Executive Functions in Developmental Disabilities

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I. Definition of Executive Functions.

Executive functions are the control functions of the brain. They enable humans to learn, adapt to our environment and live a successful and productive life. They are critical for success socially, academically and vocationally.

In many ways, the brain's executive functions are like an executive in a large business. They include setting short and long-term goals, selecting strategies to reach those goals, initiating and organizing activities as directed by these strategies, and monitoring the results of these activities in order to ensure that the initial goals are reached. Executive functions are *not* the same as cognitive skills and abilities, such as language and perceptual abilities. Rather, they allow an individual to successfully coordinate and apply their cognitive abilities, skills and knowledge in pursuit of a goal. Another helpful analogy might be to consider how a symphony orchestra functions (Goldberg, 2001). Without the conductor to coordinate and direct the musicians, the result would more likely be cacophony than beautiful music. The musicians in the orchestra can be compared to the various cognitive abilities and skills an individual has; while the conductor represents the way the executive functions coordinate and organize the various components to produce a desired result.

Executive functions are composed of a variety of component functions, as different authorities and researchers have proposed. Some executive functions that have been suggested include: the ability to formulate goals and generate plans and strategies, the ability to recognize when a problem exists, the ability to organize one's behavior, the ability to select effective as well as efficient strategies, and the ability to monitor or observe one's performance or behavior and to make changes as necessary. Control of attention is also an executive function. This includes focusing attention on important or relevant stimuli and information, maintaining attention over time, and shifting attention to other relevant stimuli when necessary. One prominent psychologist in the field of Attention Deficit Hyperactivity Disorder (ADHD), Dr. Russell Barkley (1997), has suggested that there are four key executive functions that are impaired in individuals with ADHD: the ability to mentally consider and manipulate information, whether verbal or non-verbal (referred to as Working Memory), the ability to regulate one's emotional responses, the ability to use inner-directed speech to control or regulate behavior, and the ability to re-organize information and behavioral responses in unique ways. Regardless of the ways in which executive functions are broken down, their primary function is one of controlling and regulating your behavior.

II. Importance of Executive Functions.

Executive functions are important in a wide range of activities important for everyday living. They allow humans to stop and think before they act, unlike many animals who respond more instinctually and automatically to events. They provide a buffer or *workspace* (i.e., *working memory*) for the individual to consider current information, plans, and needs, along with prior knowledge about the world, in order to more carefully select a specific course of action. Barkley considers the ability to *inhibit* automatic or impulsive reactions to situations and events an essential aspect of executive functioning that allows for further thought before action occurs.

Examples of executive functions at work in the course of an average day might include thinking about your day when you arise, preparing yourself appropriately for the day (e.g., dressing for work or school versus for the weekend), reviewing your schedule and making plans in anticipation of certain

activities and events. Executive functions are also thought to be important in social interactions, where there is an ongoing assessment of the situation and people with whom you are interacting. Possible responses and actions are mentally reviewed and assessed based on prior experience, in order to select the best one. The activity of executive functions is an ongoing process. There appears to be an inter-relationship between executive functions and conscious awareness.

Executive functions are also particularly important in *learning*. Academic learning is an active process, which involves attention, organization, and application of effective learning strategies. As will be discussed below, disorders of learning, as well as social functioning, often appear to involve deficits in executive functioning.

III. Development of Executive Functions.

Compared to the development of language, motor and perceptual skills, which approach the adult level much more rapidly, executive functions continue to develop over a prolonged period. Some forms of self-regulation begin to appear within the first year of life, such as the ability to self-soothe (Kopp, 1982). However, the frontal lobe of the brain, and the executive functions associated with frontal lobe, continue to develop into late adolescence or early adulthood (Diamond, 2002). Research has only recently begun to explore the course of development of executive functions. This has been complicated by the fact that there is no universal agreement on how to parse or measure the components of executive functions. Nevertheless, research has begun to suggest that different components of executive functioning may develop and mature at different times.

A number of studies have found evidence of at least 3 major stages of development of executive functions, occurring about age 6, age 10, and at adolescence (Welsh, et al., 1982). It is interesting to note that these ages generally correspond with the beginning of formal academic instruction (1st grade), the introduction of multiple instructors, changing schedules, and greater expectations for independent performance (middle school), and even greater demands for complex planning, organization and performance (high school). The fact that executive functions do not completely mature (if at all) until the late teens or early twenties is implicit in society's concept of the "teenager" as a still immature person, who is inconsistent in terms of planning and judgement.

