Chapter 15
Assessment of Executive Functions in Children with Neurologic Impairment

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OVERVIEW

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Jenny is an eight year old girl in the second grade who was struck by a car while riding her bicycle in her neighborhood. Unfortunately, she was not wearing her helmet that afternoon six months ago. She was unconscious for 2 days and was unable to learn any new information for a period of 5-7 days following her accident (post-traumatic amnesia). She was unable to recall the accident or any events leading up to her injury. In fact, her last memory of that day is having breakfast with her father at a local restaurant. Her recovery in the rehabilitation hospital was slow but steady over a two month period after which time she returned home. Everyone was impressed at her quick physical recovery and Jenny even began school two weeks into the school year. Her teachers and parents quickly observed, however, that she was having trouble attending during group instruction in the classroom, had increased frequency of emotional outbursts with peers and adults, and was very unorganized with her school materials and personal belongings.

On interview, while her parents report that she had always been somewhat fidgety and talkative in class, she had never exhibited the degree of overactivity and impulsivity that she has during the past school year. She has no overt physical signs of the injury and although she may become more fatigued in the afternoon and evening, she is able to walk and run without much difficulty and her speech is clear and fluent. Her teacher and parents, however, are very concerned about her functioning because she was an excellent student prior to the injury and they do not understand why she is having so much trouble given her apparent remarkable recovery. Jenny has begun to dislike school and often asks to stay home.

Phillip is a fourteen-year-old 9th grader referred for evaluation to assist in understanding poor academic performance and motivation during the Fall of his ninth grade year. His parents report that he is apathetic towards school and, despite educational and cognitive evaluations which suggest Superior intellectual potential, he is failing most of his classes. His parents also report that he was an A student throughout elementary school but that his grades began to fail once he reached middle school and have steadily declined to their current level of failure. Phillip reports, and his parents confirm, that it has nothing to do with his ability to understand the work but it is more a problem with completing work, starting work at the last minute, or poorly organized work. Phillip actually completes about half of his homework as assigned but often does not turn it in or cannot find it. He complains that he is bored at school and cannot tolerate sitting in class. Relevant history is remarkable for several diagnoses. Phillip was diagnosed at the age of seven with Tourette's Syndrome which originally manifested as a chronic sniffing tic that was attributed to allergies. He later began to demonstrate eye blinking, shoulder shrugging and throat clearing tics and he *was given the diagnosis of Tourette's Syndrome. Approximately a year later, Phillip was also noted to be somewhat overactive and anxious and was notably impulsive both at home and at school. He was diagnosed with Attention Deficit/Hyperactivity Disorder, Combined Type. Since that time his tics have waxed and waned. He demonstrates no negative social impact of the tics. Phillip is a popular student but tends to have only a small select group of friends. He is a good athlete and plays lacrosse and football. His tics are only a problem during periods of high stress such as during examinations or at the beginning of each school year. His attentional difficulties and overactivity have decreased in the past 2-3 years and he has not been taking stimulant medication.*

Regarding academic difficulties, Phillip reports difficulty starting long-term projects and often puts them off until the last minute. Additionally, he frequently starts projects without much thought as to how the steps should be sequenced. As a result, he often has to start over and it takes him much longer to complete a task than predicted. This causes significant frustration for Phillip and his parents. His handwriting has always been poor and, when he is working or taking notes, his work is even sloppier. In his haste to complete work, he often makes careless errors that go unchecked. When his parents have tried to help him, he quickly becomes angry and insists on doing the work his own way, regardless of the cost. He often attempts to solve problems via trial and error rather than strategically. His parents report that his desk, locker and bookbag are disorganized and full of old papers and "useless junk". He often forgets to write down homework assignments or loses the assignment sheets.

These case studies illustrate the complex assessment picture presented by children with neurological impairment. The purpose of this chapter is to focus on one aspect of assessment, that of the executive functions, that are at the core of each of these scenarios. This is an expanding area of interest in neuropsychology, psychology, and education with substantial relevance to many neurologic disorders of childhood (Barkley, 1997; Benton, 1991; Denckla and Reiss, 1997; Mateer and Williams, 1991; Pennington, 1997). We have chosen to focus on this critically important aspect of the child's functioning from both an assessment and intervention perspective. Our task is to describe the critical set of executive functions relevant not only to neuropsychologists but also to clinical child, pediatric and school psychologists who work with children with neurologic impairments. This neuropsychological mechanism of regulatory control plays a fundamental role in the child's cognitive, behavioral, and social-emotional development with substantial implications for everyday social and academic functioning. Disorders of specific subdomains of the executive functions are found in a variety of clinical conditions due to the vulnerability of the brain during development. This functional domain is equally applicable to the assessment of all children with neurologic impairment including those with developmental origins (e. g. , learning disabilities, attention deficit hyperactivity disorder, autism/ pervasive developmental disorder, mental retardation) and acquired etiologies (e. g. , traumatic, infectious, toxic, metabolic, neoplastic encephalopathies).

Given the potentially wide scope of this chapter, it is important to clarify what will <u>not</u> be covered here. This chapter will not describe all neurologic conditions or all possible aspects of psychological/ neuropsychological assessment of children with neurologic impairments as this is far too broad a task. The reader is referred to a number of authoritative works reviewing the many different types of neurologic disorders in childhood (Spreen, Risser and Edgell, 1995; Berg, 1997). Furthermore many aspects of general neuropsychological assessment of children have been covered quite effectively in other references (e. g. , Baron, Fennel, and Voeller, 1995; Bernstein and Waber, 1990; Rourke, Fisk and Strang, 1986; Pennington, 1991). The intent of this chapter is to provide the reader with an understanding of a specific area of neuropsychological functioning that has broad relevance to the everyday functioning of the child with developmental and acquired neurologic impairment. To this end, we examine definitions and the historical, theoretical, and descriptive aspects of executive function, and review assessment approaches and instruments. Assessment of executive function can be carried out through a variety of methods including traditional psychometric performance tests, quasi-experimental measures, observational tools, interview and structured behavior rating scales. We also consider formal and informal methods to assess these critical functions.

Returning to our two cases, Jenny is having difficulties at home with poor control of her impulses and difficulties following through on everyday chores and tasks. She is weepy and forgetful at times, particularly when asked to perform jobs that involve more than one step. With her peers, Jenny is happy and effusive but emotionally unpredictable, and she frequently yells at her friends over seemingly minor disagreements. She is also more aggressive with her younger sister and has been repeatedly punished for hitting and yelling at her. Her parents report that it appears Jenny has fewer friends as of late and is not invited to as many outings as before her accident. She has been referred for further assessment regarding difficulties in behavioral adjustment and school learning. Jenny's history is not at all uncommon among children with mild to moderate traumatic brain injury. While motor and orthopedic disturbances heal relatively quickly, cognitive disturbances often are masked by the stringent routine of inpatient rehabilitation setting, and outpatient rehabilitation schedules. Additionally, as parents are usually relieved by their child's recovery, and are more attuned to their physical needs, the cognitive difficulties usually associated with TBI are ignored or rationalized as product of hospitalization.

If a child's history of TBI does come to light during a parent interview, then it is essential to elicit a clearer picture of the severity of the injury and change in function since the injury in order to determine its potential impact. In Jenny's case, the dramatic change in function was clear. She demonstrated difficulties in several of the subdomains of executive functioning including the abilities to inhibit, sustain and organize. She also demonstrated problems with emotional control and working memory. In a case such as Jenny's, a thorough neuropsychological evaluation is essential to document her profile of strengths and weaknesses to assist with clinical management. In other cases of TBI, however, even though the injury may be seemingly mild and the dysfunction more subtle, the impact on daily function may be substantial.

As we can see from the case of Phillip, he also demonstrates difficulties within many of the subdomains of executive functions including difficulties with sustaining performance, inhibiting competing thoughts and actions, flexibly shifting his problem-solving approach, organizing complex information and his environment, initiating tasks, planning, and self monitoring his performance. These difficulties have a profound effect on his academic performance despite his excellent cognitive potential. The assessment challenge is to determine the severity and nature of his difficulties in order to develop appropriate intervention strategies. As we will discuss later, executive dysfunction is a common aspect of Tourette's Syndrome.

History and Definition of the Executive Functions

Though the concepts related to goal-directed behavior have been described in some fashion for decades (Bianchi, 1922; Luria, 1966), the term "executive control" is attributed to the cognitive psychologist, Neisser (1967), who described the orchestration of basic cognitive processes during goal-oriented problem-solving (Welsh and Pennington, 1988). This early definition is important because it began the differentiation of "basic" cognitive functions from the "executive" or directive, cognitive control functions.

More recent authors have viewed the executive functions as a collection of related yet distinct abilities that provide for intentional, goal-directed, problem-solving action. Fuster (1985) discussed the critical subfunctions of the prefrontal cortex necessary for performing long-term tasks via the "mediation of cross-temporal contingencies". In his conceptualization, executive functions are necessary for the organization of goal-directed behavior over a time dimension. These executive functions are highlighted by delayed tasks, which require the ability to hold information actively in mind as it is operated on in the service of a future goal. Fuster (1985) described three key components of this system, including the temporally retrospective function of working memory, the temporally prospective function of anticipatory set, and interference control. In Fuster's (1989) view, cells within the prefrontal regions of the brain become activated for a sustained period of time during these cognitive activities, bridging the temporal delay between events. In their classic treatise on functions associated with the frontal lobes, Stuss & Benson (1986) provided a set of related capacities for intentional problem-solving including anticipation, goal selection, planning, monitoring, and use of feedback. Their hierarchical model highlights important aspects of the executive functions that relate to the highest levels of cognition, including anticipation, judgment, self-awareness, and decision-making. Welsh and Pennington (1988) characterized the early development of the executive functions in terms of "the ability to maintain an appropriate problem-solving set for attainment of a future goal". Denckla (1994) defined the critical features of the executive functions for active problem-solving as follows: providing for delayed responding, future-oriented, strategic action selection, intentionality, anticipatory set, freedom from interference, and the ability to sequence behavioral outputs.

Although different aspects of the executive functions have been discussed by various authors, most would agree that the term is an umbrella construct for a collection of interrelated functions that are responsible for purposeful, goal-directed, problem-solving behavior. A useful metaphor for conceptualizing their general purpose is as a conductor of an orchestra where the component "instruments" of the orchestra are the "basic" domain-specific cognitive functions (e.g., language, visuospatial functions, memory) while the conductor serves as the directing system – making intentional decisions regarding the final output of the music and recruiting the necessary components in reaching the intended goal. Thus, the executive functions are defined as the control or self-regulatory functions that organize and direct all cognitive activity, emotional response, and overt behavior. In cognitive and educational psychology, the executive functions are described in terms of metacognition, the domain-general functions that serve an oversight role.

