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# Prefrontal Executive Function Syndromes in Children

Kristin B. Powell, PhD; Kytja K. S. Voeller, MD

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## ABSTRACT

“Executive function” is a term describing the processes required for conscious control of thought, emotion, and action that are central to the management of one’s day-to-day life. Executive function is subserved by the prefrontal cortex and related subcortical structures. Disorders affecting the prefrontal cortex–subcortical system are numerous and heterogeneous, but contemporary research has begun to elucidate the mechanisms and consequences of dysfunction in various subsystems with increasing specificity. Prefrontal executive dysfunction results in impaired regulation of cognition, attention, behaviors, arousal, and emotion, all of which have serious and pervasive consequences for functioning across the life span. These executive function deficits are typically difficult to treat, ameliorate, or remediate and require sensitive handling by caretakers. Executive dysfunction can arise as a consequence of many different factors (metabolic, genetic, certain types of epilepsy, cerebral dysgenesis, prematurity, traumatic brain injury, hypoxia, and toxic exposure). The present review delineates the features of prefrontal executive function deficits in children and proposes a roadmap for their diagnosis, treatment, and management. (*J Child Neurol* 2004;19:785–797).

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## PREFRONTAL CORTEX AND HUMAN BEHAVIOR

The last several decades have seen an astounding proliferation of research into the role of the prefrontal cortex in human behavior. These investigations range from genetics, neurophysiology, and pharmacology to detailed behavioral and neuropsychologic case studies in adults and children. This article briefly reviews some of the relevant neuroanatomy of the prefrontal cortex and then focuses on behaviors in children resulting from prefrontal dysfunction and the problems that they pose for parents and teachers. It concludes with suggestions relating to management.

“Executive functions” refer to the “command and control” functions of the prefrontal cortex. Information about the external environment is delivered to the prefrontal cortex from all sensory modalities, arriving in a “preprocessed” state, that is, it has already

undergone considerable analysis in other networks. For example, visual information has been processed within the computational networks of the primary visual cortex and related association cortices. The prefrontal cortex also receives information about one’s internal emotional and autonomic status, and all of these inputs are linked to relevant memories about past experience. The prefrontal cortex exerts “top-down” control on the information that is coming in, so that information that is relevant at the moment is attended to, whereas less important information remains in the background. All of these data are then integrated within the prefrontal cortex with short- and long-term goals and are used to regulate immediate behavior and plan behaviors in the future. Internal representations of “if-then” scenarios are developed. This results in inhibition of a behavior, which, although highly appealing at the moment, could have detrimental consequences (“If I throw that spitball at Suzy, I will get in trouble!” or, for an adult, “If I spend the night drinking and socializing, I will not function effectively tomorrow at work.”). Thus, the prefrontal cortex (in the role of the chief executive officer) plays a key role in human behavior and personality.<sup>1–3</sup> Moreover, as opposed to other neural regions and networks that process specific types of information (vision, smell, hearing) or link this information to other types of information (eg, linking visual information to object recognition or place), the prefrontal cortex processes contingencies and does this in a flexible manner that is appropriate to the situation rather than responding in a rigid or stereotyped manner (see Table 1 for a list of executive functions).

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**Table 1. Executive Functions: Subdomains of Self-Regulation**

Cognitive regulation
Working memory
Regulation of attention (includes detection, vigilance, control of distractibility, and shifting attention)
Planning
Goal setting and monitoring
Time estimation
Time management
Organizational strategies
Mental flexibility or ability to shift cognitive "set"
Fluency or efficiency of processing
Abstract reasoning and concept formation
Novel problem solving and judgment
Maintaining self-awareness and identity across time and place
Integration of social-emotional information into future plans and behaviors (includes sensitivity to the emotional and cognitive states of others)
Behavioral regulation
Initiation of movements or behaviors
Inhibition of automatic motor responses
Sustaining motor performance through time
Shifting motor response when appropriate
Ability to delay immediate gratification (impulse control)
Anticipation and sensitivity to future consequences of present actions
Emotional regulation
Modulation of emotional arousal
Modulation of mood
Self-soothing strategies

## PREFRONTAL CORTEX AND RELATED SUBCORTICAL AREAS

### Cortical Regions

The frontal lobe can be divided into three areas: premotor cortex, primary motor cortex, and prefrontal cortex. These regions are tightly connected to each other, to other cortical regions, and to subcortical structures, but each serves specific functions (see Figure 1 for a diagram of these brain regions). The prefrontal cortex is the latest brain structure to develop, both phylogenetically (in the species) and ontogenetically (in the individual).<sup>4,5</sup> Based on cytoarchitectonic characteristics and connectivity, the prefrontal cortex can be divided into three regions, each of which is part of a specific frontal-subcortical system. These are the dorsolateral circuit, the orbitofrontal circuit, and the anterior cingulate circuit (Figure 2). Related subcortical areas include the basal ganglia, thalamus, and cerebellum.

### Basal Ganglia and Thalamus

The basal ganglia consists of the caudate nucleus and putamen (collectively, the striatum), the globus pallidus, and the substantia nigra pars reticulata. The basal ganglia are phylogenetically old structures that emerged in reptiles and regulated many of the behaviors seen in these creatures, such as mating behaviors and displays of aggression and territoriality. They are rich in various excitatory and inhibitory neurotransmitters (glutamate, dopamine, serotonin, acetylcholine,  $\gamma$ -aminobutyric acid [GABA]). The thalamus is another subcortical gray-matter mass that integrates sensory input, motor behaviors, and emotional-cognitive information and relays this information to cortex. It plays an important role in maintaining arousal.

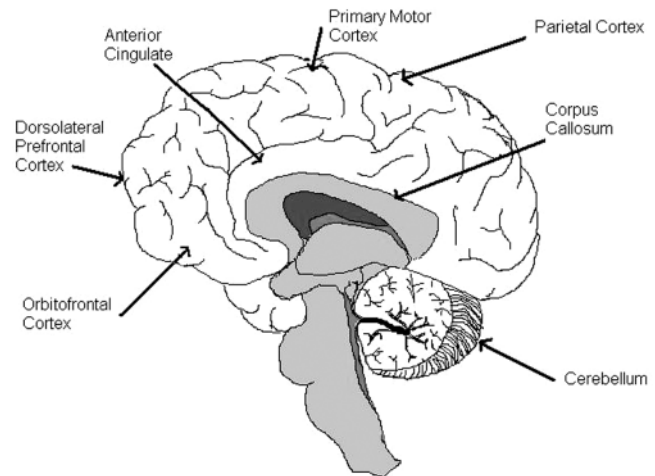


Figure 1. Diagram of prefrontal cortex and related structures.

The basal ganglia and thalamus are linked to specific cortical areas by a number of parallel corticostriathalamocortical circuits. The general structure of these circuits is portrayed in Figure 2. In simplified terms, the cortical neurons send excitatory (glutamatergic) inputs to a specific region of the dorsal striatum (caudate or putamen) or the ventral striatum (nucleus accumbens). The specific region of the striatum then projects to the globus pallidus/substantia nigra, which, in turn, projects to a specific nucleus of the thalamus. The thalamus then sends an excitatory glutamatergic projection back to the specific cortical region from which the circuit arose. Circuits that involve the ventral striatum process emotion, and autonomic responses are part of the limbic system, which refers to an interconnected neural system that integrates autonomic functions, emotion, and memory. These circuits follow the general pattern described above but involve the anterior cingulate, medial orbitofrontal cortices, amygdala, and hippocampus.

