ADULT LEARNING DISORDERS

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CHAPTER 9

Executive Functioning and Self-Regulation in Young Adults

Implications for Neurodevelopmental Learning Disorders

LORRAINE E. WOLF and EDITH KAPLAN

Contents

Self-determination and control of one's actions are perhaps *the* adult hallmarks of normal human development. Young children intuit this when they assert that "you are not the boss of me," as they yearn for greater autonomy. This attitude changes sequentially into the rebellion of the teenager and the independent stance of the young adult moving towards college and career, as they become the "chief executive officers" of their own lives. The biological and psychological mechanisms underlying these fundamental skills remain a central mystery of neuroscience and neuropsychology. The effort to define and identify the brain components and processes underlying this perhaps ultimate higher brain function is certainly one of the great challenges of these fields and thus generates great excitement and controversy.

The salient feature of this cognitive and behavioral control is the capacity to direct one's thinking and action towards achieving future goals. In the field of neuropsychology, definitions of control center usually relate in some fashion to the useful concept of "executive function" (EF). The *American Heritage Dictionary* (2000) defines executive as:

> 1. A person or group having administrative or managerial authority in an organization. 2. The chief officer of a government, state, or political division. 3. The branch of government charged with putting into effect a country's laws and the administering of its functions.

Thus, common synonymous terms invoked when discussing executive functioning include the "conductor" (Brown, 2006) or "supervisor" (Norman & Shallice, 1986; Shallice & Burgess, 1996). As we will explore later, these psychological entities are commonly believed to reside in the frontal lobes of the brain and represent the "command and control function of the prefrontal cortex" (Powell & Voeller, 2004).

The term "executive function" is broadly defined and often used as shorthand for a complex set of behaviors, thought to be unique to human cognition, that depend on the intact function of many centers of the brain. This construct of an overarching managing agent has a long tradition and much appeal from a scientific and commonsense perspective. Many models of this construct have emerged, each with its own terms but all attempting to describe the operation of an aspect of the brain that takes control over behavior under novel conditions and that monitors, detects, and corrects errors in ongoing behavior. Further, as these structural and functional systems mature over the life span, individuals come to rely on these processes to manage the complex tasks of adult life (see Wolf & Wasserstein, 2001). Clearly, the developmental disorders that compromise this system may have profound implications for the educational outcome and adaptive function of the individual.

Despite the large body of EF literature, there is one critical aspect that is almost entirely left out of the classical neuropsychological conceptualization of command and control. Although newer models discuss motivation and regulation of affect, the dimension of personal choice as a subcomponent of motivation is often overlooked. We believe this missing element is the key to understanding how executive dysfunction degrades the learning experience. We thus introduce the concept of "self-regulated learning" (SRL) as a model linking the classic definitions of EF with other regulatory functions critical to academic success.

In this chapter, we review some of the common relevant definitions and terminology and discuss alternative conceptual views. We discuss cognition and motivation as separable subcomponents of an overall regulatory system, and we briefly review the development and functional anatomy of cortical regions relevant to this dichotomy. As the focus of this book is on developmental learning disorders, we do not separately discuss acquired disorders but instead concentrate on understanding and assessing students who have difficulties in self-regulation as part of a neurodevelopmental disorder (see Rey-Casserly and Bernstein, Chapter 14, this volume, for a discussion of some acquired conditions). We therefore conclude that any assessment should always proceed with the understanding that executive dysfunction involves much more than problems with cognition.

Thus, we argue that clear distinctions must be drawn between the cognitive components of EF and the regulatory components of motivation and affect if we are to better understand how the system operates smoothly and how developmental disorders may affect overall self-regulation. We suggest that, in the academic learning environment in particular, an integrated self-regulatory system reflects the interaction of these two parallel systems. We shall argue below that we should keep these two systems distinct when discussing the overall regulatory framework. It has become clear that these separable functions indeed reside in different functional brain systems. In order to better understand this, we turn to a brief discussion of the neuroanatomical regions and the development of regulatory control.

Brain Regions

EF depends on the intact function of many centers of the brain, yet it is most closely associated with the frontal lobes. While the frontal lobes (particularly the prefrontal cortex) have traditionally been considered the "seat" of EF (Luria, 1966; Fuster, 1997), it is now well understood that a bilateral network of parallel, widely distributed cortical and subcortical circuits are involved (Alexander, DeLong, & Strick, 1986). A complete discussion of frontal cortical and subcortical brain anatomy and development is beyond the scope of this chapter. The interested reader is directed to the many excellent references for this topic (Miller & Cummings, 2007; Risberg & Grafman, 2006; Krasnegor, Lyon, & Goldman-Rakic, 1997; Bradshaw, 2001; Lichter & Cummings, 2001). Here, we review briefly the key concepts needed for further discussion. Although we may not state so explicitly, the reader is reminded that we are talking about a network of structures and circuitry.