Specific subdomains that make up this collection of regulatory or management functions include the ability to: initiate behavior, inhibit competing actions or stimuli, select relevant task goals, plan and organize a means to solve complex problems, shift problem-solving strategies flexibly when necessary, and monitor and evaluate behavior. The working memory capacity to hold information actively "on-line" in the service of problem-solving is also described within this domain of functioning (Pennington, Bennetto, McAleer and Roberts, 1996). Finally, the executive functions are not exclusive to cognition; emotional control is also relevant to effective problem-solving activity.

Basic behavioral definitions for each of nine subdomains of the executive functions are provided in Table 1. A brief example is also provided, which illustrates the types of dysfunctional behaviors for each area of executive function. These nine areas are not exhaustive of the entire spectrum but include the major components described in the literature.

Neuroanatomic Organization of the Executive Functions

The developmental course of the executive functions parallels the protracted course of neurological development, particularly with respect to the prefrontal regions of the brain. A commonly held view of the neuroanatomic organization of the executive functions, however, is that they are seated *solely* in the prefrontal region. This position is an oversimplification of the complex organization of the brain. Although damage to the frontal lobes can result in significant dysfunction of various executive subdomains (Anderson, 1998; Asarnow, Satz, Light, Lewis, and Neumann, 1990; Fletcher, Ewing Cobbs, Miner, Levin, Eisenberg, 1990; Eslinger and Grattan, 1991), the executive functions do not simply reside in the frontal lobes. Nevertheless, an understanding of this phylogenetically unique neuroanatomic region is important in any discussion of the executive functions. The neuroanatomical essence of the frontal lobes is their dense *connectivity* with other cortical and subcortical regions of the brain. The prefrontal system is highly and reciprocally interconnected through bi-directional connections with the limbic (motivational) system, reticular activating (arousal) system, posterior association cortex (perceptual/ cognitive processes and knowledge base), and the motor (action) regions of the frontal lobes (e.g., Johnson, Rosvold and Mishkin, 1968; Porrino and Goldman-Rakic, 1982). This central neuroanatomic position underlies the regulatory control that the frontal systems exert over the perceptual coding/ conceptual processes of the posterior cortex, attentional, and emotional functions subserved by the subcortical systems (Welsh and Pennington, 1988).

It is worth mentioning the intentional use of the term frontal *system* as opposed to frontal *lobe* in this discussion. The concept of frontal system explicitly acknowledges and directly incorporates the frontal lobe's interconnections with the cortical and subcortical regions of the brain. The relevance of this concept is that a disorder *within any component* of the frontal system network can result in executive dysfunction (Mesulam, 1981). Conditions that render the frontal systems vulnerable to dysfunction include: disorders affecting the connectivity of the brain such as cranial radiation and white matter development (Brouwers, Riccardi, Poplack and Fedio, 1984), lead poisoning affecting synaptogenesis (Goldstein, 1992), direct trauma to the prefrontal regions in traumatic brain injury (Fletcher et al.,1990), dysfunctional neurotransmitters such as dopamine in Tourette's Syndrome and ADHD (Rogeness, Javors, and Pliska, 1992; Singer and Walkup, 1991), disorders of the posterior cortex including learning disabilities (see discussion in Developmental Spectrum), and disorders of the arousal mechanism such as that seen in brain injury and severe depression. Thus executive dysfunction can arise from damage to the primary frontal regions as well as to the densely interconnected secondary posterior or subcortical areas. Understanding this network is a crucial point for the functional control aspects of the executive functions that will be discussed later. The associated basic cognitive "partners" must be present in order for the executive regulatory functions to have any operational purpose. Thus, a close complementary and contributory relationship (Kaplan, 1988) of the anterior cerebral region with the posterior and subcortical structures is necessary.

Developmental Spectrum

The developmental course of the executive functions across childhood has been an intriguing area of research (e.g., Passler, Hynd, et al., 1985; Welsh and Pennington, 1988; Levin et al., 1991). A key developmental feature of the executive control functions is their protracted ontogenetic course in comparison with other cognitive functions - paralleling the prolonged pattern of neurodevelopment of the prefrontal regions of the brain. Although earlier views of the executive functions argued for their emergence in early adolescence (Golden, 1981), studies in developmental psychology suggest a much earlier trajectory. The development of attentional control, future-oriented intentional problem-solving, and self-regulation of emotion and behavior can be observed beginning in infancy and continuing through the preschool and school-age years (Welsh & Pennington, 1988). Examples of this work include studies of the development of goal-directed, planful problem-solving behaviors in 12-month-old infants using an object permanence and object retrieval paradigm (Diamond and Goldman-Rakic, 1989). A comparative study with intact infant monkeys and frontally-operated adult monkeys found these behaviors to be localized specifically to the frontal lobes (Diamond and Goldman-Rakic, 1985). Eighteen-month-old children exhibit the self-control abilities to maintain an intentional behavior and inhibit behavior incompatible with attaining a goal (Vaughn, Kopp & Krakow, 1984). These examples demonstrate the utilization of early intentional self-control behaviors by infants and toddlers for the purpose of goal-directed problem-solving. The executive self-control at these early ages is variable, fragile, and bound to the external stimulus situation, whereas increasing stability is gained between 18-30 months of age. Developmental studies of children through adolescence demonstrate a time-related course of development for specific subdomains of executive function, including inhibitory control (Passler et al. 1985), flexible problem-solving (Chelune & Baer, 1986; Levin et al, 1991; Welsh et al., 1991), and planning (Klahr & Robinson, 1981; Levin et al., 1991; Welsh et al., 1991). As is the case with most dimensions of psychological and neuropsychological development, the emergence of executive control functions during development can vary across individuals in terms of when specific subdomains emerge and to what ultimate degree.

Developmentally, the executive control functions must be considered not only in terms of their own unique developmental progression but also in light of the type and nature of the age- relevant functions with which they are intimately associated (e.g., language, memory, visual-spatial processes). For example, preschoolers are working on different cognitive tasks than school-age children, who in turn are working on different tasks than adolescents. Thus, the early executive control functions would not be expected to take the same form in preschoolers as in older age groups. Certain general similarities may appear in terms of the structure of executive functions (e.g., initiate, sustain, inhibit, shift, plan, organize/strategize, monitor), but several aspects are different which result in different behavioral manifestations. First, the types of representations or information being operated on are very different for the younger child (e.g., simpler language structures, more immediate time frame, more concrete representations). Second, various executive functions, though not absent, may be at earlier stages of development and therefore not fully operational. The interaction of simple task demands and immature executive functions in early development may make it difficult to observe such functions in their less mature form. In the adult, such functions reflect easily initiated, well-planned and organized, flexible, abstract thought processes that can be sustained over a long period of time considering multiple possibilities, inhibiting the inappropriate actions and selecting the appropriate in pursuit of an established goal, all the while monitoring the adequacy and efficiency of the process.

Executive functions of self-awareness and control develop in parallel with the domain-specific content area or functional areas as described by Stuss and Benson (1986). For example, as basic memory skills (e.g., immediate memory span, encoding or retrieval) develop, the child develops a concurrent "metamemory" knowledge about how to strategically use and control these memory abilities for particular tasks or situations (Brown, 1975). An important corollary is if the basic ability does not develop, then the associated "meta" knowledge and control skill (i.e., the executive function) would not develop as fully. This point relates directly to the interest in metacognition in learning disabilities (Siegel and Ryan, 1991; Swanson, Cochran and Ewers, 1991; Pressley and Levin, 1987; Wong, 1991) and the development of self-control strategies within the context of specific processes (e.g., reading disorder, writing process). Part of the assessment and intervention in learning disabilities, therefore, must include the control strategies (e.g., recognizing the critical "problem" situation, planning and evaluating the use of specific learning strategies), in addition to the primary domain-specific content/ processing disorder (e.g., decoding words, extracting meaning from sentences).

Clinical Manifestation of Executive Function Disorders

With a working understanding of executive functions and the developmental course, we now turn to how deficits in the executive functions, broadly and in specific subdomains, may present as clinical symptoms or disorders, or contribute to other disorders, such as ADHD and Tourette's Syndrome. Deficits in executive functions are characteristic features in a variety of clinical disorders. For example, inhibitory control is a primary element of dysfunction in ADHD (Barkley, 1997). Children with LD can vary in their ability to organize and plan long term tasks (Denckla, 1989). Problem solving rigidity has been associated with acquired brain injuries (Ylvisaker, Szerkeres, & Hartwick, 1992) and lead poisoning (Gioia, Guy & Isquith, 1997, Bellinger, Hu, Titlebaum & Needleman, 1994). Executive dysfunction has been reported in other disorders, including following treatment for leukemia (Waber, Isquith., Kahn, Romero, Sallan, & Tarbell, 1994), Tourette Syndrome (Denckla et al., 1991), psychiatric disorders (Rothenberger, 1992) and developmental disorders such as Pervasive Developmental Disorder (Klin, Vokmar, Sparrow, Cicchetti, & Rourke, 1995).

At the outset, it is important to acknowledge and emphasize that there is no singular, core disorder of executive function. Clearly defining a singular executive disorder is difficult for several reasons. First, there is considerable variation in how subdomains of executive function are defined in the research domain. Some authors perceive little general agreement among researchers as to the subdomains of executive function, with agreement on only four or five central components (Eslinger, 1997). Among 9 clinical practitioners, however, Gioia, Isquith, Guy & Kenworthy (1998) found good agreement for the 9 executive function subdomains presented in Table 1 with 75% or better agreement as to approximately 100 behavioral descriptors of these domains. Second, Pennington et al. (1997) point out that disorders with different neuroanatomical bases can present with similar broad manifestations of executive function deficits (for example, treated PKU, ADHD, Autism, and Fragile X in women). On the other hand, a single clinical syndrome such as ADHD may reflect different executive function deficits, such as inhibiting and sustaining. Unlike a domain-specific function such as language where a commonality of deficits is seen in a clinical syndrome, executive function deficits can present differently within a syndrome or similarly across syndromes. Third, while neuropsychologists attempt to measure executive function in a variety of disorders in an effort to define the domains, there is not yet a full complement of sensitive and reliable measures with good specificity (Pennington et al. 1997). Further, although using the same measure of executive function, various researchers define the task requirements differently. For example, the Wisconsin Card Sorting Test (Heaton, Chelune, Talley, Kay & Curtiss, 1993) is sometimes referred to as a measure of mental flexibility or shifting, but also is referred to as a test of concept development, idea generation, abstraction (e.g., Berg, 1948), or attention (Mirsky, 1989). Such a measure may indeed involve several components of executive function, rendering a relatively pure interpretation difficult. Thus, it is not a simple task to define the clinical manifestation of executive function deficits as they may be broad, variable, and difficult to measure accurately both within and across clinical syndromes.