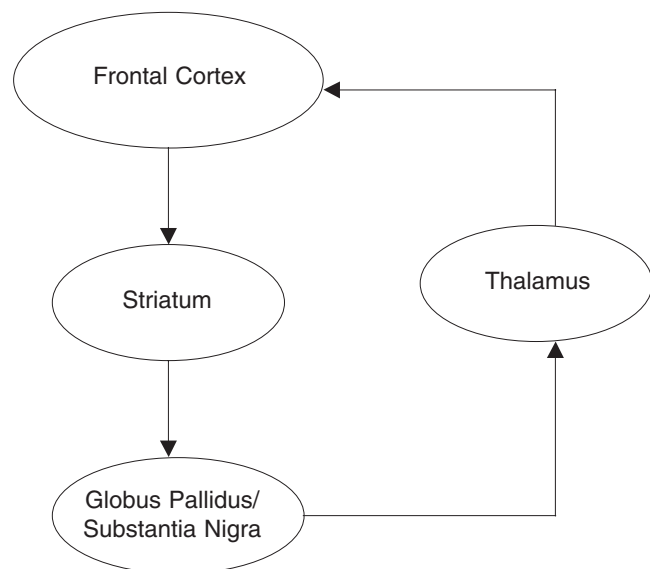


Figure 2. Schematic diagram of corticostriathalamocortical circuits.

The striatum, and other basal ganglia structures, serve to integrate the selection and execution of both motor and cognitive programs. These functions are subserved by a complex network of inhibitory and excitatory neurons that involve a multitude of neurotransmitters. At the cellular level, there are two compartments in the striatum: the matrix and the striosomes. The matrix receives input from the sensorimotor cortex and is involved in the regulation of motor behaviors; the striosomal compartment is predominantly innervated by the orbitofrontal cortex and is involved in the regulation of cognitive and emotional behaviors. Thus, one can see a disturbance of both motor behaviors and cognition/emotion resulting from dysfunction of the basal ganglia, as exemplified by the fragmented movements of Tourette syndrome, the repetitive thoughts of obsessive-compulsive disorder, and the slowed motor and cognitive processing seen in Parkinson's disease. Because the basal ganglia are closely linked to the cortex through the corticostriothalamocortical circuits, dysfunction in any segment of these circuits can result in much the same pattern of behavior as would be seen from a lesion affecting the cortex.<sup>5-7</sup>

### Cerebellum

The cerebellum, once viewed as primarily a motor control center, is now recognized as playing an important role in regulating such processes as language, visuospatial organization and memory, planning and sequencing, emotional response, and personality. The relationship of the cerebellum to executive function is supported by a great deal of converging evidence. Neuroanatomic studies reveal that the dorsolateral prefrontal cortex projects to the neocerebellum<sup>8,9</sup> and receives projections from the neocerebellum.<sup>9-11</sup> The cerebellum is anatomically organized for parallel processing and preserves modularity, as well as having connections to brain regions that process cognitive material.<sup>12</sup> Neuroimaging studies reveal that the cerebellum and the dorsolateral prefrontal cortex are activated at the same time during performance of a number of different types of cognitive tasks. Berman et al conducted a positron emission tomographic study of young adults while they were performing the Wisconsin Card Sorting Test and noted that there was activation not only of the dorsolateral prefrontal cortex but also of parietal-temporal visual association areas, as well as of the cerebellum.<sup>13</sup> Nagahama et al observed a similar pattern during performance of a modified card sorting task.<sup>14</sup> Diamond pointed out that both regions are activated under certain conditions, namely, when the task is difficult and/or novel, task conditions change, and quick response and concentration are required.<sup>15</sup> Tasks demanding working memory activate both the prefrontal cortex and the cerebellum. Schmahmann has suggested that cerebellar dysfunction results in a "dysmetria" of thought and emotional regulation, that is, either an over- or underresponding.<sup>16</sup>

Numerous studies have demonstrated that the cognitive deficits following damage to the cerebellum ("the cerebellar cognitive affective syndrome") bear a strong resemblance to the pattern of deficits following lesions to the prefrontal cortex and are dissociable from motor deficits.<sup>16-20</sup> The symptoms described include postsurgical mutism evolving into speech and language disorders and behavioral disturbances that range from irritability and attention deficit to autistic spectrum behaviors. Other classic "executive function" deficits are also common, including impairments in set shifting,

planning, verbal fluency, abstract reasoning, and working memory. Children who had lesions of the lateral cerebellar hemispheres manifested characteristic executive function deficits on the Wisconsin Card Sorting Test, whereas those with temporal lobe lesions did not.<sup>21</sup> In a group of children who had undergone surgical excision of cerebellar astrocytomas, memory deficits were noted in 100%, attention deficits in 83%, executive function deficits in 74%, and a broad spectrum of behavioral disorders in 48%, as well as dysregulation of affect. The same array of symptoms was not seen in every child, which led the authors to question the concept of a "syndrome."<sup>22</sup>

### FRONTAL-SUBCORTICAL CIRCUITS

Although there are a number of circuits linking other cortical areas to the basal ganglia and thalamus, here we will focus only on those playing a key role in prefrontal function. These circuits play an important part in executive functions, and lesions affecting other sites in these loops result in much the same pattern of behavior as would a lesion affecting the prefrontal cortex.

#### Dorsolateral Circuit

The dorsolateral prefrontal area, located in the upper and lateral aspects of the prefrontal cortex, receives connections from the parietal and temporal lobes, which convey information regarding location ("Where?"), information about objects and their meaning ("What?"), faces ("Who?"), and the emotional status of others ("What are they feeling?"). The dorsolateral prefrontal area plays a central role in the control, regulation, and integration of cognitive activities. It mediates attention and focus, controls distractibility, maintains focus of cognitive set as well as flexible shifts of cognitive set when required, and is involved in memory and generating fluent verbal or nonverbal activity. Thus, persons with damage to this system have difficulty paying attention to a task and being able to stick to a goal but at the same time can be rigid and perseverative. They might "forget to remember."

