cognitive, behavioral, and social domains. And although EDF is typically not the cause of many clinical conditions, it often presents as accompanying symptoms to various conditions that affect children, which can in turn add to or magnify the impairments associated with that condition. Since EDF is 'higher-order' and typically not a directly observable manifestation of cognitive deficits (i.e., language or motor impairments), it may go unnoticed or mistaken for lack of motivation or 'bad behavior', and cause a great deal of frustration for the affected individual. Thus, it is important to understand the various components of EF that may be affected in a particular disorder in order to develop intervention and remediation programs.

To properly assess EF, it is important to develop or select tests that are: (i.) suitable for children and formulated based on knowledge of cognitive development, (ii.) can separate various components of EF, (iii.) include various levels of difficulty or complexity, (iv.) assess EF performance within different modalities, i.e., verbal, non-verbal, auditory and visual presentation and response, and most importantly (v.) are ecologically valid. In addition, it may be beneficial to use standardized batteries of EF, as they provide norms for children of various age groups that have been randomly selected. This is not the case with most individual measures of EF. One example of a standardized EF battery is the Delis-Kaplan Executive Function System (Delis, Kaplan, & Kramer, 2001). This measure includes battery of subtests adapted from common neuropsychological tests typically used to assess EDF, such as a Stroop task, Trail Making Test, Verbal Fluency, and Design Fluency. This battery also includes various degrees of complexity and difficulty, which increase the sensitivity of the test to subtle EF deficits. Furthermore, most subtests include baseline measures to account for individual differences in performance. This test has been standardized amongst large populations providing comparison norms with various demographic characteristics. Thus, stronger conclusions can be draws about relative strengths and weaknesses.

Although research in determining the basis of EDF and other deficits is an important and necessary step in understanding the etiology and outcome of the developmental disability, remediation is the ultimate goal. While research on etiology is progressing, it is also important to develop and test the validity of various intervention techniques that build on research findings, in order to improve or compensate for deficits in executive functioning, as well as other cognitive, behavioral, and social functions that are impaired. Various intervention techniques have been proposed to help individuals with EDF (Akhutina, 1997; Cicerone, 2002a, 2002b; Kaplan, 2001; Stratta & Rossi, 2004; Ylvisaker, Szekeres, & Feeney, 1998); however, much more research is needed to develop additional remediation strategies, particularly for children, and assess the outcomes of such programs.

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Author Note

Valorie N. Salimpoor, valorie.salimpoor@mail.mcgill.ca, Psychology Department, McGill University, Stewart Biology Building, 8th Floor W, 1205 Dr. Penfied Avenue, Montreal, QC, H3A-1B1