In this context, there is some general agreement as to basic components of executive function. Most researchers agree that working memory, mental flexibility or shifting, and inhibition are essential characteristics of executive function. In a factor analytic study, for example, Pennington and colleagues (1997) identified separable working memory, shifting, inhibiting, and planning components. Pennington's findings support the notion that executive function subdomains may contribute differentially to different disorders. The researchers found that individuals with ADHD, Autism, early treated PKU, and women with Fragile X syndrome exhibited similar within-group profiles but different between-group profiles on executive function measures. Subjects with Autism were most impaired on shifting set followed by the women with Fragile X syndrome and, last, by those with ADHD. Inhibitory control problems were greatest for the ADHD group while the Autistic group was not different from controls. For planning, the Autistic group was most impaired. Such patterns of findings suggest that, with further study, we may be able to more clearly define subdomains of executive function, develop more specific ways to measure executive function clinically, and define how these executive function subdomain deficits manifest in clinical disorders.

As we attempt to measure executive functioning in children, it is important to appreciate that deficits in one or more subdomains of executive function may not be visible until later in adolescence or adulthood. Eslinger (1997) points out that, while executive functions are several steps removed from fundamental psychological development, they are highly influenced by such development. The explicit emergence of executive function is variable and susceptible to influence by a number of factors, including domain-specific abilities, environmental demand, and a variety of insults to the developing brain. As we have noted, there is a prolonged developmental course for the executive functions, in part attributable to the continued integration of prefrontal circuitry with all brain systems into late adolescence. Further, the demand for complexity and organization of cognitive processes increases with age. Thus, two factors are at work that can obscure behavioral manifestations of deficits in executive function until later in the developmental trajectory: Normal biological development and naturally increasing environmental demands on the executive functions as the child ages.

In summary, there is no singular disorder of executive function, but rather a variety of presentations that involve one or more aspects of executive function, including a number of common syndromes that reflect different patterns of executive dysfunction. These syndromes may be *developmental* in origin, such as learning disabilities, Tourette Syndrome, or ADHD, or *acquired* such as TBI or cranial radiation as treatment for leukemia. We now discuss some of these syndromes that characteristically involve executive function.

<u>The "Dysexecutive" Child</u>.

Deficits in one or more aspects of executive function may be the primary presenting problem in a clinical setting. Many children present in a clinical setting with difficulties in academic, social or behavioral functioning that do not meet criteria for a standard clinical syndrome (e.g., ADHD, Learning Disabilities, Tourette's Syndrome). When assessment can rule out deficits in specific cognitive domains (e.g., language, attention, visuospatial, motor), executive difficulties alone may be suspected. As we will show in our review, parents, teachers and children themselves often report a coherent cluster of behavioral characteristics that suggest an executive basis for functional deficits (Gioia, 1992). For example, similar to the case of Phillip, a parent who complains that their child is disorganized in all that they do, loses papers for school even when completed, misses the point of reading materials and has trouble writing a coherent answer on paper may be describing a child who fails to organize behavior, thinking or output. Similarly, a child who is described as lazy, unmotivated, unable to get work done, underactive, confused about how to begin tasks, or a "couch potato" may have initiation deficits.

The timing of manifestation of a child's executive difficulties is also important to assess. As Holmes (1987) describes in her discussion of the "Natural History of Learning Disabilities," the demand for executive functions are very limited until the upper elementary grades and, most notably, the middle school years. This is due to changes in environmental demands and expectations: As children make the adjustment from learning specific academic skills (e.g., reading, writing, calculating) to applying these skills for learning content areas (e.g., literary analysis, report writing, algebra), the demand for the executive functions increases dramatically. Further, the organizational support and structure of elementary schools are reduced as children enter middle school, a context in which increasing executive problem-solving independence is expected of the child. Suddenly, children who had previously been good students without any academic problems become poor performers in school. The parents first complaint about a 7th grader may be that he was always a good student, but that his grades have dropped steadily since 5th grade. This reflects the natural impact of an executive deficit in academics. Socially, these children may also experience increasing difficulties as they enter middle school. The middle school environment is a demanding social milieu that requires intact executive function to grasp the gist of social interactions, inhibit impulsive responses to challenges, and effectively regulate emotions.

Attentional Disorders

As can be presumed from the nature of executive function, there is a close link with attentional functioning (Barkley, 1997; Mirsky, 1989). Indeed, executive function deficits may be most noticeable, and perhaps most measurable, as expressed via the attentional system. An intact executive system is necessary to support the ability to initiate, sustain, inhibit, shift and direct the child's attention (Denckla, 1989). A child who cannot initiate attention or is slow to do so may never manage to focus on what someone is saying or on what he, himself, is doing. Disorders of sustaining attention and performance are characteristic of the inattentive type of ADHD. Isquith and Gioia (1999) recently demonstrated that initiating, sustaining, planning, organization and working memory are likely functional underpinnings of the inattentive subtype of ADHD, while inhibiting, shifting, self-monitoring and emotional control are strongly related to the combined subtype of ADHD. Barkley also gives thorough consideration to inhibitory control as a central problem in ADHD (Barkley, 1990, 1997).

Language Disabilities

The development of language is an important aspect of, and possibly a precursor to, the development of executive controls as proposed by Vygotsky and Luria (Reiber and Carton, 1987; Tinsley and Waters, 1982). Verbal formulations play a role in inhibitory control and working memory and, subsequently, executive function in general (Denckla, 1997). An internalized language system allows the child to delay responses, in turn increasing working memory and allowing for mediation of multi-step problem-solving (Welsh and Pennington, 1988). The language system presumably also aids in generating appropriate strategies for problem solving. It may help children remain focused on tasks and direct their attentional systems according to plans or set goals. When the language system is impaired, there is a greater likelihood that the child will also manifest some degree of executive deficit. Clinically, we are often asked to sort out whether a child has a language deficit or executive deficit. Language and executive disorders can be difficult to tease apart, as they are inextricably linked.

Hydrocephalus

Children with this type of neurologic condition, with or without myelomeningocele, can present with a variety of symptoms, depending on site, onset, duration, and shunting (Baron, Fennell, & Voeller, 1995). Although Wills (1993) notes that executive functioning is often overlooked in this population, general descriptions of hydrocephalic children's behaviors reflect problems sustaining attention and inhibiting distraction (Fennell, Eisenstadt, Bodiford, Redeiss, & Mickle, 1987) and increased disinhibition in general. One often cited characteristic of hydrocephalic children is disinhibited, automatic, so-called "cocktail party chatter" (Tew, 1979), although this is not entirely supported in the literature (Byrne, Abbenduto, & Brooks, 1990).

Epilepsy

The cognitive characteristics of epilepsy are highly varied and multifactorially determined . Cognitive dysfunction varies depending on timing (during an epileptic event, post-ictally, or between events), location of seizure focus, onset of seizures, type and severity of seizures, and medications. Certainly, children with epilepsy are at significantly greater risk for learning difficulties, with 5 - 50% exhibiting problems (Aldenkamp, 1987; Thompson, 1987). While documentation with regard to the rate of executive function problems in children with epilepsy is limited, there is likely a rate commensurate with this estimate of learning problems. Research in this area is difficult, given the multiple variables that influence functioning over time, within an individual and between groups.

Childhood Cancer

While the direct effects of childhood cancer on executive function are not known, there is considerable research on the cognitive profiles of children who undergo treatments for cancers such as leukemia. As such treatment typically involves various toxic agents that are designed to interrupt cell function (radiation, chemotherapy agents), there is evidence of a variety of "late effects" or cognitive difficulties that emerge later in development, long after chemotherapy and radiation have been terminated (Waber, Isquith, Kahn, Romero, Sallan and Tarbell, 1994; Brouwers, Riccardi, Poplack and Fedio, 1984). Of particular interest in children treated with cranial irradiation is a consistent finding of initiation deficits (Waber et al., 1994; Einsiedel, Weigl, & Gutjahr, 1979, Ross, 1982, Stehbens et al., 1991) and perhaps also of organization deficits (Waber et al., 1994).

Brain Injury

Perhaps the most widely studied population with executive function difficulty is children with traumatic brain injury (Ylvisaker, 1998). Problem-solving rigidity (Ylvisaker, Szekeres, & Hartwick, 1992), social interaction deficits (Eslinger 1997; Eslinger and Grattan, 1997), disinhibition, and planning deficits (Scheibel & Levin, 1997; Levin et al., 1994) have all been described in children who sustained TBI. In this acquired disability, the greatest impact of executive deficits may not be seen in children at the time of injury, but emerge later with the dramatic increase of environmental, academic, behavioral, emotional and social demands on the executive system during adolescence. Problems in the social realm of functioning for this group are often the most distinctive features (Eslinger, 1997; Ackerly, 1964; Eslinger & Damasio, 1985; Marlowe, 1992). Executive function deficits can result in a demanding, self-centered personality, lack of social tact, impulsive speech and behaviors, disinhibition, apathy and indifference, and a lack of empathy (Eslinger, 1997). Prospective case studies (Grattan and Eslinger, 1991; Ackerly, 1964) show the onset of marked behavioral, social and emotional problems in children who sustained, and appeared to "recover" from, brain injury as children.

Tourette Syndrome

Tourette Syndrome (TS) has been the focus of much research in the last few years (Singer and Walkup, 1991). In particular, a number of researchers specifically examined executive functions in TS (Denckla, Harris Aylward, Singer, Reiss, Reader, Bryan, & Chase, 1991). Theoretically, inefficient functioning of the inhibitory control system can account for the inability to inhibit tics. Some recent work, however, (Schuerholz, Baumgardner, Singer, Reiss & Denckla, 1996), however, found difficulties largely on word generation fluency in children with TS, suggesting possible initiation deficits in addition to inhibitory deficits. However, children with TS exhibit fewer deficits in executive function than those with the comorbid condition of ADHD (Harris, Schuerholz, Singer, Reader, Brown, Cox, Mohr, Chase, and Denckla, 1995). Thus, the picture may not yet be entirely defined as to which subdomain(s) of executive function are at risk for impairment in Tourette's Syndrome.