The dorsolateral area also plays an important role in working memory, which refers to the ability to hold information "on-line" or "in the mind's eye" to manipulate it for a few seconds (as in remembering a telephone number before dialing it, decoding words phonologically, keeping the first part of a long sentence in mind until one reaches the end, or performing mental calculations). Working memory helps guide behavior over time (as in keeping a goal in mind to inform choices).<sup>23-28</sup> Neurophysiologic studies have shown that neurons in this area exhibit sustained, elevated levels of firing when information is maintained in working memory.<sup>29</sup> The delayed response task is the classic task used in assessing working memory. In the spatial delayed response task, a desirable object is presented, which is then removed from sight (it might be hidden in one of several covered wells). After a delay of variable duration, the subject is expected to locate the object or perform a task that requires remembering where it was hidden. Successful performance on the delayed response task requires that the subject keep the relevant information in mind (ie, holding information in working memory) even though the item is not physically present. The dorsolateral prefrontal cortex encodes information related to the original stimulus, keeps it "in mind" during the delay ("maintenance"), manipulates it during the delay period in anticipation of the cue, scans memory

related to location, and then selects an appropriate response. The delayed response task can also involve a spot of light that disappears and the subject is expected to look at that location after a delay or holding specific words or numbers in mind during a delay. It is apparent that by increasing the delay period, increasing the number of items that must be encoded, and adding distractions, the delayed response task can be quite challenging. These different types of working memory tasks, some visual, some auditory, involve slightly different neural circuits and seem to be processed in somewhat different areas of the dorsolateral prefrontal cortex.<sup>30,31</sup>

### **Orbitofrontal Circuit**

The orbitofrontal cortex is located at the most anterior aspects of the frontal lobe and is considered a polymodal “convergence zone” that integrates diverse sources of information.<sup>32</sup> It is part of the limbic system and involves two subcircuits. The lateral orbitofrontal subcircuit projects to the ventromedial caudate, globus pallidus/substantia nigra pars reticulata, ventral anterior nucleus of the thalamus, and back to the medial orbitofrontal cortex. The medial orbital subcircuit follows a similar pathway but initially projects to the ventral striatum. This circuit integrates emotional and autonomic information and memories into behavioral programs. It is involved in the modulation of social behavior, including aspects of empathy, morality, self-monitoring, and social restraint. Compared with patients with lesions in other locations and normal controls, patients with medial orbitofrontal lesions are impaired in their ability to empathize with other people.<sup>33</sup> Damage to this circuit is likely to result in disinhibited, tactless, and impulsive behavior if not frank sociopathy. Simply put, patients with orbitofrontal lesions have difficulty understanding other people’s feelings and adhering to societal rules and fail to learn from previous experience.

One of the earliest illustrations of the effect of orbitofrontal damage on personality resulted from an accident involving Phineas Gage, a disciplined, hard-working foreman with excellent “people skills.” While building a railroad in rural Vermont, in 1848, an accidental detonation propelled a metal tamping rod through his skull. Surprisingly, he walked away from the accident and spoke coherently and survived with what appeared to be full recovery. However, in the months and years following his injury, those who knew him well came to realize that “Gage was no longer Gage.” Despite his seemingly complete recovery, he had been transformed from a highly respected member of his community into a disinhibited lout. Harlow, the physician who cared for Gage, noted the following:

His contractors, who regarded him as the most efficient and capable foreman in their employ previous to his injury, considered the change in his mind so marked that they could not give him his place again. The equilibrium or balance, so to speak, between his intellectual faculties and animal propensities, seems to have been destroyed. He is fitful, irreverent, indulging at times in the grossest profanity (which was not previously his custom), manifesting but little deference for his fellows, impatient of restraint or advice when it conflicts with his desires, at times pertinaciously obstinate, yet capricious and vacillating, devising many plans of future operation which are no sooner arranged than they are abandoned in turn for others appearing more feasible.<sup>34</sup>

Gage lost his “people skills” and was never able to hold a job for any length of time after his injury. At one point, he was examined by a professor of surgery at Harvard Medical School, who pronounced him fully recovered. Contemporary reconstructions of the trajectory that the tamping iron took through his brain traced its path through the orbitofrontal cortex.<sup>35</sup> As a result, Phineas Gage has become the most famous case history in neurology, serving as a classic example of the effect of damage to the orbitofrontal cortex. His skull and the tamping iron that caused the injury remain on display at Harvard Medical School.

In contrast to the dorsolateral area, where one can often see atypical performance on certain neuropsychologic tests, patients with lesions in the orbitofrontal region often look completely normal on all of the available forms of neuropsychologic assessment but have dramatic changes in personality, emotions, and psychosocial functioning.<sup>36,37</sup> Damasio and colleagues developed a gambling task to study this insensitivity to feedback and to the possible future consequences of a given behavior. The task uses uncertainties in premises and outcomes, as well as reward and punishment, to simulate real-life conditions.<sup>37–39</sup> Patients with orbitofrontal lesions ignore feedback about risk and pursue short-term rewards much more aggressively than controls, not manifesting the autonomic arousal that alerts normal controls to the risk of impending disaster. Damasio and colleagues put forth the “somatic marker hypothesis”: the orbitofrontal area contributes to decision making in part by integrating emotional information (“gut feeling”) into cognition. They also suggested that the orbitofrontal cortex serves to enhance attention and working memory in other cognitive areas. The interested reader might want to read Damasio’s book, *Descartes’ Error: Emotion, Reason and the Human Brain*, which provides a detailed review of carefully studied cases of the sequelae of orbitofrontal lesions.<sup>37</sup>

Other reports of patients who have sustained lesions in this area have described the striking preservation of intellectual and neuropsychologic function, coupled with dramatic deficits in self-awareness and socioemotional functioning and blunted autonomic responses to emotional stimuli.<sup>40–43</sup> Cato et al described a patient with an orbitofrontal lesion who performed very well on virtually all neuropsychologic tasks but was impaired on tasks requiring inhibition, switching, discriminability, and maintaining set, suggesting that the orbitofrontal cortex also involves the integration of two or more cognitive operations directed at higher-level goals.<sup>44,45</sup>

### **Anterior Cingulate Circuit**

The anterior cingulate subdivision of the prefrontal region is often considered to be a component of the limbic system. Indeed, subcallosal regions of the cingulate, which are most directly connected to the orbitofrontal cortex and other limbic structures, are more involved in the regulation of autonomic nervous system functions. Supracallosal regions of the cingulate appear to activate during more effortful activities during the early stages of learning or when increased attention and arousal are required.<sup>5</sup> Hence, the supracallosal areas are involved in executive control, divided attention, error detection, response monitoring, and the initiation and maintenance of appropriate ongoing behaviors.<sup>5</sup> Given its central role in attention, arousal, emotion, and motivation, it is not surprising that damage to the anterior cingulate circuit results in



decreased motivation, apathy, monosyllabic verbal responses, indifference to and loss of interest in the outside world, poor attention, hypokinesia (reduced movement), and flattened affect or, in the extreme, akinetic mutism (also called *coma vigil* because the patient is awake but does not move). Some patients can manifest indifference to pain. Affective blunting can give rise to depressed mood ("pseudodepression"). Conversely, increased activation of this area (often in conjunction with the orbitofrontal cortex) is seen in neuroimaging studies of patients with obsessive-compulsive disorder.<sup>46</sup> Cognitive neuroscience models of anterior cingulate activity have attributed to it a role in monitoring one's own behavior and guiding compensatory responses. In addition, the anterior cingulate is involved in the detection of conflicting information (ie, information that does not conform to expectations or automatic responses) and in generating the subsequent increase in activation or arousal required for addressing the conflict.<sup>47</sup>

In summary, the three areas of the prefrontal cortex and their subcortical connections (the corticostriathalamocortical circuits) form functional units, each subserving different executive processes. Damage to either the cortical area or the subcortical structures associated with these areas or their connections results in characteristic patterns of behavior.