We know that the brain appears in some ways to be "preprogrammed" to develop language and other cognitive skills, but that the specific course of development is influenced by one's environment and experience. The extended developmental period of executive functions suggests that experience and learning play a significant role in their development as well. In particular, your social interactions and home and school environment may have a major influence on the course of development of executive functions. Although this is as yet an understudied area of investigation, the implication is that there may be opportunities to optimize the development of executive functions or intervene when there are weaknesses.

IV. Executive Functions and the Brain.

A great deal of what we know about executive functions comes from the study of the brain (neuroscience and neuropsychology). In particular, research on the functions of the frontal cortex of the brain has contributed to our understanding of executive functions. The large outer, convoluted layer of the brain is called the *neocortex*. The neocortex is comprised of a number of areas, or lobes, including the occipital, parietal, temporal and frontal lobes. The frontal lobe, or frontal cortex, is located toward the front of the brain, behind our eyes and forehead. Although other mammals have frontal lobes, the amount of brain dedicated to the frontal lobe is greatest in human beings. For example, the frontal lobes comprise approximately 29% of the cortex in humans, 17% in chimpanzees, and only 3.5% in cats (Goldberg,

2001). The front portion of the frontal lobe, called the *prefrontal cortex*, is the part of the brain that has been most associated with executive functions. From an evolutionary perspective, it is the most recent part of the brain to develop.

Early neuropsychological studies of the prefrontal cortex were conducted in humans with specific brain damage, with many conflicting and confusing results. Over time, a general idea began to emerge that this part of the brain was crucial in the regulation or control of behavior. The neuroanatomy of the prefrontal lobe was consistent with this, as it has strong connections bilaterally (in both directions) between: a) the rest of the neocortex, which processes information from the outside world, and may be where memories are stored; b) the limbic system, which processes information, such as current needs, drives and motivations, from the inner self; and c) the motor control area of the cortex, responsible for the initiation and control of conscious behavior. Thus, the prefrontal cortex receives information concerning current drives and motivations, the world around us, and our prior knowledge of similar situations, in order to select a specific plan of action or behavior. The prefrontal cortex is seen by some as a *buffer* between data input and behavior output. Rather than rely on built-in instinctual responses to stimuli, humans can pause and reflect before they act. This allows for much greater flexibility of responding, as well as the incorporation of previously learned information about a situation.

More recently, researchers have been able to use non-intrusive brain imaging techniques, such as functional Magnetic Resonance Imagery (fMRI), to determine what parts of the brain are working during certain activities and tasks. A number of researchers have discovered that the prefrontal cortex plays an important role in the initial learning and subsequent retrieval of new information (e.g., Fletcher, et al, 1998a & b). In addition to studies on humans, animal studies have also contributed to our understanding of the prefrontal cortex and executive functions. For instance, research points to the prefrontal cortex as an area of the brain where new information about internal drives and external stimuli are constantly being updated in order to direct behavior. This is also referred to as *working memory* (Goldman-Rakic, 1992).

V. Executive Functions and Developmental Disorders.

Recent studies have suggested that impaired executive functions are present in a number of developmental disorders. For example, impaired executive functions have been found in studies of individuals with pervasive developmental disorders, such as autism and Asperger's syndrome, with Attention Deficit Hyperactivity Disorder (ADHD), with learning disabilities, and with certain genetic developmental disorders, such as fragile x and mental retardation (Pennington & Ozonoff, 1996; Hughes, 2002; Skoff, 1988).

While this article is focusing on the executive deficits that are in common in a variety of developmental disorders, it is important to note that these disorders differ significantly in terms of their defining impairments, their effects on an individual's life, and their prognosis. In other words, although executive deficits have been found to be associated with all these disorders, they are not necessarily the most significant or diagnostically important deficits. For example, the autism spectrum disorders are largely defined and characterized by their social deficits, as well as other cognitive impairments; while learning disorders, by definition, are characterized by their effects on academic achievement. Nevertheless, it is increasingly apparent that a widely disparate group of developmental disorders all include at least some impairments of executive functioning. The *type* and *degree* of executive impairments in these disorders, however, are often different, although at present there is no consensus as to the specific profile of executive deficits in each disorder. A few of these will be discussed in more detail below, with a particular emphasis on ADHD and school problems.

Executive Functions in Developmental Disabilities

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ADHD:

Perhaps the best studied, and possibly the "purest" in terms of being an executive function disorder, is ADHD. A number of neuropsychological studies of children, adolescents and adults diagnosed with ADHD have found impaired executive functions (e.g., Grodzinsky, et al., 1992; Seidman, et al., 1997). In fact, the "core" deficits in ADHD that define the disorder include problems with inhibition, attention and organization, control skills which are commonly included in most descriptions of executive functions. Studies have found that children with ADHD have deficits in their ability to inhibit a preprogrammed or automatic response (Roberts & Pennington, 1996). Other researchers have implicated problems with working memory and regulation of affect (Barkley, 1997). Barkley states that individuals with ADHD are "less regulated and governed by internally represented information..., more controlled by the moment, ... and their behavior will be less directed at maximizing the future and more directed at maximizing the moment." As a result, their behavior "is more regulated by the immediate context and less by themselves...."