Assessment of Executive Functions

In considering whether or not a child has difficulty in the executive domain, suspected executive difficulties need to be viewed within the larger context of a neuropsychological framework (Bernstein and Waber, 1990). While it may be possible to identify isolated executive deficits or strengths based on tests, observations, behavioral ratings, or interview, confirmation requires that problems in other domain-specific functions be understood. These domain-specific functions include attention, language, visual/nonverbal processing, sensory inputs, motor outputs, and learning and memory. For example, the child who, on copying a complex figure, produces a disorganized figure with distortions, repetitions of details, or no apparent grasp of the overall structure, may be doing so because of executive function difficulties such as organization or inhibition problems, or because of visual-perceptual or visuoconstructional deficits. Before executive function deficits can be confirmed, the underlying specific functions (in this case, visual-perceptual functions) must be shown to be intact (Denckla, 1996). The child must be able to process visual information both at the primary vision level and at the the cognitive/ perception level, must be able to grasp simpler figures that do not require higher level organization, and must be able to produce these simpler figures from a cognitive representation through the graphomotor system. If the latter functions are intact, then the problem can be presumed to be within the executive domain. On assessment in this case, one might rule out perception and reproduction for simpler figures with a task such as the Test of Visual-Motor Integration (VMI, Beery, 1967, 1982, 1997) as a control for copying a more complex figure such as the Rey-Osterrieth Complex Figure (Rey, 1964). Denckla (1996) , argues for the use of a domain-specific control task (e.g., VMI) as a covariate for the more complex task (e.g., Rey-Osterrieth Complex Figure). When the specific function is controlled for, the remaining difficulty can more surely be attributed to an executive problem, such as organization, planning, or inhibition.

At the same time that requisite skills in the underlying domain-specific content area must be intact, the executive problem should also be seen in *more than one* content area. Since executive functions are theoretically domain-general or overarching, a deficit in an executive function should influence performance across *two or more* specific domains. Disorganization in performance on one task might suggest an executive problem with organization but is not solely sufficient. Instead, the organization problem should be observable in other domains, such as in language (e.g., tangential expression, difficulty formulating a clear goal-oriented messge) or in behavior on a day-to-day basis (e.g., difficulty keeping his room or belongings organized). In the case of the disorganized copy of the complex figure, a disorganized approach to problem solving on other tasks, such as the Block Design subtest of the Wechsler scales (Wechsler, 1991) or in the recall of a Story Memory task (e.g., Wide Range Assessment of Memory and Learning, Sheslow & Adams, 1990) might be seen. The child might also be described as disorganized in work habits or as unable to keep their room reasonably organized. Confirmation of a suspected deficit in one or more of the executive functions requires *both* that the more basic domain-specific functions be adequate for the task *and* that the deficit be demonstrated across more than one specific domain. To fully examine whether a problem is broad, as in the case of executive functions, or domain-specific, a neuropsychological framework is important to guide assessment.

A General Neuropsychological Assessment Model

A neuropsychological model provides a theoretically-based framework for assessment of cognitive and behavioral functions within which executive functions can be integrated and more thoroughly assessed (Bernstein and Waber, 1990). Such a model, to be useful, must be theoretically consistent, allow for integration of the wide variety of cognitive functions, explain patterns of deviation from normal or typical function, and translate to assessment methods and tools. The model should also, in turn, suggest methods for intervention or accommodation. Given that neuropsychology evolved, in part, from the study of cognitive functions and the underlying neurological substrate, a model of neuropsychology might also be expected to refer to brain function at some level. Indeed, for a period of time in the history of neuropsychology, neuropsychological assessment was primarily a diagnostic tool that attempted to localize suspected structural lesions (Reitan, 1958). With the advent of neuroimaging and other diagnostic techniques, however, this role for neuropsychology has declined substantially. Instead, current neuropsychological assessment typically plays a much greater role in *functional* diagnosis and treatment or intervention planning (Lezak, 1995). It is difficult, particularly with children, to translate from function to structure (e.g., from neuropsychological test performance profile to brain structures). Although a neuropsychological model can be helpful conceptually for generating hypotheses, it is risky to assume that deficits on one or more tests implicate specific brain structures, particularly in the case of developmentally-based disorders. (For a thorough discussion of this issue and a functional model of brain-behavior relationships in children, see Rudel, Holmes and Pardes (1988) and Bernstein and Waber (1990)). For children whose neurological difficulties are of a congenital rather than an acquired nature, neuropsychology can play an essential role in describing the child's pattern of cognitive strengths and weaknesses and the functional impact on academic, social, emotional, and behavioral domains. With a growing rehabilitation focus within neuropsychology (Meier, Benton and Diller, 1987), assessment will likely play an increasing role in predicting recovery or improvement, planning interventions, measuring change over time, and documenting effects of interventions.

There are various approaches to neuropsychological assessment with different historical roots. Each model has advocates and opponents, as well as advantages and limitations. While there are fixed test batteries such as the Halsted-Reitan Neuropsychological Test Battery, (Reitan & Wolfson, 1993) and, at the opposite end of the spectrum, pure clinical hypothesis-testing models (Kaplan, 1988), many clinicians rely on similar sets of measures in a flexible form that allow for both psychometric analysis and qualitative, hypothesis-driven observations. Neuropsychological assessment is *not* a collection of tests, but a *conceptual framework* for understanding specific domains of cognitive, social and emotional function and their integration. While a wide array of tests are available, a great deal about a child's cognitive functioning comes from careful observation of the process rather than test scores in isolation (Rudel et al, 1988). The child who offers a one-word correct response to a Similarities item on the Wechsler Scales (Wechsler, 1991) gets full credit yet he or she arrived at a correct solution quite differently from the child who explains his or her answer in detail. Both types of responses suggest problem-solving or verbal capacities quite different from yet another child who circumlocutes, or talks around the answer, until arriving at a satisfactory solution. In assessing executive function, it is essential to make careful observations about *why* a child did well or poorly, rather than simply that they did or did not arrive at a correct solution.

Neuropsychological assessment typically involves examination of several domains of cognitive function. The amount of time required, number of tests, and depth of evaluation in each area depends on the referral question, history, and examiner's observations. A child with clearly intact spontaneous language and clear, well-formulated responses to questions likely would not need a comprehensive examination of language. On the other hand, a circumlocutory child or child with long verbal response latencies requires further exploration in the language domain. As a context for evaluating executive functions, we offer a brief overview of domains typically examined in a neuropsychological evaluation.

<u>General cognitive functioning</u>

In order to place specific functions in context, it is important to include assessment of the child's general cognitive or intellectual ability as it relates to each area. While it is not necessarily the case that children with higher IQ sores should have better executive function than those with lower IQ scores, the greater knowledge base and problem-solving capacity that defines strong performance on intelligence tests likely also leads to less requirement for executive functions. A larger repertoire of problem-solving approaches means the child is less likely to have to generate novel strategies, monitor for success or failure, and shift strategies as much as a child with lower IQ who has a more limited knowledge of problem-solving strategies. For this reason, it is important to have an assessment of the child's overall cognitive ability, typically derived from all or part of a standardized intelligence test battery, such as the Wechsler scales (Wechsler, 1991), Differential Ability Scales (Elliot, 1990), or Stanford-Binet (Thorndike et al., 1986).

Both quality of performance and subtest patterns on standardized tests can suggest executive dysfunction. As noted above, just as overall cognitive ability may influence the degree to which executive functions are called into play on test performance, deficits in executive functions can also influence performance on intellectual assessment batteries. Tasks requiring active problem-solving with novel material or efficiency and speed of performance, such as the Performance subtests of the Wechsler scales (Wechsler, 1991), are more susceptible to the influence of executive difficulties than are rote verbal measures (Gioia, 1993). This is a result of the demand that each subtest places on the executive functions. While some verbal subtests on the WISC-III require language formulation, most verbal subtests primarily tap rote verbal knowledge. Executive functions are invoked in limited fashion when tasks require existing knowledge or vocabulary. The Performance subtests, on the other hand, involve novel, complex, speeded problem solving, the very same demand situations that tap executive function. Thus, reduced scores on some or all of the Performance measures might suggest problems with initiating ideas or strategies for problem solving, or with working memory, inhibiting attentional pull to details, or organization. For a full discussion of subtest patterns see Holmes (in Rudel, Holmes and Pardes, 1988).

<u>Attention</u>

Attention is a well-studied complex phenomenon that is closely linked with, and highly influenced by, executive function (Barkley, 1997; Isquith & Gioia, 1999). This is perhaps the most difficult specific domain to separate from executive function. At the outset, attention is not a unitary phenomenon (Mirsky, 1989): It involves many basic and higher level components that are referable to several brain systems. A review of the attentional system starts with arousal, a child's tonic level or general state of alertness. In the extreme case, coma or unconsciousness reflects gross underarousal and likely damage to the reticular activating system in the brainstem. At the opposite extreme, overarousal can be seen as chronic hypervigilance associated with anxiety disorders or thyroid disorders (e.g., Graves disease) that artificially activate the sympathetic nervous system. Among more moderate cases, the underaroused child may be less able to attend to simple tasks yet may perform well on tasks that are more challenging and stimulating, requiring greater mental effort. The classic example of such a condition is evident when a child can repeat more digits backward than forward, the latter task in most cases, being less challenging than the former. Arousal is assessed by observation across the testing setting and by history. Is the child generally lethargic, slow moving, and underactive? Is the arousal level influenced by external, environmental factors, such as something the child finds exciting? One child seen for evaluation was described repeatedly as having a Pervasive Developmental Disorder. He presented with a flat affect, poor eye contact, and monotone vocal production. On evaluation, the child presented as described and was slow moving, inattentive, and physically floppy or hypotonic. When given challenging tasks or when the examiner infused the assessment session with energy via rapid pacing and vocal intonation, the child became much more aroused and demonstrated average performance on most tasks, producing good vocal intonation and prosody, and maintaining adequate eye contact. Further, while his performance on complex figure copying and story memory tasks was previously grossly impaired, administration of similar tasks while the child was aroused produced average results. In essence, the child was tonically underaroused but could be "jazzed up" by external means. As this case illustrates, the diagnostic implications, and subsequent interventions, are quite different for a child who is underaroused versus a child with the complex features of Pervasive Developmental Disorder.

With general level of arousal as a backdrop, attention can be examined globally and in detail. Observations during conversation and testing can show fluctuations in ability to sustain attention. Does the child become fatigued across the evaluation, respond with better sustained attention to certain tasks versus others, or does the child attend initially at the outset of a task, then fade quickly? For example, on a lengthy verbal learning test where the child must listen to and repeat a word list five times, many attentionally disordered children will initially *increase* the number of words they report but *decrease* reported words dramatically after a few trials. Qualitatively, these same children often complain of boredom by the third trial. Continuous performance tasks such as the Gordon Diagnostic System (Gordon, McClure & Aylward, 1996; Gordon, 1983), Test of Variables of Attention (TOVA, Greenberg et al., 1996), or other continuous performance tests can be helpful in examining sustained visual attention formally.

More demanding tasks might require higher level attentional functions, such as rapidly shifting attention or dividing attention. Can the child shift attention from one set or problem to another? Can he or she divide attention between simultaneously competing stimuli? This might be seen in a complex figure copying task when the child has to attend to the overall structure as well as the details.