### HEMISPHERIC SPECIALIZATION OF THE PREFRONTAL CORTEX

Traditionally, the left and right hemispheres of the brain have been characterized as devoted largely to language and visuospatial functions, respectively. This is, of course, an oversimplification and is generally more applicable to right-handed individuals and to men more than women. However, more current theories of lateralization conceptualize the division in terms of the type of processing performed by each hemisphere rather than the content. Podell et al identified the right hemisphere as specialized for dealing with novel cognitive situations and the left for well-routinized representations and strategies, which would include language.<sup>48</sup> The left frontal system appears to be more driven by the content of working memory and by the typical demands of a specific context, whereas the right frontal system plays a critical role in adjusting the organism's response to changing environmental stimuli.<sup>48,49</sup> This conceptualization is supported by the finding that many language functions shift from greater right to greater left hemisphere activation as children become more linguistically proficient. In adults, both verbal and nonverbal tasks shift from right to left hemisphere activation as task performance becomes increasingly efficient and automatic.<sup>48</sup>

Left prefrontal lesions are, however, more often associated with language-related impairments, and right prefrontal injuries are more likely to engender problems in visuospatial functions or in the nonverbal aspects of communication. For example, decreased verbal fluency and impoverished spontaneous speech frequently result from left prefrontal injury,<sup>50</sup> whereas impaired design fluency (generation of unique designs under time pressure)<sup>51,52</sup> and deficient spatial working memory<sup>53,54</sup> are associated with lesions of the right anterior prefrontal area. Encoding verbal information appears to be transiently disrupted by transcranial magnetic stimulation to the left prefrontal area, whereas encoding of visuospatial information

is disrupted by right frontal stimulation.<sup>55</sup> A child with a left prefrontal injury can display impoverished speech and written language characterized by simplified syntax, incomplete sentences, disorganized and confused narratives, and perseverations. The child with right prefrontal damage will also show impoverished expressive language (as well as lack emotional vocal expressivity) but would be particularly taxed by the demands of organizing the output, managing visuospatial materials, and solving new problems.

Left and right prefrontal lesions also have differential effects on emotional behaviors. Depressed and anxious patients show more rapid, excitatory activity in the right frontal lobe and posterior cingulate areas on a resting electroencephalogram (EEG) than controls.<sup>56</sup> Pathologic crying and depressive symptoms have been observed in association with lesions affecting the left frontal-subcortical system.<sup>57,58</sup> In adults who have suffered strokes, the severity of the depression is related to its proximity to the left frontal area, but no such correlation exists for right frontal strokes.<sup>59</sup> Pathologic laughter, indifference, euphoria, and even mania have been reported following right-sided prefrontal lesions.<sup>5,60,61</sup>

### DEVELOPMENT OF THE PREFRONTAL CORTEX

The prefrontal cortex takes longer than most other areas of the brain to reach maturity, and development continues into the early years of adulthood.<sup>62</sup> The maturation of executive function starts in infancy and continues into late adolescence and early adulthood. Within the first year of life, one can observe rudimentary evidence of executive function. Using a version of the delayed response task, a desirable object is hidden in full sight of the baby in one of two locations (usually a covered well). After a variable period of delay with distraction, the baby is then allowed to reach for the object. The task requires holding the location of the object in working memory. Around 7½ to 8 months, infants can remember where the item is located for 2 to 3 seconds.<sup>63</sup> By 12 months, they can succeed after a 10-second delay.<sup>64,65</sup> Several investigators have suggested that working memory and inhibition might underlie the larger subset of executive functions.<sup>66-68</sup> On a modified version of the Iowa Gambling Task, there is evidence of increasing ability to inhibit disadvantageous decisions and make advantageous decisions with maturation. Whereas 3-year-old children perform in a manner reminiscent of patients with orbitofrontal lesions,<sup>69</sup> there is a steady improvement across the early school years continuing into late adolescence.<sup>70</sup> Stable autobiographic memory (the all-important ability to be able to organize the events in one's life in relation to self and time) begins to emerge around age 4 years.<sup>71</sup> Between the ages of 9 and 18 years, there is an increase in a child's spatial working memory capacity that correlates with increasing levels of activity in the dorsolateral frontal and parietal areas.<sup>72</sup>

The growing ability of the adolescent to comprehend abstract ideas, anticipate the long-term consequences of their actions, and mentally manipulate increasingly complex information is a manifestation of the ongoing maturation of the prefrontal cortex. At the neuronal level, there is a gradual reduction in gray-matter density (synaptic pruning)<sup>62</sup> and the refinement of the myelinated pathways that connect prefrontal cortex with other brain regions.<sup>73</sup> This occurs in tandem with the refinement of morality,<sup>45</sup> abstract thought, and the adult personality.<sup>72,74-76</sup>

### Long-Term Outcomes of Prefrontal Cortex Lesions in Early Life

Unlike areas of damage in most areas of a child's brain, which often manifest improved function with maturation, lesions affecting the prefrontal-subcortical system can result in increasingly severe and incapacitating dysfunction as the child grows up.<sup>77</sup> This was demonstrated in experimental studies by Goldman and colleagues, in which early lesions of the caudate nucleus and prefrontal cortex in monkeys did not result in any behavioral effects until much later in development.<sup>77,78</sup> Such delayed changes can be very puzzling to parents (and physicians) because these children often display few, if any, obvious neurologic deficits and can function adequately in early academic situations. However, at the point at which they are expected to develop autonomy and independence in their day-to-day function and demonstrate appropriate social behaviors, they manifest disappointing impairments in insight, foresight, social judgment, empathy, and complex reasoning.<sup>79-81</sup> Although some researchers have described this as a "compartmental learning disability,"<sup>79</sup> families often attribute their adolescent's struggles to motivational or character flaws rather than a long-past brain injury.

### IDENTIFYING PREFRONTAL EXECUTIVE FUNCTION DEFICITS IN THE CHILD

There are many different neuropsychiatric disorders in children that involve some degree of impairment in prefrontal executive function (Table 2). It is beyond the scope of this article to review in detail these specific syndromes.

Making an accurate diagnosis of prefrontal executive dysfunction is particularly important because it is the basis for the development of an effective management plan. Arriving at a diagnosis of impaired prefrontal executive function in a child is particularly complex. One challenge is to identify when childish behaviors exceed a reasonable threshold. The behaviors of children with prefrontal cortical deficits are all typical child behaviors to some extent: tantrums when things do not go their way, telling lies, taking things that do not belong to them, drifting into more pleasurable tasks rather than completing work, and attempting to ignore or circumvent parental instructions (Table 3).