Support for ADHD as primarily an impairment of executive functions also comes from brain imaging studies of individuals with ADHD. A number of studies have now found significant differences in the functioning of the frontal cortex of individuals with ADHD (Zametkin, 1990). The implication is that the efficiency of the prefrontal cortex is compromised in individuals with ADHD, thus affecting their ability to self-regulate or their executive functioning.

The current diagnostic categories for ADHD include two subtypes: predominantly Inattentive type (ADHD/I) and predominantly Hyperactive-Impulsive type (ADHD/H), as well as a combined type (ADHD/C). Criteria for the Inattentive type fall into three main areas: problems with attention, organization and memory. Criteria for the Hyperactive type stress problems with behavioral regulation (motor hyperactivity or restlessness and impulsivity). A comparison of these areas of deficits in ADHD with the definition and components of executive functioning reveals the similarity between the two. Although there have been few studies looking at executive impairments in the different subtypes, one would expect that individuals with ADHD/I, given their problems with control of attention, organization and control of memory, should primarily be expected to have difficulties with academic learning and performance. Studies have in fact indicated that individuals with this subtype are mostly at risk for school problems (DuPaul & Stoner, 2003). In contrast, individuals with the Hyperactive subtype, by definition, have problems with behavioral inhibition, and should thus be at-risk primarily for behavior problems. Studies have found a high rate of co-morbid behavior disorders in children diagnosed with ADHD/H (Barkely, 1997).

School Difficulties:

Certain specific learning disabilities have been shown to be the result of specific disorders of processing. The most studied is probably the role of impaired phonological processing in specific reading disability or dyslexia. There is also, however, a growing body of research that points to the importance of executive functions in academic learning and performance and the role of executive deficits in different school problems. While some researchers have focused on the *performance* or *output* problems that result from executive deficits, there is also some evidence that executive deficits can interfere with learning. This makes sense looking again at the three general impairments reflected in the criteria for diagnosing ADHD/I: problems with attention, organization and memory. Models of human learning all include a major role for attention; if information is not attended to, it will not be "encoded" or learned. Furthermore, it has become clear that learning is an active process, which involves making connections between new information and prior knowledge and organizing this information in a useful way. Students

who have trouble making such connections and organizing information can be expected to have difficulties with academic learning.

Research bears out the fact that children with ADHD/I often tend to have school difficulties. DuPaul & Stoner (2003) point out that "up to 80% of children with this disorder (i.e., ADHD) have been found to exhibit learning and/or achievement problems." Furthermore, the few studies that have addressed the relationship between ADHD and learning problems have suggested that it is the attention deficits that influence academic achievement rather than the converse (cited in DuPaul & Stoner, 2003).

More recently, the role that specific executive functions and their deficits might play in school difficulties has been explored. A large scale study in England of students attending private schools found that students with low levels of achievement performed poorly on tests of working memory, especially central executive measures (Gathercole & Pickering, 2000). The importance of working memory in learning, and the consequent learning deficits associated with impaired working memory, has also been confirmed by other studies. Studies of specific learning disabilities have also found working memory deficits in students with reading disabilities (Swanson & Sachse-Lee, 2001), math disabilities (Geary, 2004) and written language disabilities (Kellogg, 2001).

Many students with executive deficits have the most trouble in terms of school performance. Depending on their overall cognitive strengths and weaknesses, they may have acquired many academic skills and knowledge, but have trouble accessing, coordinating or applying them in a consistent manner. Individuals with executive deficits often have trouble "remembering to remember;" that is, they do not always search their memory when they need to for an answer. This may also take the form of poor planning, resulting in the student who "remembers" a big assignment the day before it is due. Executive functions are involved in the coordination of abilities, and students with executive deficits can also be expected to have trouble with more complex tasks that involve the integration of many skills. This is often most apparent in terms of written language deficits. Finally, students with executive deficits can be amazingly inconsistent in their performance, and can do well one instant while failing the next on the same subject. This is of course often baffling to parents and teachers, who often mislabel such inconsistency as a motivation problem. By their nature, however, executive deficits are not all-or-none, but are typically inconsistent in their manifestation.