<u>Language and Language-Related Processing</u>

Assessment of basic language functions typically involves examining basic *expressive* functions such as rate and fluency of speech, articulation, voice volume, intonation, prosody, syntax, grammar, vocabulary usage, word finding, and fluency of language formulation, as well as *receptive* functions involved in registration and comprehension of language. Additionally, pragmatic use of language in social interaction is important. While many formal tests exist for most of these areas, observation through conversational interaction often serves as a clinical screen for problems. As the Wechsler scales are more a test of verbal knowledge than of language functions *per se*, the neuropsychological evaluation typically includes a sampling of measures that involve more focused or complex language processing, such as naming and word retrieval tests (e.g., Boston Naming Test, Kaplan et al., 1983), sentence repetition or formulation tasks, and comprehension tasks (e.g., Verbal Comprehension from the Differential Abilities Scale, Elliot, 1990, and Comprehension of Instructions subtest from the NEPSY, Korkman et al., 1998).

The relationship between language and executive function is complex in a bi-directional fashion. In one direction, deficits in executive function domains may interfere with language production. Problems of initiation can be seen in latencies to respond to questions or in word-retrieval difficulties (Ylvisaker, 1993). Organization problems are typically expressed as disorganized verbal output, with frequent, sometimes random, topic changes. Disinhibition may present as inappropriate verbosity or inappropriate or irrelevant questions. For example, one child who could discuss famous guitarists in a rote, one-sided monologue was unable to maintain an organized topic outside of that area and tended to ask inappropriate questions of the examiner. Problems sustaining attention can be seen in the child who frequently loses track of what he or she was saying. In the opposite direction, language deficits can interfere with executive function. As children develop language skills, they increasingly rely on an internal monologue to self-monitor, generate strategies for problems solving, direct attention, and select desired behaviors. They use language, then, to assist in organizing information, choosing where to pay attention, and inhibiting inappropriate behaviors. We need only to think of the internal discussion we have with ourselves when a rude driver cuts us off during the morning traffic rush. While the impulse may be to hit the other driver, our internal language system helps direct our thoughts toward better solutions and allows us to inhibit aggressive action. In children, language and executive disorders often go hand-in-hand. It is not uncommon to find marked language problems in impulsive, aggressive children.

Visual/Nonverbal Processing

This area involves the ability to process at the primary visual and perceptual level, decode simple and complex visual stimuli, and grasp the structure or meaning of the material. On the output end of the process, the child must be able to reproduce visual stimuli either from memory, as in a clock drawing, or from a present stimulus, such as design copying (e.g., VMI, Beery, 1997). More complicated "constructional" tasks such as the WISC-III Block Design (Wechsler, 1991) further ask the child to comprehend and reproduce more complex designs from component parts. Although there are many individual tests for examining minute aspects of visual perception and reproduction, the more process-oriented neuropsychological evaluation relies on starting at more difficult integrative levels and assuming that the basic functions are intact. For example, if a child can adequately reproduce a complex figure drawing, it is reasonable to assume intact ability to copy simpler designs (e.g., VMI). Should problems be apparent on the copy production of the complex figure, there are many tests that break down visual information processing into simple recognition and matching, rotation of figures, comprehension for degraded stimuli, and so on. It is useful to note whether the child can comprehend meaningful visual information such as pictures of familiar objects versus more abstract, nonverbal/visual materials such as the Rey-Osterrieth Complex Figure (Rey, 1964) or Block Design (Wechsler, 1991) items.

The overlap between visual/nonverbal functioning and executive functions is often seen in children with inhibitory control and organizational difficulties. Classically, the child who copies the complex figure in a highly disorganized manner but, on production from memory, demonstrates a good grasp of the gestalt and organization displays a problem with disinhibition, characterized by an impulsive, poorly planned approach to the figure. If, however, the child has the same pattern of performance for the figure during recall as during copy, then organization may indeed be a problem. Self-monitoring difficulties may be displayed on this type of task as a failure to recognize errors. During testing, the child who makes a noticeable error on a Block Design and makes no move to correct it can be challenged to find the error or to compare his or her work with the stimulus after formal administration. If the child finds the error on a second, closer look, they likely were not monitoring their production carefully.

Learning and Memory

Learning, the complex phenomenon of being able to acquire new skills and knowledge, and the requisite memory processes are inextricably linked with executive functions (Schneider & Pressley, 1988). On assessment, it must first be shown that basic memory processes are intact. These are typically defined as the ability to encode, store, and retrieve stimuli of any type (e.g., visual, verbal, olfactory, motor). A stimulus must first be perceived, reflecting intact visual/nonverbal and language functions, then held in immediate memory sufficiently long to be encoded into storage. Later, information is retrieved from storage as needed. Although "memory" difficulties are often reported in children ("He doesn't remember when I ask him to do three things"), instead these are often problems of executive function, attention, language, or even behavior which can adversely affect memory processing or performance. Assuming these areas are adequate to the task, we can then examine the memory functions. A typical approach assesses immediate memory via repetition for limited amounts of rote information (e.g., digits, letters, visual sequences, sentences). Story memory tasks check for encoding by requiring immediate report of the story after hearing it, then check retrieval by requiring another report of the story after a delayed period. While a significant decrement in recall might suggest storage difficulties, cues or recognition testing most often show the problem to be one of encoding or retrieval. Storage deficits are rare in children unless they have clear neurological damage to the temporal lobes, such as with some seizure disorders, tumors, or infectious encephalopathies (e.g., Herpes encephalitis). Other memory storage difficulties can be seen in children who have undergone cranial irradiation therapy for leukemia, although this may be partially attributable also to steroid treatments (Waber et al., 1995). There is also some indication in the literature of storage deficits in severely traumatized children who perform poorly on memory tasks (Gurwitch, Sullivan & Long, 1998;

Stein, Koverola, Hanna, Torchia & McClarty, 1997). The current literature suggests a decrease in temporal lobe volumes, specifically hippocampal volumes, with protracted trauma (Bremner & Narayan, 1998; Golier & Yehuda, 1998; Joseph, 1998).

As noted, the association between executive function and memory makes the two difficult to separate. Sustaining attention and concentration for the duration of the information is a prerequisite to encoding. Beyond simply attending to the material, the child must initiate encoding strategies for efficient storage. Efficient strategies will likely invoke organization systems and may involve a plan to remember the material. The child must also inhibit distraction to minor aspects of the information while attending to essential features. On the retrieval side of the equation, initiation of retrieval strategies is necessary with more efficient retrieval typically reflecting more planful and organized search strategies.

To illustrate the association between memory and executive function, a repeat-trial, word list learning task can be administered, such as the California Verbal Learning Test-Children's Version (CVLT-C, Fridlund & Delis, 1994). Immediate memory is demanded on the first trial and number of words recalled is often commensurate with digit span forward performance. With repeated presentations, the child is asked to compare what he or she has already encoded with the rapidly presented list to fill in the missing information. The child who plans to remember and initiates an active encoding strategy will be more successful than the child who passively listens. In the case of the CVLT-C, there is a clear semantic organization inherent in the task that the child can use to organize and "chunk" the words, facilitating performance on the task. Children with sustained attention problems often show an inverted "U" pattern of recall: They increase the number of words recalled until about the third trial, after which time, they show a decrease in the number of words recalled. Typically, they also often complain about this type of task. The CVLT-C, and other verbal learning tasks (e.g. Rey Auditory Verbal Learning Test, (Rey, 1964)) also require storage and retrieval after a delay and measure perseverations and intrusions, both of which may reflect disinhibition.

Motor and Sensory Functions

The motor output system and sensory input system are of interest to the evaluator. Much is learned about the child's motor system through general observation beginning in the waiting room: Can the child navigate the hallways? Do they drift to one side or another? Can they maintain posture while seated at the testing table? During testing, key behaviors to be observed include pencil grasp, fluidity of letter making, ability to grasp and manipulate small objects, and differences in use and control with each hand. Formal tests can document fine motor speed, control, strength, and laterality. Tactile sensory functioning is less directly observable but may be of interest. A variety of formal test procedures in this area are available including subtests from the sensory-motor domain of the NEPSY (Korkman et al., 1998) as well as from the Childrens adaptation of the Halstead Reitan Neuropsychological Battery (Knights & Norwood, 1980).

As with other domain-specific functions, executive function provides a supervisory role in the integration of motor outputs and sensory inputs. Motor impersistence, though infrequent, may reflect a general inability to sustain output in a neurologically impaired child. Motor disinhibition is commonly seen in the impulsive-overactive child. Many times one is asked to differentiate between a problem of primary graphomotor production (i.e. can't adequately form the letters), and an impulsive approach to handwriting (i.e. can form basic letters but rushes quickly through writing tasks). Motor overflow or disinhibition of motor outputs in the face, mouth or opposite hand is commonly seen in children for whom writing is difficult (Denckla, 1985). Thus, motor planning difficulties may reflect an executive function component.

Academic Skills

Academic skills are an outcome of the underlying cognitive processes, rather than a domain-specific function per se. That is, reading, writing, and calculation are developed skills that rely on a variety of specific brain systems that, in turn, must be functional. At a basic level, the auditory processing system must register sounds, allow for segmentation of sounds into basic units (i.e. phonemes), and the association of phonemes with the visual symbol (i.e. letters and letter combinations), and into the graphic units (Rudel et al., 1988). The graphemes are produced motorically via an integrated fine motor system. Similarly, calculation requires the ability to perform symbolic translations with numbers, as well as an understanding of number concepts. Increasingly, many more systems are invoked as the child eventually applies basic academic skills to more complex mathematical concepts and more complex, integrated reading and writing tasks to learn and to communicate.

Executive functions are implicated differently at various stages of academic development. Clearly the ability to inhibit plays a large role in the acquisition of early academic skills. For example, inhibitory deficits are seen in the child who is responding to other stimuli in the classroom rather than the learning task at hand. Another example is the child who impulsively attends to only the first letter of a word, rather than fully decoding all the critical phonemic elements, and thus erroneously "reading" the word. While acquiring the basic technical skills of reading and writing, the ability to sustain is necessary for overpractice so that the skills become automatic. Once successfully automatized, they require little attention and effort from the child. At this point, the focus in school typically shifts to applying these basic skills to learn more advanced reading, writing and calculating skills. Such advanced application of basic skills requires more of the executive system, particularly for organization and integration of novel information, written output, and thinking in general. Hence, children with executive/organizational difficulties are more likely to present with problems during later elementary grades when this change in educational demand takes place (Bernstein, 1987).

Social/Emotional/Behavioral Functioning

As in most assessments, it is helpful to have information about the child's social skills, emotional status, and day-to-day behaviors. Many assessment methods are available for evaluating children's social, emotional, and behavioral function and a number of these have been described elsewhere in this book. Executive functions play an important and often readily apparent role in the modulation of behavior, emotions, and social interaction. An evaluator can learn much about a child's likely executive function through observation of general behavior and through parent and teacher reports.