It is important that parents understand something about the complexity of the diagnostic process, which can be very time-consuming and can involve a number of different specialists and an array of different types of tests. Children with prefrontal executive function deficits can be learning disabled and can have severe behavior problems. These behavior problems are very hard to differentiate from common psychiatric disorders (attention-deficit hyperactivity disorder [ADHD], anxiety, obsessive-compulsive disorder, depression, mania, conduct disorder, or disorders in the nonverbal learning /Asperger's syndrome /autistic disorder spectrum). Thus, the evaluation must cover a broad range of information: how the child functions in day-to-day life (obtained from parental history and interviews with others who deal with the child), the child's intellectual ability, academic achievement, features of personality, and social adjustment. Importantly, the child with prefrontal executive function deficits lives in a social context. To develop an appropriate management plan, it is necessary to work with both the family and the school, and this

**Table 2. Some Neuropsychiatric Syndromes and Conditions in Children and Adolescents Involving Dysfunction of Prefrontal-Subcortical Circuits**

Attention-deficit hyperactivity disorder (ADHD)
Conduct disorder
Depression
Bipolar disorder
Obsessive-compulsive disorder
Tourette syndrome
Huntington's disease
Wilson's disease
Schizophrenia
Autism
Asperger's syndrome
Nonverbal learning disorders
Turner's syndrome
Fragile X syndrome
Phenylketonuria
Frontal brain tumors
Traumatic brain injury
Acquired brain injury, via toxins, anoxia, infections, etc
Complex partial epilepsy of frontal origin
Williams syndrome
Velocardiofacial syndrome
Hydrocephalus
Fetal alcohol syndrome
Metachromatic leukodystrophy
Cerebellar tumors

obviously requires understanding how the child behaves in these different contexts.

An adequate examination of a child with prefrontal dysfunction requires a multidisciplinary approach. It involves a psychological evaluation, a neuropsychological assessment, often an evaluation by a child psychiatrist, a neurologic examination, and other laboratory and neuroimaging studies.

#### Psychological Evaluation

A standard psychological examination of a child generally includes several components: intelligence testing (eg, Wechsler intelligence scales such as the Wechsler Intelligence Scale for Children [WISC]-IV, the Wechsler Preschool and Primary Scale of Intelligence [WPPSI]-III or, in the older adolescent, the Wechsler Adult Intelligence Scale [WAIS]-III or the Stanford-Binet Intelligence Scales), personality assessment (using parent questionnaires and perhaps projective testing with the child), behavioral observation, and achievement testing. Evaluation by a child psychologist can also identify life stressors and family issues that might be contributing to a child's clinical presentation.

#### Neuropsychological Evaluation

Neuropsychology is a subspecialty within the field of clinical psychology. The neuropsychologist extends the evaluation beyond basic personality and intellectual functioning into a broader range of neurocognitive functions that can be affected by neurologic conditions. A neuropsychological evaluation will typically be quite time-consuming, involving 4 to 10 or more hours of direct observation and testing of the child, in addition to interviews with parents, record reviews, and statistical analysis of test results. The evaluation provides a "circuit check" to try to pinpoint the brain areas that are impaired.

**Table 3. Behaviors Observed in Children With Impaired Executive Function (Relative to Age-Appropriate Standards)**


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Difficulty sustaining attention, particularly when tasks are boring or frustrating
Procrastination/difficulty initiating new or challenging tasks
Poor time estimation
Losing track of time, chronic lateness
Difficulty prioritizing or self-pacing
Difficulty dealing with novelty
Difficulty transitioning from one activity to another, especially terminating pleasurable tasks
Forgetful (loses things, cannot keep “things in mind,” forgets to turn in homework)
Cannot remember time or place of events or learning experiences
Easily distracted
Difficulty multitasking
Difficulty controlling impulsive responding
Carelessness, sloppiness, disorganization
Marked variability in academic performance
Marked restlessness or talkativeness
Difficulty regulating emotional states (easily angered)—impatience, low frustration tolerance
Underarousal—“spacey,” “sluggish,” “laid back” (“What? Me worry?”)
Lack of awareness of other people’s feeling and social situations

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A comprehensive neuropsychological examination includes sensory processes, motor systems, attention and concentration, learning and memory, language, visuospatial processing, conceptual skills, executive functions, intelligence, academic or achievement skills (eg, reading, spelling, and mathematics), and personality functioning. To establish a profile of the overall integrity of brain function, the neuropsychologist will look not just at individual scores within each of these domains but also, most importantly, at the pattern of strengths and weaknesses across the entire test battery. Neuropsychologists with a pediatric specialization will place particular emphasis on “discrepancies” between areas of development, particularly between intellectual skills and other specific cognitive and academic domains. They can also engage in detailed “task analysis” to identify the specific nature of the difficulties that lead to deficits on an individual measure because many tests require several different functions for efficient performance (eg, visuospatial skill and speed or fine motor control). Children can have difficulty writing because they have trouble controlling motor movements or cannot plan movements at a conceptual level. A neuropsychologist who works with children will also refer to experience and normative data to distinguish unequivocal deficits from age-appropriate performance in the developing brain.

The assessment of executive function is a particularly challenging task and has a unique set of limitations. Executive function includes a range of skills not easily measured in an office setting, where it is difficult to measure a child’s ability to independently initiate and organize behaviors. Nonetheless, numerous measures have been developed to identify the more fine-grained cognitive deficits involved in executive dysfunction. Table 4 lists commonly used tests of executive function. These assess different aspects of executive function; therefore, no single measure should ever be used as an estimate of overall executive function abilities.

As mentioned above, a particularly confusing aspect of prefrontal executive dysfunction is that some adults and children can

**Table 4. Commonly Used Assessments of Executive Function in Children**


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Wisconsin Card Sorting Test
Tower Tests, such as the Tower of Hanoi or Tower of London
Trail Making Test
Stroop Color-Word Interference Test
Verbal fluency tests
Design or figural fluency tests
Concept generation tests
Contingency Naming Test
Matching Familiar Figures Test
Estimation tests
Continuous performance tests
Processing speed tests
Working Memory/Delayed Response Test
Delis-Kaplan Executive Function System™ (a test battery)
Motor Impersistence Test
Autobiographical Memory Assessment
Memory (Organizational and Strategic Aspects)

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exhibit normal performance on formal neuropsychologic test measures but are highly dysfunctional in their daily lives. Thus, the absence of deficits on executive function tests does not eliminate the possibility of executive dysfunction if the patient’s day-to-day functioning is clearly impaired. Day-to-day life offers nearly limitless opportunities for distraction, disorganization, disinhibition, and dysregulation. For this reason, it is also essential that parents and teachers are given the opportunity to describe the problems that occur for a child in the real world. A number of questionnaires regarding attention and executive functions are available that provide very useful information (eg, the Behavior Rating Inventory of Executive Function [BRIEF]).<sup>82</sup>

Perhaps the most classic task assessing executive function is the Wisconsin Card Sorting Test. Deficits on this measure have been directly correlated with decreased activation in right dorsolateral-subcortical circuits.<sup>83</sup> In most clinical situations, it is a good indicator of a specific type of prefrontal cognitive deficit,<sup>66,84,85</sup> but there are significant limitations in its specificity that must be considered.<sup>86,87</sup> Thus, interpretations about localized prefrontal deficits based solely on the Wisconsin Card Sorting Test are suspect. Impairment on the Wisconsin Card Sorting Test (as with any test) does not provide a specific diagnosis—only an indication of difficulties with set shifting, goal tracking, inhibition of prepotent (ie, previously correct) responses, or abstract problem solving. Detailed description of how a child gets derailed on such a task is far more helpful in understanding the nature of the dysfunction and in developing compensations than is a test score or a diagnostic category alone. For example, children who display an unusual tendency to “perseverate” on the Wisconsin Card Sorting Test will have difficulty “shifting” their attention off a previously rewarding stimulus, even in the presence of information indicating that they should attempt a new strategy or pursue a different goal. Identifying such difficulties can provide parents with clues about where and when to intervene in their child’s daily functioning.