Autism:

Numerous studies have also found executive deficits in individuals with autism (Pennington & Ozonoff, 1996). Some studies suggest that the patterns of deficits are different than those found in individuals with ADHD. For example, one study found that, unlike children with ADHD, autistic children did not have significantly worse problems on a behavioral inhibition task than IQ matched controls (cited in Roberts & Pennington, 1996). Another found verbal working memory deficits in children with autism, but not in children with ADHD (Siegel & Ryan, 1989).

Other studies have suggested that problems with mental flexibility differentiate autistic individuals from normally developed individuals and individuals with ADHD (Pennington & Ozonoff, 1996; Hughes, 2002). Mental flexibility is thought to be critical for the development of a "theory of mind", which refers to the ability of most people to put themselves in another's place and understand how they feel or think about something. Research has indicated that individuals with autism do not develop this ability to the same extent as their peers, and that this in turn has a significant effect on their social interactions (Baron-Cohen, 1995). Although there continues to be disagreement as to the nature of the specific profile of executive deficits in different developmental disorders, there is increasing consensus on the commonality of executive deficits in such disorders.

Developmental disorders as distinct as ADHD, autism or school difficulties clearly vary in significant ways. At the same time, they are all associated with executive deficits. Developmental disorders differ in terms of their defining characteristics, which likely reflect damage or dysfunctions in different brain systems due to a variety of different etiologies. As noted above, they also appear to differ in terms of their different profiles (type and degree) of executive deficits. These differing executive profiles may correspond to the different etiologies of the disorders, which may be genetic, environmental, structural or biochemical. Just as the different etiologies produce different developmental disorders, they may differentially affect prefrontal cortex or prefrontal systems in the brain, resulting in different types and degrees of executive deficits.

The question arises as to whether there is such a thing as a "pure" executive function disorder; that is, a disorder that primarily or exclusively manifests in terms of executive dysfunction without associated non-executive deficits. While ADHD is probably the closest disorder that meets these criteria, it is not synonymous with executive dysfunction. ADHD is defined and diagnosed behaviorally, not by way of neuropsychological assessment of executive functions. Individuals with ADHD have executive deficits by definition, if not in testing, since the criteria include either behavioral dysregulation or attention and organizational deficits. On the other hand, there appear to be many individuals who exhibit executive deficits (without any other significant deficits) who nevertheless do not meet behavioral criteria for diagnosing ADHD. While this may sometimes reflect the subjectivity of diagnosing a disorder using behavioral reports, which can be unreliable and/or biased, it may also reflect a narrower focus in defining and diagnosing ADHD. Currently, there is no formal diagnostic code for so-called "Executive Function Disorder."

VI. Individual Differences & Executive Deficits.

Even within a diagnostic category, such as ADHD, there is clearly considerable variability in the presentation of the disorder in different individuals, which has contributed to difficulty in diagnosis. There are likely a number of factors involved in this variability. First, as discussed above, there is often a different *profile* of executive strengths and weaknesses, as well as different *degrees* of dysfunction. This is so not only in different disorders but, to some extent, even within a disorder. As discussed above, the two subtypes of ADHD may represent two distinct patterns of executive dysfunction. Second, by their nature executive deficits will manifest differently in different individuals, since they are deficits of *self-regulation*. Since executive functions act by moderating or regulating cognitive and emotional functions, executive deficits will reflect individual differences in cognitive ability and personality.

When an individual has very strong cognitive skills in a certain area, executive functions may play less of a role. For example, if a person has strong visual-spatial abilities, many visual-spatial tasks will depend less on planning and organization than they would for an individual with average or impaired visual-spatial skills. Executive weaknesses may be harder to demonstrate on visual-spatial tasks for such an individual. In contrast, if visual-spatial skills are weak, the individual may rely more on planning, organization and other executive abilities, and executive deficits may have more significant impact on the person's functioning on such tasks.

VII. Why executive deficits are so common.

As increasing evidence points toward the frequency of executive deficits in so many different developmental disorders, the question arises: why are executive deficits so common? There are a number of likely answers. First, the nature and extent of anatomical inter-connectivity of the prefrontal cortex with the rest of the brain increases the likelihood that whenever there is an insult or disruption in the brain, the functioning of the prefrontal cortex will be affected. The prefrontal cortex is the most

interconnected part of the brain, with neurons coming from, and going to, most other areas in the brain. When any part of the brain is adversely affected (structurally or neurochemically), it is likely that this will also impact the functioning of the prefrontal cortex in some way. In other words, there does not have to be specific damage or malfunctioning of the prefrontal cortex for executive deficits to occur; such deficits are possible whenever any part of the brain that functionally interacts with the prefrontal cortex is damaged or disrupted. This likely explains why executive deficits (including problems with attention and memory) commonly result from closed head injuries (Levine, Eisenberg, & Benson, 1989). It also explains the fact that executive deficits are commonly seen as a result of disorders with presumably very distinct etiologies, such as acquired (lead poisoning) or genetic (fragile x) disorders (Roberts & Pennington, 1996).