Many parents report clear characteristics of general disinhibition: The child is "always into things", acts before thinking, races through homework carelessly, intrudes into adult conversations repeatedly, and requires continual supervision in order to stay out of trouble. Organizational problems may be similarly described by parents: The child is messy, has a messy room, locker, and desk, can never find her homework even when it has been completed, and doesn't remember where things are or doesn't follow through on routine chores or activities. Parents who describe their child as "drifty", fading from tasks, having difficulty finishing homework that is within their mastery level, or as "zoning out" may be describing problems with sustaining attention and effort. Planning deficits may be reported as difficulties figuring out what things are needed for a project, starting activities without all the requisite materials, or having problems completing projects on time for school. Children who get "stuck" on one topic or become overly focused on a peripheral point or minor detail may have difficulty shifting attention. Such children may be rigid in their use of problem solving strategies, leaving them at risk for social problems. Finally, initiation difficulties are often seen in children who are described as "couch potatoes," or as generally lethargic: "He sits around all day, but if you invite him to do something, he'll get up and join you." Children with initiation deficits also may have trouble knowing where or how to begin on homework, but once they begin, they perform well.

In summary, neuropsychology provides a conceptual framework for assessment that encompasses a wide range of cognitive functions. There are several different models for approaching the assessment, and each model offers valuable tools and techniques. Against this background of testing fundamental domain-specific cognitive functions, we now consider the assessment of executive function in some detail.

Special Issues in the Assessment of the Executive Functions

While the collection of behaviors and processes known as the executive functions may be defined in a relatively straightforward manner, their precise assessment can be very challenging. A clear understanding of the differences between assessment of the "basic" domain-specific content areas of cognition (e.g., memory, language, visuospatial) and the domain general or "control" aspects of cognition and behavior is essential. What may appear as a problem with the expression of language may be due less (or not at all) to the basic aspects of linguistic functioning (e.g., vocabulary, syntax, semantics) than to poor "meta-linguistic" functions (e.g. formulating and maintaining an organized, planful approach to the topic of conversation). There is no test or battery that singularly assesses executive function. By necessity, there is always a "domain-specific" content area regulated by the executive control process. Returning to our orchestral metaphor, the conductor (executive function) must have players (cognitive processes) to direct in order to make "cognitive" music. Teasing apart executive functions from domain-specific functions is part of the challenge of the neuropsychological assessment.

Dynamic essence

Historically, clinical assessment of the executive functions has been challenging given their dynamic essence (Denckla, 1994). Any assumption that the executive functions are static abilities amenable to traditional testing is simply false and can lead to their misrepresentation. In many respects, fluid, strategic, goal-oriented problem-solving is not as amenable to paper and pencil methods as are the more domain-specific functions of language, memory, motor, and visual/nonverbal abilities. Furthermore, the structured and interactive nature of the typical assessment situation may relieve the demands on the executive functions, and thereby reduce the opportunity to observe critical behaviors associated with the executive functions (Bernstein and Waber, 1990). That is, in many testing situations, the examiner provides the structure, organization, guidance, and plan, as well as cueing, and monitoring necessary for optimal performance by the child, thus, serving as that child's external executive control (Stuss & Benson, 1986; Kaplan, 1988). A child with significant executive dysfunction can perform appropriately on well-structured tasks of knowledge where the examiner is allowed to cue and probe for more information, thus relieving the child of the need to be strategic and goal-directed.

Novelty-Familiarity Dimension

Recognizing the different stimulus conditions which are provided within the comfort of the controlled setting of testing (which may be very necessary to identify the child's knowledge and abilities) versus those existing within the child's "real" day-to-day world is critically important. Frequently, the more novel and/or complex the task, the greater the demand for the executive functions. The more familiar, automatic and simple the task, the less the child needs to recruit their executive function functions. What may be a complex, novel task for one child may be a relatively familiar and automatic task for another, requiring that these children recruit vastly different degrees of executive control functions toward solving that particular problem. The ultimate application of assessment data into formulating credible practical recommendations and intervention strategies demands a clear understanding of this issue. Assessing the child's behavior and responses under greater and lesser degrees of examiner-determined control and structure can help clarify the child's executive control competence. This point stresses the importance of an intra-individual approach to assessment as opposed to a simply normative model.

A paradox in the assessment of the executive functions is that some individuals with significant deficits in specific executive function subdomains may, in fact, perform appropriately on many purported "tests of executive function" yet have significant problems making simple real-life decisions (Stuss and Buckle, 1992). It is critical to remember that all tests are multi-factorial, requiring for any particular individual greater and/or lesser degrees of domain-specific content knowledge and experience (the novelty-familiarity issue) and thereby demanding varying degrees of organization, planning, inhibitory control, or flexibility. For example, a child may be able to perform appropriately on the Wisconsin Card Sorting Test (Heaton et al. 1993), which requires flexibility in problem-solving, yet fail miserably in strategically modifying his/her approach to completing a set of math problems in the classroom. In the assessment of the executive functions it is particularly important to remember Teuber's (1964) classic statement "absence of evidence is not evidence of absence". One may not be collecting the relevant data to document the full essence of strengths and weaknesses in the array of executive functions.

An additional complicating factor in the assessment of the executive functions in children is that most existing standardized clinical measures are downward extensions of adult measures that have not been constructed with developmental change in mind. Given the extensive literature in developmental psychology documenting changes of strategic behavior and knowledge from infancy through adolescence (Welsh & Pennington, 1988), recognition of these effects in the use of assessment instruments is of critical importance . There is, of course, a related priority for the construction of instruments which are sensitive to developmental effects.

As will be more fully addressed in the discussion which follows, assessment requires a variety of approaches to characterize fully the profile of the executive functions for a given child. The examiner must (1) maintain systematic observations of the ways that the child manages task demands within the context of the assessment situation, including their social behavior during interviews, in the waiting room, and during testing, (2) recruit reliable reports of critical problem-solving behaviors in the child's "real world", and (3) provide psychometrically and developmentally appropriate tests for direct observation of executive problem-solving performance.

Methods of Assessing the Executive Functions

We now consider the various methods of assessing each of the different subdomains of executive function. Table 2 provides a representative sample of the measures currently available to assess these functions in children and adolescents. When examining the psychometric properties of the performance measures, it is important to recognize that there is an inherent confound which limits the utility of the test/retest indices. As discussed earlier, measures of executive functioning assess the individual's ability to solve problems or complete tasks with novel and complex demands. Once a person has been exposed to a novel problem-solving task, the practice effect limits interpretation of retest performance as "executive". In other words, the second administration is no longer "novel" and therefore, the nature of the task demands are likely somewhat different from an executive problem-solving perspective. Caution is also warranted regarding the validity indices of the measures. As Pennington (1997) points out, the consistency, severity and profile of executive function deficits vary across the various developmental disorders, creating challenges in establishing discriminant validity of the measurement tools. Nonetheless, most tasks have been found to adequately discriminate between clinical and normal samples and have strong clinical utility. Perhaps as important as the derived standard scores, which offer only partial information, these tests also yield rich qualitative observations of a child's problem-solving capabilities.

The ability to *initiate* is described as beginning a task or activity, or the process of generating responses or problem solving strategies. Performance measures which tap this ability often involve the rapid generation of responses such as words or designs (e..g. Controlled Oral Word Association (Benton & Hamsher,1989), Design Fluency (Jones-Gotman & Milner, 1977; NEPSY, Korkman, Kirk, & Kemp, 1998). For example, verbal fluency tests require the examinee to say as many words as possible which begin with a certain letter or are within a certain category (e.g. animals, foods). The design fluency tasks require a subject to draw as many different designs as possible in a given time period. This function can be also be readily evident through observation during the assessment process as children with initiation difficulties often require additional cues from the examiner to start a task. Furthermore, caregivers often report that children with initiation difficulties have trouble getting started on homework or chores, and require prompts or cues in order to begin. It is important to emphasize that problems with initiation are not the result of non-compliance or disinterest in the task. The child typically has an interest in the task or activity and wants to succeed but cannot get started.

A child's ability to *sustain* performance and attention is a common reason for referral for evaluation and treatment. Not surprisingly, there are a variety of methods to assess this function. Continuous performance measures are popular methods that require the child to maintain attention on a non-stimulating or minimally reinforcing task (TOVA, Greenberg et al., 1996; Gordon Diagnostic System, Gordon, McClure & Aylward, 1996; Gordon, 1983) for an extended period of time. Other tests of sustaining require intense concentration under difficult task demands. For example, the Children's Paced Auditory Serial Addition Test (CHIPASAT; Dyche & Johnson, 1991; Johnson, Roethig-Johnston & Middleton, 1988) requires the examinee to mentally add two consecutive digits, which are steadily presented over a period of time. Still another method to assess a child's ability to sustain is through caregiver report as there are numerous opportunities in daily activities to observe these behaviors. A common complaint for children who cannot sustain is that they cannot "stick to" an activity for an age-appropriate amount of time (e.g. has trouble completing tasks, switches from one activity to another). In the context of the evaluation, frequent requests by the child for breaks may be a sign of difficulties sustaining attention and effort.

The ability to *inhibit* is a critical trait for success in school and home. Measures to assess this subdomain examine the ability to not act on (inhibit or resist) an impulse and/ or to appropriately stop one's own activity at the proper time. Several continuous performance measures described above provide distracting stimuli in an effort to measure the child's ability to ignore the conflicting or distracting information. Additionally, some tests examine the ability to wait or withhold a response until all information is processed. For example, a subtest on the Gordon Diagnostic System (Gordon, McClure & Aylward, 1996; Gordon, 1983) requires the child to wait at least 7 seconds between responses in order to score points. If the child does not wait the allotted time then they do not receive the point and the interval is repeated. An impulsive child who is eager to gain points typically cannot inhibit responses and typically will not attain as many points as a child who is able to estimate the necessary delay period and learn the most effective way to gain points. On the Matching Familiar Figures Test (Welsh, Penington & Grossier, 1991), the examinee is asked to match a target figure with its exact mate from among a set of nearly identical figures. The child's performance is not only based on accuracy, but the time taken in responding. The longer the time to respond, the better the ability process all relevant information, and to inhibit an incorrect response. Other measures examine the ability to suppress a natural, prepotent response (e.g., Stroop Test, Stroop, 1935). The ability to inhibit is also readily observed in daily activities with common examples of disinhibition including: acting without thinking, being easily distracted, and being unable to sit still. Parents and teachers typically possess a wealth of information about a child's ability to inhibit their responses and rating scales are effective means of gathering information about this subdomain.

The ability to *shift* one's problem solving strategy during complex tasks is a key aspect of executive function. Thinking flexibly and being able to switch or alternate attention is an essential component of novel problem solving. The most common performance measure used to assess this ability is the Wisconsin Card Sorting Test (Heaton et al., 1993) on which children match cards and receive feedback regarding their accuracy after every response. Once the correct matching strategy is determined and maintained for 10 consecutive responses, the matching principle changes unbeknownst to the child. The child must flexibly develop a new strategy to perform adequately. In their day-to-day lives, children who are rigid or inflexible may exhibit problems transitioning from one situation, activity, or aspect of a problem to another as the situation demands. Caregivers often describe these children as "getting stuck" on a topic or as being highly perseverative.