### Psychiatric Evaluation

The *Diagnostic and Statistical Manual of Mental Disorders, Fourth Revision (DSM-IV)* provides psychiatric diagnoses based



primarily on behavioral descriptors.<sup>88</sup> Deficits of executive function or frontal lobe deficits are not mentioned explicitly at any point in the *DSM-IV*, except in the most nonspecific way (“due to a general medical condition”) and thus might not be on the diagnostic radar screen when it comes to a psychiatric diagnosis. However, prefrontal executive function impairment is an important feature of many psychiatric disorders listed in the *DSM-IV*. A critical decision to be made in any evaluation involves whether to begin by treating the psychiatric symptoms, to focus on treating the executive function deficits, or to initiate both simultaneously. Many children can have both a primary mood disorder and an attention or learning disorder, necessitating a more complex treatment regimen. Differential diagnoses such as these cannot be made without a thorough developmental history, including academic and medical records, a family and genetic history, observations by parents and teachers or other caregivers who see the child in different contexts, and direct examination of the child.

### Neurologic Examination

A neurologic examination is an important step along the path to diagnosis. Neurologic examinations in the context of prefrontal or executive functions deficits can reveal sensory, motor, or dysmorphic features associated with particular prenatal or congenital conditions, acquired brain injury, genetic disorders, neurometabolic disorders, and other difficult to identify neurologic syndromes. On the other hand, the examination can be quite normal. Children with small, focal prefrontal lesions can walk, talk, and be free of abnormal reflexes or evidence of sensory dysfunction. A normal neurologic examination should be cause for relief but is only one step in the pursuit of a diagnosis and does not rule out a prefrontal lesion. (One only needs to remember that Phineas Gage was examined by a Harvard professor and pronounced to be entirely normal.) An important variation on the standard neurologic examination is the comprehensive neurodevelopmental evaluation provided by a behaviorally trained pediatric neurologist. Although such specialists are rare, a behavioral neurologist has more extensive training in evaluating higher-level cognitive functions, such as learning and memory, attention, language, and reasoning skills.

### Laboratory Studies

Additional laboratory studies are often required to assist with the differential diagnosis of executive function deficits. Overlapping symptoms can result from a number of neurodevelopmental conditions (see Table 2). Studies can include genetic testing (eg, girls who are fragile X carriers can manifest prefrontal executive function deficits) and neurometabolic testing. In specific cases, unequivocal prefrontal lesions can be detected on neuroimaging studies. There are also reports of prefrontal dysfunction associated with prefrontal neuromigrational disorders, such as bilateral frontoparietal polymicrogyria.<sup>89,90</sup> Developmental anomalies of the anterior corpus callosum can be associated with prefrontal executive impairment. Frontal lobe epilepsy is particularly hard to diagnose and can present as sleep terrors or a primary psychiatric disorder.<sup>91</sup> Executive function deficits occur more frequently in the context of frontal seizures than in temporal lobe seizures<sup>92</sup> and sometimes respond dramatically to

antiepileptic medication.<sup>93</sup> Thus, the data provided by EEGs, magnetic resonance images (MRIs), or single-photon emission computed tomographic scans can, in some situations, be quite informative, but this is not always the case. Patients with neurometabolic disorders can have EEG and neuroimaging studies that are entirely normal yet have substantial neurocognitive deficits referable to prefrontal function.

In summary, no single psychological or neuropsychologic or medical test can be relied on to provide a diagnosis. Some patients with serious prefrontal executive function deficits can perform well on neuropsychologic tests and have normal laboratory and radiologic studies. The most sensitive evidence of a problem comes from observation of day-to-day behaviors. Information from numerous sources—behavioral descriptions, information about the family, the results of tests by specialists from several disciplines, and laboratory tests—must be collected and thoughtfully reviewed.

### CASE EXAMPLES

Children with executive function deficits present quite different and puzzling behaviors. This variability is in part related to age and in part to the specific prefrontal-subcortical system that is involved. Because one does not expect autonomous function in the very young child, the behavioral profile can be much more difficult to recognize. In the adolescent, the difficulty with self-regulation can become very obvious indeed and will depend on the specific circuits that are involved. Children with dorsolateral prefrontal lesions can have difficulty sticking to a task. They can get “overfocused” on a task and have difficulty shifting cognitive set. Their working memory can be impaired. Parents and teachers commonly complain that they are distractible and seemingly cannot learn from experience. Children with medial orbitofrontal circuit lesions are impulsive, emotionally labile, and often socially inappropriate. Some are extremely restless and hyperactive. In sharp contrast, a child with dysfunction of the cingulate circuit is inactive, slow-moving, apathetic, and unmotivated. A common complaint is that they lack initiative and do not seem to care. It is rare, however, that one sees these pure syndromic constellations.

Executive function deficits are manifested by confusing inconsistencies in the classroom, which are often interpreted as character problems. It is not unusual for such children to demonstrate knowledge in one context but be unable to access that same information in another setting or at another time. Not surprisingly, it is tempting for parents and teachers to interpret such inconsistency as evidence of laziness or not trying. However, this pattern of “memory” or retrieval deficits is typical of individuals with prefrontal dysfunction; they forget to remember.

The following case vignettes clearly portray the frustration these children evoke in their teachers. The letters are transcribed verbatim except for changing the child's name.

#### Case 1

Sam is an 8 year-old boy of normal intelligence who is in a regular classroom. He had sustained a large area of injury to the left prefrontal area, which was readily apparent on the MRI. There was a right hemiparesis. This information, as well as a lengthy evaluation and specific implications relating to classroom management, had been shared with the school. The following letter was sent to his mother at the beginning of the second semester:

I have been having problems with Sam looking on other children's papers to get answers. I have spoke [sic] with him about this many times. From now on I will put up a folder or something to keep him from doing this. I know Sam can do his own work by hisself [sic] & I have told him this, but he continues to look on others [sic] papers. Please talk with him about this. He is a VERY smart boy, I just think he is being lazy!"

On another occasion:

Sam got his name on the board before lunch during the math facts drill. Sam needs to be paying attention during this so he can do his math facts better. First, I took a book from him and second, I took a pen away that he was playing with. Just talk to him about paying attention during math facts, because this will help him out in the long-run...

Sam's behavior had also resulted in considerable isolation. Other children, at the behest of the teachers and their parents, tended to avoid him, and he often ate lunch by himself. He told his mother that he was sad because other children told him that they had been instructed not to sit with him.

### Case 2

Another example concerns an 8-year-old girl of normal intelligence who was in a regular second grade classroom. The neuropsychologic profile provided strong evidence of a prefrontal executive function deficit. Her teacher sent the following note to her parents early in the second semester:

My concerns about Mary in the future are twofold: academics and social skills. At this point, Mary has few friendships. Recess is still a difficult time for her and is often a rather miserable experience. We have spent a great deal of time talking and practicing social skills in order to build friendships such as how we approach kids we want to play with, how we work out conflicts, how we compromise and she still struggles with these skills. Mary's lack of awareness—at times—of the people around her and what they are thinking or feeling make [sic] it hard for people to feel comfortable with her.