In addition to its neuroanatomical inter-connectivity, the fact that the frontal lobes undergo the lengthiest period of development of any part of the brain also contributes to their susceptibility. As discussed above, the frontal lobes continue to develop through adolescence and into early adulthood, while most other areas of the brain are either pretty well developed at birth (those sub-cortical systems necessary for life) or develop fairly rapidly within the first few years of life (those cortical systems responsible for language, perception and motor output). This means that there is a more extensive period when development of prefrontal systems (and thus executive functions) can be interrupted or impaired. The developmental "window", so to speak, is open longer for prefrontal cortex and executive functions, thus increasing the likelihood that any developmental interruption will affect its development.

Finally, the fact that prefrontal cortex is the most recent part of the brain to develop on the evolutionary scene may also contribute to its vulnerability. There tends to be very little variability in those parts of the brain (and their corresponding functions) that evolved long before the prefrontal cortex. For life-sustaining systems of the brain, any variability typically results in non-viability. Even when other areas of the neocortex are considered, there tends to be much less variability in functioning, although there are disorders which can compromise sensory, perceptual, and motor functions. But the greatest amount of variability is present in the executive functions of the frontal lobe. This includes both normal variability, which likely explains many individual differences in intelligence and everyday functioning, as well as more extreme variability, as presented in a number of developmental disorders.

VIII. Basic principles of interventions for executive deficits.

There are many books and articles that discuss interventions for the behavioral, academic and social difficulties that are the result of executive deficits. Most such books or articles focus on a specified problem (e.g., temper tantrums, homework problems, etc.) or more often on specific disorders, such as ADHD, LD or autism. One can, however, extract some basic principles from these materials that apply to executive deficits in general. Interventions for executive deficits are generally two-pronged: 1) focusing on the environment in which the individual with deficits acts, and 2) focusing on improving the executive functioning of the individual (see Dawson & Guare, 2004 for detailed recommendations for addressing and improving executive deficits).

Environmental modifications, in the broad sense that includes principles of behavior management, are often the first way of dealing with executive deficits. Recall that the prefrontal cortex acts as a sort of "buffer" between the world and an individual's response to the world. Animals with less evolved prefrontal systems tend to rely more on instinctual or built-in responses. In humans, prefrontal cortex allows one to stop and assess a situation before responding, and to plan a specific response based on prior knowledge. Individuals with executive deficits, however, often tend to respond more automatically to a situation, without "stopping to think." The balance between their self-control and the ability of the environment to control their behavior often tips in favor of the environment. This means that

the environment, including the people one interacts with in the environment, plays more of a role in determining the behavior of individuals with executive deficits. This is the rationale for intervening at the level of the environment with such individuals. It may mean devising a behavior modification program, including attending to salient environmental cues or triggers of certain behaviors. In other situations, it may mean providing a child with additional external supports and modifications to help them compensate for their executive deficits.

The second general approach to dealing with executive deficits focuses on the individual, with the goal of helping him or her learn ways to develop their executive functions or to compensate for their deficits. It is important to keep in mind that the prefrontal cortex continues to develop throughout adolescence even into early adulthood. This extended development suggests that there is a much wider window of opportunity to actively intercede and direct the development of executive functions. Clearly adolescents undergo significant development in terms of their executive and self-regulatory skills throughout the teen years. There is currently little research that looks at the ability to remediate executive function skills in individuals with deficits. It is likely that the degree of success of such interventions may depend of the specific nature and etiology of the deficits. However, even if it proves difficult to remediate these deficits, it may be possible to teach individuals compensatory strategies. In other words, a disorganized student with ADHD may never become the most organized person on their own, but may be able to learn specific organizational skills over time. Such skills are probably better thought of as "habits," which develop only after an extended period of time in which the habit is taught and monitored.

IX. Conclusions

It is becoming increasingly clear that understanding the brain's executive functions is critical to understand many aspects of brain functioning. Though much research remains to be done, the importance of executive functions in everyday life, in learning, and in social interactions has already been established. It is also becoming apparent that executive deficits play an important role in many developmental disorders. We need to continue to explore ways to remediate, improve, or compensate for executive deficits. It is important to keep in mind that the prefrontal cortex continues to develop throughout adolescence and into early adulthood. This extended development suggests that there is a much wider window of opportunity to actively intercede and direct the development of executive functions.

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