The ability to *plan* involves anticipating future events, setting goals, and developing appropriate steps ahead of time to carry out an associated task or action. Planning involves imagining or developing a goal or end state, and then strategically determining the most effective method or steps to attain that goal. This often involves the sequencing and stringing together of steps in order to most efficiently move toward an end state. The ability to plan had previously been considered as a skill of later development, but research has illustrated its active use in even preschool children. A variety of "tower" tasks have been developed which can measure this subdomain (e.g. Tower of Hanoi (Welsh et al, 1991), NEPSY Tower (Korkman et al, 1998)). These tasks require the child to reach a goal (replicating a tower model) via a self-generated sequence of planful steps. The ability to plan or strategically solve problems can also be observed in a variety of other measures. For example, the WISC-III Object Assembly Subtest provides the opportunity to directly observe a child's strategy when problem solving. Does the child stop to determine the gestalt or whole and then use that knowledge to guide performance? Does the child begin by randomly shuffling the puzzle pieces and arrange them via trial and error? Do they use an efficient strategic approach (e.g. lining up the internal details on the pieces, placing recognizable pieces where they should eventually be placed and organizing around them), or do they use the external or less salient information (e.g. shape of the pieces)? The ability to plan can also be assessed from caregiver observations. For example, parents and teachers may complain about the child's lack of planning ability, tendency to start assignments at the last minute or not thinking ahead about possible problems.

The ability to *organize* complex amounts of information is a subdomain that becomes increasingly important as demands for independent functioning increase. Organization involves establishing and maintaining order within an activity or carrying out a task in a systematic manner. The way in which information is strategically organized can play a critical role in how it is learned, remembered and retrieved (Schneider and Pressley, 1989). Numerous information processing tasks are available which involve presenting the subject with a complex or seemingly overwhelming amount of information and then observing how the child responds to the problem. While there are no direct "organization" tests, tasks such as the ROCF can be scored for organization (Bernstein & Waber, 1996; Stern, Singer, Duke, Singer, Morey, Daughtrey & Kaplan, 1994), and the CVLT-C provides an index of semantic versus serial clustering (Fridlund & Delis, 1994) . The child's approach provides critical information about how they are able to organize in the face of complexity. Common reports from caregivers which suggest disorganization in a child include a scattered approach to solving problems, being easily overwhelmed by large tasks or assignments, or having difficulties organizing personal belongings.

The ability to *self monitor* is typically not assessed via a discrete performance measure but rather by direct examiner observation and caregiver reports. The ability to self monitor includes checking on one's own actions during or shortly after finishing a task to assure appropriate attainment of a goal. Children who do not self monitor often rush through assignments without checking their work for mistakes. Additionally, such children may be unaware of how their actions affect others in a social context.

Emotional Control is the manifestation of the executive functions within the emotional realm. It is closely associated with the ability to inhibit and modulate responses. Emotional control is not a characteristic which can be directly assessed, but it is readily observed at home, school, and during assessment. The Behavioral Rating Inventory of Executive Function (BRIEF) (Gioia et al, 1998) and other behavioral checklists are the most effective methods to measure this function. The inability to modulate one's own emotional response may manifest as the child's overblown emotional reactions to seemingly or as a general affective reactivity. Such children are often described as emotionally explosive.

Working memory is the process of holding information in mind for the purpose of completing a specific and related task. Working memory is essential in order to follow complex instructions, complete mental arithmetic or perform tasks with more than one step. There are a variety of assessment tasks that directly or indirectly tap this subdomain. Digit repetition tasks, specifically in the reverse order, is a common method to assess working memory. In the reverse format, a child must hold the information in mind while they actively perform an operation on that information (i.e., manipulate the digits in a different order). Tasks requiring the ability to mentally compute arithmetic problems such as the CHIPASAT (Dyche & Johnson, 1991a) or the Wechsler Scales Arithmetic subtest (Wechsler, 1991) also tap working memory. Several research tasks have been developed to assess working memory, however, they are not yet available in standardized, norm-referenced forms (e.g., Sentence Span, Counting Span; Siegel and Ryan, 1989). Problems of working memory may also be observed by parents and caregivers. A common observation made by parents is that their child often has trouble remembering things for even a few minutes, or when sent to get something, forgets what s/he was supposed to get.

Structured Behavior Rating Scales

A rich tradition exists in utilizing structured behavior rating systems in the assessment of psychological and neuropsychological functions (Achenbach, 1991; Conners, 1989; Reynolds and Kamphaus, 1994). The use of rating scales completed by parents and teachers measuring overt behavior is an often-used and well-proven method for the assessment of various domains of social, emotional, and behavioral functioning in children. In addition to performance tests, the need exists for other methodologies to assess the executive functions. Observations of the child at home or in school by adult caregivers provide an essential source of information in the assessment of executive functions. Given the difficulties and complexities involved in performance assessment of executive function, an ecologically valid system of assessing the everyday self-control behaviors of children serves as an important adjunct to the clinical evaluation and treatment of executive dysfunction. One such measure, the Behavior Rating Inventory of Executive Function (BRIEF), was designed to assess the behavioral manifestations of executive functions in children aged 5 to 18 years (Gioia, Isquith, Guy & Kenworthy, in press; Isquith, Gioia, & Guy, 1998).

Behavior Rating Inventory of Executive Function. The BRIEF assesses 9 subdomains of executive function: Initiate, Sustain, Inhibit, Shift (Flexibility), Organize, Plan, Self-Monitor, Working Memory and Emotional Control. More general domains of executive function (e.g., self-regulation, anticipation) for which specific behaviors could not be generated were not included. Other possible domains (e.g., goal setting, strategic problem-solving) were incorporated within the nine existing domains (e.g., planning, shift). Items were generated primarily from behavioral descriptions of executive difficulties during clinical interviews with parents and teachers, ensuring good face and content validity. Item-category membership was validated by the sorting decisions of nine clinical neuropsychologists, as well as statistical analyses (item-total correlation analyses, principal factor analyses, and interrater agreement). The correlations between parent and teacher informants are moderate, with an overall mean of .36, which is consistent with the literature on consistency among parent-teacher informants (Achenbach, McConaughty & Howell, 1987). The subscales and their representative items are provided in Table 3.

To establish a measure of convergent and discriminant validity, the BRIEF was examined in relationship to a general measure of behavior in children (i.e. Child Behavior Checklist (CBCL) and Teacher Report Form (TRF), Achenbach, 1991). Correlations ranged between .3 and .6, indicating an appropriate low to moderate relationship. Principal factor analysis (PFA) of the parent and teacher BRIEF and Achenbach (1991) forms resulted in a three-factor structure with most of the BRIEF scales separating from the TRF and CBCL scales and forming an "executive" factor, an "externalizing" factor, and an “internalizing" factor (Gioia, Isquith, & Guy, 1998). The BRIEF was successful in differentiating between a diagnostically-mixed clinical group and a matched initial normative group (age 5-13 years) on all executive function domains. That is, there were significant differences with large effect sizes between clinical and normative groups on all domains of the BRIEF (.Isquith, Pratt, Guy, & Gioia, 1999). Pratt (1999) recently demonstrated that children with inattentive versus combined subtypes of ADHD exhibit distinct scale patterns on the BRIEF versus children with reading disorders and controls. Children with reading disorders exhibited primarily working memory and sustaining difficulties.

Observational Procedures

In addition to formal tasks that assess the executive functions, the examiner can also apply a systematic set of observational procedures for any task or test that the child is administered (Ylvisaker and Gioia, 1998; see Table 4). The goal of these procedures is to identify the child’s control processes in performing a given task. These procedures can accompany virtually any task when there is interest in documenting the inherent executive functions and thus can be used in real-world or informal context as well as the testing setting.

Before the beginning of the task, the examiner assesses the child's self-awareness of their own ability as it relates to that task. This gives an indication of whether the child is accurately appreciating the type of task that lies ahead. The child is then asked what their goal is for the task and the strategies they plan to use to achieve the goal. Once the task is underway, observe the child's ability to initiate necessary problem-solving activities, especially when a problem arises. This gives a good understanding of their skill in initiating strategic behavior to solve the problem. In order to assess the child's ability to inhibit inappropriate stimulation during the task, observe their skill at not attending to non-task activity. It may also be necessary to create distraction (e.g., auditory, visual) and observe their response. Documenting the length of time the child remains on the task can give information regarding their capacity to sustain. During the task, note whether the child is aware of mistakes that are made. Also, questioning regarding how they view their performance provides information regarding self-monitoring skill. As stated above, when obstacles occur during the task, observe the child's ability to flexibly try a different strategy. When the task is completed, asking the child to evaluate their performance as it relates to their goal and their prediction assesses their self-evaluation skills. Asking for a summary of what worked and didn't work can be useful to understand how well the child appreciates the full scope of their problem-solving efforts.

A creative play observation strategy has been employed in a number of research projects with preschool and school age children to assess goal-oriented play schemas that have much relevance to "real world" executive functions (Ewing-Cobbs, Landry, Prasad, Steubing, Leal, and Canales, 1999; Landry, Smith, Miller-Loncar and Swank, 1998; Landry, Denson, and Swank, 1997). Ewing-Cobbs et al. (1999) demonstrated that the complexity and duration of age-appropriate play activities was significantly disrupted by traumatic brain injury in infants and preschoolers. Similarly, Landry and colleagues have demonstrated deficits in the child's ability to independently formulate play goals and sustain goal-directed activity in both social and nonsocial situations for children with Down's Syndrome, complications associated with prematurity, and hydrocephalus associated with spina bifida. Thus, such ecologically-valid executive behaviors as sustained attention, task initiation, task maintenance and goal regulation can be assessed in children's everyday exploratory play behavior, even in infants and preschoolers. Assessment methods such as these, though early in their development, deserve much more attention as ecologically-valid procedures to tap the child's profile of executive function.

Implications for Practice

An understanding of the executive functions is necessary in conceptualizing the full complexity of developmental and acquired neurologic disorders in children. Mental ability is not simply the knowledge of "domain-specific" content that the child demonstrates on a test. It also involves the general supervisory performance across domains, that is, how the child executes such knowledge and skill in a sustained, appropriately inhibited, and systematic, organized, and planful manner with flexibility and monitoring of the adequacy of the performance - all toward the attainment of the end goal. Certain testing conditions facilitate the assessment of the executive functions while others limit the opportunity. The examiner must know the difference and, in fact, intentionally manipulate these conditions to tease apart the executive control behaviors from the "domain-specific" aspects of performance. The psychologist should consider the use of several different assessment methodologies toward this end. In addition to standardized tests, the observational procedures and behavior rating scales can be used in assessing the "real world" aspects of the executive functions. The more general psychological assessment can contribute to the identification of possible executive dysfunction in children with neurological impairment. Given the specialty training typically required to perform a comprehensive neuropsychological evaluation, referral for more in-depth testing of the executive functions (and their concurrent "domain specific" partners) would be warranted should further definition be necessary.