In terms of academics, Mary has shown growth in both reading and math. However, there are several periods of time (beginning of the year, weeks after Thanksgiving and Winter Break, the afternoons when she first started leaving for special ed) when learning did not take place because of the overwhelming stress of the transition to something new. A whole morning of learning may also be eliminated due to the loss of a favorite pencil or turning in something to the lost and found that she found but does not belong to her. These times are more frequent than I would like and lessen the times when she is available and ready to learn. In order for Mary to learn, she still needs considerable one-on-one support and small groups with teachers/adults on a daily basis. As the academics continue to become more difficult, I am concerned about Mary's ability to remain confident rather than overwhelmed and frustrated.

Mary's parents observed that she required constant reminding and noted that she often got into trouble when left to her own devices. She might put cardboard down the toilet, try to clean the television with lots of water, kick the dog, or leave the house without telling her parents she was leaving. Mary did not respond to her teacher's sensitive attempts to instruct her about appropriate social behaviors. She had difficulty understanding a situation from another's point of view. Changes in routines and environments were extremely distressing to her. Her teacher clearly observed the difficulty she had during relatively unstructured times at school. There is also the theme of moral understanding. The teacher alludes to Mary's problems in not being able to keep an attractive object that she found as her own rather than turning it in to the lost and found. Mary was accused of stealing another child's piece of jewelry that she had found. She had great difficulty grasping the concept that an attractive object that she happened to find might belong to someone else and the "finders, keepers" rule did not apply in that situation. Here the immediacy of the gratification overwhelmed consideration of possible future consequences and appropriate behavioral expectations. Her unawareness of social rules was apparent when she incorporated the jewelry into her own wardrobe and proudly wore it to school.

Both Sam and Mary illustrate how dependent these children are on the environment and structured routines. Both children were of average intelligence, and their teachers assumed that they were quite capable of learning. This belief undoubtedly contributed to the teachers' difficulties in understanding the nature of the children's problems. Although it seems counterintuitive, this illustrates the point that persons with executive function deficits often learn well and know a great deal; they just cannot use the information effectively. The following case study describes a child with a severe amnesic syndrome.

### Case 3

Barbara, a 17-year-old girl with low-average to average-range intelligence, was referred for evaluation of a memory impairment following an operation for an aneurysm in the prefrontal area 10 years previously. Scans revealed a prominent midline prefrontal lesion. Neuropsychologic testing and behavioral reports revealed a profound memory impairment coupled with a lack of insight. Her mother reported that she would pour herself a glass of water, put it down, and forget where she left it. In school, she could not remember the schedule but had learned to get from class to class by following her friends. She was able to get to special school events by writing the date in her calendar, which was then left to her mother to remind her. Her academic performance was strong, and she had failed only one math class (her grade point average was 2.75). When tested at age 17 years, she was functioning close to the 70th percentile in all academic skill areas.

One possible explanation for this interesting phenomenon is that although she had disabling memory deficits, she was able to recall academic information because it was highly overlearned and became part of the "habit memory" system. Several other cases of children with amnesic syndromes who were able to progress academically have been reported, although the explanation for this phenomenon is still controversial.<sup>94,95</sup>

Children with executive function deficits are often attractive, intelligent, and informed and have few, if any, outward signs of brain dysfunction. Thus, adults usually attribute behavioral problems in these children to oppositionality or lack of motivation. One of the basic problems is that understanding executive function deficits requires modifying one's concept of autonomous, independent action and "free will." Patients with frontal dysfunction are often so sensitive to environmental factors ("stimulus bound") that they are quite unable to exercise "free will" or autonomously regulate behaviors.

### Case 4

John was a 20-year-old man who had sustained a prefrontal injury at the age of 12 months when a car ran over his head. After he recovered from the acute effects of the injury, his development progressed normally. An MRI revealed a large prefrontal lesion involving the medial orbitofrontal area, maximal in the left hemisphere, with little damage to the dorsolateral or anterior cingulate areas. During the pre-high school years, he was hyperactive and argumentative but generally functioned well in the classroom. Repeated IQ tests revealed normal-range intellectual ability. In high school, his performance declined, and he dropped out after a brief stint in a vocational program. He then worked in a number of jobs (bagging groceries, loading trucks, and on a production line) but was discharged because of his lack of consistent work effort. He never had more than one or two friends. He left home for several years and lived on the street and slept in cars. He ultimately returned to live with his parents and was able to work at night on a janitorial job. His parents felt that his success in that setting was entirely due to a motherly supervisor who reminded him frequently about what he should do next, when to eat, and not to pilfer.

Each of these case studies reinforces some basic principles. They indicate the importance of modifying the way in which children with executive dysfunction are managed in the classroom and in the home. In the first two cases, the teachers attempted to teach the child how to behave, delivering rational lectures on why certain behaviors are not desirable. Both were disappointed because the children did not appear to benefit from this information, even though it is likely that they could repeat the lecture verbatim.

There is also an understandable propensity, based on the assumption that positive or negative consequences will train behaviors, to use a behavior modification approach. Behavioral consequences (rewards and punishments) are typically amazingly ineffective when applied to children with executive function deficits. Moreover, the more distant the consequences, the less effective they are likely to be. This is related to the "insensitivity to future consequences" that is typical of prefrontal executive function problems. Parents say, "We have taken everything away from him, and he is grounded for the next month but still won't do his homework or take care of the dog!" "He keeps doing the same thing, and he knows it is wrong!" Or "She could earn another Barbie doll but simply won't keep her end of the bargain!"

The staff at Sam's school felt that they were dealing with a disruptive, oppositional child who was willfully thwarting their attempts to teach him. Because the concept of prefrontal dysfunction was unknown to them, it was extremely difficult for them to realize that Sam's ability to control some of his behavioral aberrations was seriously impaired. In Mary's case, the staff of her school responded rapidly to recommendations and promptly hired a classroom aide to provide the needed cuing and structure. Some children will require testing modifications. In Sam's case, his left frontal injury markedly decreased verbal fluency and made it very difficult for him to generate answers to test questions; however, he was often able to come up with the answer if presented with a multiple-choice format. Left to his own devices, his compensatory solution was to try to locate the answer on another child's paper.

Another source of frustration for adults is that the child "knows what to do" but does not do it. Although the child can often describe in considerable detail what is expected and appropriate in a specific situation and might, in fact, be able to carry it out on some occasions, he cannot reliably use the information to regulate his behavior. This might be because the rule cannot be evoked at the proper time, or it might be because of impersistence; the intention fades as a task progresses. Parents often say, "He knows how to get dressed in the morning [or take a bath, mow the lawn, etc], but some days, I have to stand over him." In school, the child might appear to understand how to carry out a math problem one day but forget it the next day.

The child with executive deficits might respond well in certain environments but be unable to perform the same action in a different setting. This can be both good and bad. For example, in a highly structured situation in which the same routines are being followed day after day, the child might behave quite appropriately. However, if the routine changes (eg, the parents go to a different store or a different restaurant) or there is a substitute teacher, there might be a dramatic decline in behavior. If a trip to the movies is planned and does not take place because a sibling becomes ill, this can result in a lengthy outburst. Once locked into an activity, a child might have great difficulty switching to a different one. A corollary of this "environmental sensitivity" is that the child is easily influenced into carrying out undesirable actions. Adolescents with prefrontal executive deficits might be perfectly aware that they should not steal, but in the company of peers who are shoplifting, they might forget this rule. On the other hand, this environmental "stimulus boundness" can be used to good advantage to help the child initiate desirable behaviors.

Social-emotional behaviors are often affected in such children. A child can be emotionally extremely labile, switching from tantrums to smiles in a very short time. At times, this can be a response to factors in the immediate environment. For example, some children do not seem to understand how other people feel (or lack empathy) and can engage in acts that seem quite antisocial to others (such as stealing or trying to copy another child's homework). When confronted, the child might be able to state that such behaviors are undesirable and might be upset and remorseful while at the same time appearing genuinely confused as to the nature of the wrongdoing.

Of course, many of these behaviors can occur on occasion in otherwise normal children. Also, some of these behaviors (hyperactivity, impulsivity, distractibility, and impaired attention) are characteristic of a child with ADHD, whereas the tendency to continue an action repetitively and become very upset when it is interrupted can be seen in a child with obsessive-compulsive disorder, and mood lability is characteristic of a child with bipolar disorder. The presence of such wide-ranging executive deficits in so many disorders is not surprising because many of these psychiatric disorders involve dysfunction of the prefrontal cortex, further emphasizing the need for a thorough and systematic diagnostic process.

#### **MANAGEMENT OF THE CHILD WITH PREFRONTAL EXECUTIVE DYSFUNCTION**

The important areas of a child's life involve living comfortably with the family and functioning adequately in school. No matter how sophisticated one's parenting or teaching skills might be, managing a child with an unreliable prefrontal lobe provides unique and frustrating challenges. Before a management plan can be initiated, it is necessary that the adults in the situation understand the nature of the problem.

As discussed above, persons with frontal executive function deficits have a great deal of difficulty regulating their own behaviors in an autonomous and consistent fashion. That is not to say that they cannot do this episodically, but autonomy requires that the child be able to determine the best course of action in different situations. It is this lack of reliability and consistency that is the problem. Thus, parents and teachers might need to act as a sort of "prosthetic frontal lobe," anticipating consequences in a given situation and providing the appropriate behavioral guidelines that the child cannot create independently. Needless to say, if a classroom aide is hired, a training program and close monitoring will be required so that the management is consistent.

All adults who deal with children with executive dysfunction need to educate themselves about the disorder. Perhaps the most difficult task is to pare down the huge amount of information that bombards one when one attempts to learn about such disorders. The Internet presents a dizzying array of possibilities, ranging from the most rigorously scientific to the highly speculative and anecdotal. Thus, it is wise to first complete the diagnostic process and obtain the most reliable medical data and then network with parents and teachers who are further along in the learning process and seek out skilled specialists who can provide information in specific areas.

Executive function disorders are challenging because of their extreme heterogeneity and the fact that the compensations they

require are highly variable. No two children with prefrontal executive function disorders are alike, any more than two children with brain tumors or learning disabilities are alike. Although schools can set up general paradigms for the management of children with reading disability, the management of the child with executive function deficits is not at that stage as yet. The child's profile of skills and the needs and resources available to each child will be highly individual and should be expected to change in concert with development. Thus, the management plan does not remain the same but rather changes over time, sometimes quite rapidly. At times, this might require pulling back on monitoring and structure to allow for increased autonomy. At other times, increased vigilance and firmness might be required. Thus, the best plan for interventions with a child suffering from executive function deficits is one that is developed collaboratively among parents, schools, and a specialist attuned to the child's unique profile of strengths and weaknesses. This is not a one-time process but requires repeated adjustments throughout childhood.

Behavioral strategies targeting these children require the adults dealing with them to focus on manipulating the antecedents to their child's undesirable behaviors rather than imposing ineffective consequences. For example, rather than expecting children to remember that they will fail their school project if they do not begin it well in advance, such projects are more likely to succeed if a timeline is set up, the project is structured well in advance, and the child is trained to monitor progress, under supervision. Incentives for completion of a project will be far more effective than punishment for failure after the fact. In other words, carefully setting the child up to succeed is far more likely to produce success than any form of punishment, even following repeated failure (see Table 5 for a list of management guidelines).

## MEDICATION

Research on the efficacy of psychiatric medications for disorders involving prefrontal dysregulation has been extensive and complex, and a comprehensive review is beyond the scope of this article. However, four major points need to be made. First, selecting a

medication because it works for a specific psychiatric diagnosis or behavior might not be helpful (eg, perseverative behaviors can be interpreted as "compulsive" and treated like obsessive-compulsive disorder, which might not work). A corollary of this is that medications might work for one child but not for another with the same diagnosis. Second, research in the area of pharmacogenomics has revealed unequivocal differences in target brain systems and in liver enzymes that detoxify the drugs, resulting in complex and variable patterns of response, particularly for some psychotropic medications. Third, when more than one medication is used, the interactions at a neuronal level and in the metabolic pathway can be quite complex and result in different patterns of response. Fourth, achieving stability might require prolonged medication trials with considerable adjustment of medication(s) and doses.

## CONCLUSION

The cognitive, behavioral, and emotional sequelae of prefrontal lobe dysfunction are common to a wide range of childhood neuropsychiatric conditions but vary greatly in their presenting symptoms and severity. Research into the differing neurophysiologic underpinnings of these disorders is progressing rapidly on many fronts. Treatment options for such conditions are more specialized and more available than ever before. Nonetheless, executive function disorders are complex and difficult to manage, and it is important that parents, teachers, therapists, and physicians understand the challenges that such conditions present. The present article has attempted to outline a roadmap for healthcare providers, parents, and teachers to assist them in navigating this somewhat intimidating group of disorders.

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**Table 5. General Guidelines for Parents of Children With Executive Function Deficits**

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Develop a long-term working relationship with a knowledgeable case manager or team of experts
Educate yourself about your child's disorder
Use Internet resources judiciously for information and support
Consider a support group for parents dealing with the same disorder
Learn to be a good "accessory frontal lobe"
Manipulate antecedents rather than consequences
Be consistent—the child may have great difficulty dealing with unfamiliar and novel situations
Set up functional routines
Use intensive, repetitive training to make routines automatic
Teach new skills when child is at his or her best (ie, not tired, irritable, etc)
Teach the child how to break down projects into component parts
Teach the child to use organizational systems and aids whenever possible (filing systems, color coding, checklists, planners, personal information managers, memory aids)
Do not be punitive or shaming about difficulties that are disorder based
Do not encourage children to use their disorder as an excuse but reinforce the need for using appropriate adaptations
Use liberal positive reinforcement (eg, praise, positive attention), remembering that this may not be as effectively motivating as it might be for a child without executive dysfunction
Do not rely on monetary, food, or other "rewards" consistently—only sporadically, so as to avoid the expectation of reward for any and all efforts
Teach, practice, and remind the child to use self-soothing or calming techniques when needed
Anticipate and tactfully control situations in which the child may become overly emotional, make poor decisions, or respond impulsively (do not expect that he or she will "learn from experience" or be able to generalize behaviors from one situation to the next)
Develop a long-term plan for future needs and services based on prognosis

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