An appropriate assessment of the profile of executive functions in a given child has significant implications for treatment. With knowledge of the child's strengths and weaknesses in the executive subdomains, including an understanding of the contributory role of environmental factors, the clinician is in a very favorable position to develop and implement treatment plans that target essential elements. For example, a child such as Phillip with significant organizational deficits would benefit from a targeted approach that facilitates his learning through the use of metacognitive strategies and problem-solving routines (Ylvisaker, 1998). This would include teaching specific organizational techniques directly to Phillip, modeling the use of these strategies by important people in his world (e.g., parents, teacher, peers), as well as providing the necessary environmental opportunities for the development of these executive routines in frequent and varied real-world, everyday situations and contexts. Assessment of executive functions thus extends the psychologist's understanding and provision of interventions for children with neurocognitive and learning difficulties.

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Table 1. Behavioral Definitions for Executive Function Subdomains

Subdomain	Definition	Expression of dysfunction
Initiate	Beginning a task or activity	Has trouble getting started on homework or chores
Sustain	Staying with or sticking to an activity for an age-appropriate amount of time	Has trouble completing tasks, switches from one activity to another
Inhibit	The ability to not act on an impulse or appropriately stop one's own activity at the proper time	Has troubles "putting the brakes" on her behavior, acts without thinking
Shift	Freely moving from one situation, activity, or aspect of a problem to another as the situation demands	Gets stuck on a topic or tends to perseverate
Plan	Anticipating future events, setting goals, and developing appropriate steps ahead of time to carry out an associated task or action	Starts assignments at the last minute, does not think ahead about possible problems
Organize	Establishing or maintaining order in an activity or place; carrying out a task in a systematic manner	Scattered, disorganized approach to solving a problem, easily overwhelmed by large tasks or assignments
Self-monitor	Checking on one's own actions during, or shortly after finishing, the task/ activity to assure appropriate attainment of goal	Does not check work for mistakes, unaware of her own behavior and its impact on others
Emotional Control	Modulating/ controlling one's own emotional response appropriate to the situation or stressor	Is too easily upset, small events trigger big emotional response, explosive
Working Memory	The process of holding information in mind for the purpose of completing a specific and related task	Has trouble remembering things, even for a few minutes; when sent to get something, forgets what he/she is supposed to get

Table 3. BRIEF Subdomains and Sample Items

Subdomain	**Sample Items**
INITIATE	Is not a self-starter Has trouble getting started on homework or chores Lies around the house a lot (couch potato)
SUSTAIN	Does not finish long-term projects Has trouble finishing tasks (chores, homework) Cannot stay on the same topic when talking
SHIFT	Does same thing over and over for no apparent reason Resists change of routine, foods, places Gets stuck on one topic or activity
ORGANIZATION	Does not bring home homework, assignment sheets, materials, etc. Backpack is disorganized Becomes overwhelmed by large assignments
PLANNING	Sets unrealistic goals Underestimates time needed to finish tasks Does not plan ahead for school assignments
WORKING MEMORY	Has trouble with chores or tasks that have more than one step When sent to get something, forgets what he/she is supposed to get Has trouble remembering things, even for a few minutes
SELF-MONITOR	Does not check work for mistakes Is unaware of how his/her behavior affects or bothers others Leaves work incomplete
EMOTIONAL CONTROL	Overreacts to small problems Has explosive, angry outbursts Angry or tearful outbursts are intense but end suddenly

Table 4. Observational procedures for assessing executive functions during task performance

Before beginning a task

1. Self-awareness of ability: Ask the child whether the task will be easy or difficult and to explain the choice of answer. If relevant, ask for a prediction of performance.
2. Goal-setting, strategic behavior: Ask the child what their goal is and to explain plans for achieving his or her goal.

During the task

1. Initiation: If appropriate, create opportunities for initiation (e.g., insufficient materials, requiring the child to initiate a request).
2. Inhibition: If appropriate, create some distractions that would require active inhibition from the child.
3. Sustain: Observe the length of time that the child persists on the task, ones that are well within their abilities and ones that are more difficult.
4. Self-monitoring: Ask the child how he or she is doing.
5. Strategic behavior/ Problem-solving: If appropriate, create obstacles that would require active, flexible problem-solving from the child.

After completion of the task

1. Self-evaluation: Ask the child how he or she did and how the results compare to their prediction.
2. Strategic behavior and problem-solving: Ask what the child did to succeed; list relevant strategic procedures; ask the child whether he or she used them or whether they might be useful.

Table 2. Representative tests and subdomains of executive function

Executive Subdomains	Measure	Publisher/ Reference	Age Range	Description	Psychometric Properties	Comments
Initiate; (Shift, Self-Monitor)	Verbal Fluency (e.g. FAS; Category Fluency)	Unpublished Gaddes & Crockett, 1975	6-13	Rapidly generate words based on letter/ category cue	Interscorer reliability=excellent test-retest reliability=.70-.88 Validity considered moderate to Good	This measure has been useful in studying ADHD and Tourette Syndrome
Initiate; (Shift, Self Monitor)	Five Point Test	PAR	6-adult	Rapidly generate different designs	test/retest=.36-.76	
Sustain; Inhibit	Test of Variables of Attention	Universal Attentional Disorders	4.-adult	11.5; 21.6 minute continuous performance measure	Studies suggest good at discriminating children with ADHD from normal subjects. Adequate test-retest reliability.	Multiple performance scores allow assessment of several subdomains of executive function.- min. practice effects
Sustain; Inhibit	Gordon Diagnostic System	Gordon (1983)	4-adult	vigilance, delay/inhibit subtests		good normative sample and research base; shorter task length makes utility with adolescents questionable.
Sustain; Working Memory	Children's Paced Auditory Serial Addition Test (CHIPASAT)	Johnson et al., 1988; Dyche & Johnson, 1991	8-15	serial addition task	Split-half reliabilty good, signifiant practice effects, moderately correlated to other attention tests	Intact math calculation skills required.
Inhibit (strategic search)	Matching Familiar Figures Test	Welsh, Pennington & Grossier (1991)	7-12	matching target figures from group of nearly identical stim	Internal consistency: response time=.89; errors=.62	Limited sample of normal children;
Inhibit; Shift	Stroop Test	Stoelting Co.	8-adult	requires inhibiting and shifting from automatic perceptual set to novel set	test/retest=.75-.90 significant practice effects	quick and easy to administer measure (5minutes).
Shift; (Inhibit/Sustain) Hypothesis Testing	Wisconsin Card Sorting Test	Psychological Assessment Resources	6.5-adult	Matching cards to stimulus features which change; Constant feedback provided by examiner	inter/intra scorer reliability =excellent practice effects skew test/retest results	Good measure of problem solving flexibility and a child's ability to benefit from feedback from their environment.
Shift/Sustain	Trail Making Test	Halstead Neuropsych. Laboratory	9-15; 15-adult	maintain an alternating number/letter sequence	Interrater reliability=.90-.94 significant practice effects	questionable discriminatory power with children; confound with automatic knowledge of letter and number sequences

Executive Subdomains	Measure	Publisher/ Reference	Age Range	Description	Psychometric Properties	Comments
Shift	Contingency Naming Test	Taylor (1989)	6-16 yrs	Naming of colored shapes according to rules and mental set shifting	Norms based on control subjects in research projects: factor analysis loads on EF factor; Test distinguishes between normal and children with early brain insults. Predicts achievement &attention	Various clinical populations studied including ALL, meningitis, TBI, low birth wt.
Concept Formation; Hypothesis Testing	Category Test	Reitan Neuropsych. Laboratory	5-8 9-14 15-adult	Deduction of principles utilizing feedback	Split-half reliability=good test-retest relaibility=variable	Long-standing history of use with neurologic disorders; tends to be related as much to global dsyfunction as with EF
Organize; Plan	Rey Osterrieth Complex Figure (ROCF)	Psychological Assessment Resources Holmes Bernstein & Weber (1998)	5-14	Drawing/copy and recall of complex visual figure	newest scoring criteria interater reliability =.87-.95; test-retest not calculated. Good discrimination between clinical and normal samples	This task has a detailed , but excellent scoring system that allows for qualitative and quantitative interpretation. Excellent measure of how children aproach and solve complex novel problems.
Organize (inhibit; sustain)	California Verbal Learning Test-Children's Version (CVLT-C)	The Psychological Corporation	5-16	Recall and storage of repeatedly presented verbal list with organizational demands	Moderate to high internal consistency; practice effects result in questionable test/retest reliability	good measure of strategic information processing; provides indices that examine organizational components of verbal learning.
Plan;(Inhibit;Working Memory)	Tower of Hanoi	Welsh et al. (1991)	3-12	Disc transfer task requiring systematic planning of sequence of steps to to reach goal state.	Interrater reliability = good Practice effects evident	limited normal sample; has been used in a number of clinical studies including PKU, LD, ADHD
Plan;(Inhibit;Working Memory)	Tower of London	Krikorian et al. (1994)	6-adult	Same as above except discreet number of moves required	Moderately correlated with other measures of executive functions.	larger normative sample
Initiate; Sustain; Inhibit; Shift; Organize; Plan; Emotional control; Self-Monitor; Working Memory	Behavioral Rating Inventory of Executive Function (BRIEF)	Gioia et al., (in press); Isquith et al. (1999)	5-18	Parent & teacher report-behavioral checklist.	Good discriminatory power between clinical and initial normal samples	Focus on behavioral manifestation of executive function; good companion to performance-based tests

Executive Subdomains	**Measure**	**Publisher/ Reference**	**Age Range**	**Description**	**Psychometric Properties**	**Comments**
Initiate; Sustain; Inhibit; Shift; Hypothesis Testing; Plan; Organize	Delis-Kaplan Executive Function Scale (D-KEFS)	The Psychological Corporation	8-15 16-adult	Renorming of 10 existing tests within single battery across a wide age span	Large, national normative study underway	Consists of a variety of subtests similar to those described above, many with additional process-oriented variables, including: a Trail Making Test; Verbal Learning Test; Design Fluency; Stroop Test; Tower test; Sorting Test; Verbal Fluency; Twenty Questions; Word Context; Proverb Test.
Plan; Inhibit; Sustain; Initiate; Shift	NEPSY Attention/ Executive Domain	The Psychological Corporation	3-12	6 subtests within general battery	Nationally stratified normative base Moderate to high reliability	Based on Luria's model; child-friendly tasks; first attempt to assess at preschool ages