Despite the caveat above, EF is tightly associated with the functions of the prefrontal cortical network. This area clearly must serve a principal integrative role in the brain, with its large white-matter tracts providing communication with posterior (sensory) systems, limbic (drive, affect, memory) systems, and anterior (motor) systems. Indeed, it has been stated that this brain region may be the only one capable of this integration between cognitive and sensory (internal and external) information, emotion, motivation, and goal direction (Royall et al., 2002). The prefrontal cortex can be further resolved into two major functional divisions that operate together in the regulation of information processing and emotional responses to control goal-directed behavior (Rule, Shimamura, & Knight, 2002). Again, it must be stressed that, despite its structural and neurofunctional differentiation and complexity, all parts of the executive brain work together in an integrated functional system (Luria, 1966).

One prefrontal subdivision is the dorsolateral prefrontal region (DLPFC), a critical area for the cognitive processing of information from the environment, memory (especially working memory), and the integration of sensory and cognitive information (Barbas, 2006; Grafman, 2006). The DLPFC is part of a circuit that includes the lateral convexity of the frontal lobe and associated subcortical structures and pathways to the caudate, globus pallidus, and thalamus. The DLPFC also contributes to the initiation and monitoring of movement patterns via its connection with the motor and premotor areas of the frontal lobe, as well as visual orientation via the frontal eye fields (Miller & Cummings, 2007). Massive connections between this region and other primary and secondary sensory and motor cortical areas as well as subcortical areas (thalamus, basal ganglia, and hippocampus) mediate its integrative role (Stuss, 1992). Classic definitions of EF (shifting, inhibition, working memory, etc.) refer to many of the cognitive functions associated with the DLPFC (Baddeley, 1986; Cummings, 1993; Lezak, 1983; Grafman, 2006). Lesions involving this area typically give rise to the so-called frontal lobe syndrome affecting movement, action, and initiation (Cummings, 1985). Features may include disorganization, perseveration, stimulus bound-ness, and deficits in working memory. Other symptoms include apathy and indifference (Cummings, 1985). This region therefore is thought to process information and to formulate rules about how the world works and to put these rules into action (Rule et al., 2002).

The other subdivision is the ventromedial prefrontal cortical region (VMPFC) comprised of the orbitofrontal cortex (OFC) and anterior cingulate cortex (ACC), including the more anterior parts of the prefrontal cortex as well as key ventral and medial structures (Rolls, 2004; Royall et al., 2002). These areas are connected via the lateral and ventral orbitofrontal and anterior cingulate circuits to limbic and thalamic areas, and to the brain stem (Royall et al., 2002; Rolls, 2004). Strong connections exist between the OFC and deeper limbic areas such as the ACC and the amygdala subserving emotional states and some aspects of memory (Rolls, 2001; Luu & Tucker, 2003). The OFC thus has a role in social cognition and social behavior, including theory of mind and empathy (Amodio & Frith, 2006; Stuss & Levine, 2004; Perry et al., 2001). Theory of mind has been described as the ability to have "flexible access to the mind of others" (Dennis, 2006, p. 143) and thus is a social construct closely related to empathy (or the recognition of feelings in others) (Becharra, Damasio, & Damasio, 2000; Eslinger, 1998). Ventral OFC regions are thought to be important in behavioral self-regulation and inhibition (Stuss & Levine, 2004; Stuss et al., 1983). The closely associated and more medial ACC has been shown to also mediate motivational behavior through its role in action planning, error detection, detecting novelty, and evaluating the potential reward benefit of actions (Rolls, 2001; Luu & Tucker, 2003; Rushworth, Walton, Kennerley, & Bannerman, 2004). The architectonics of the ACC parallel that of the PFC, with more dorsal parts responding to novel cognitive tasks and more ventral parts responding to emotion (Luu & Tucker, 2003; Amodio & Frith, 2006). Thus, together, the OFC and ACC are thought to regulate social-emotional behavior (Becharra, Damasio, Damasio, & Anderson, 1994), promote social and emotional appraisal of the environment (Eslinger & Damasio, 1985), mediate social behavior (Stuss & Levine, 2004), and measure the affective value of reward contingencies and thus maintain motivation (Rolls, 2001).

Damage to the VMPFC often results in derangements of personality (Cummings & Miller, 2007; Barbas, 2006; Grafman, 2006) and decision making (Barbas, 2006), while performance on cognitive neuropsychological tests may look entirely normal (Stuss & Levine, 2004: Becharra et al., 2000). A disinhibition syndrome may emerge (often called "acquired sociopathy" or pseudopsychopathic syndrome), which includes emotional outbursts, poor insight, risky behavior without regard for consequences, and violation of social conventions (Cummings, 1985; Miller & Cummings, 2007). Children with damage to these areas may show antisocial behavior and restricted empathy (Eslinger & Damasio, 1985). Injury to the ACC may result in disorders of volition and apathy, the so-called pseudodepressed state (Barbas, 2006; Cummings & Miller, 2007). These areas thus are believed to link our cognitive understanding of a situation with our affective responses (Becharra et al., 2000) and to shape future goals in keeping with their reward values.

Development of the Brain and Executive Functioning

The frontal lobes, and in particular the prefrontal cortex, are the last brain regions to develop in humans. Electrophysiological, neuroanatomical, neurochemical, and neuroendocrine changes continue from infancy through adolescence and adulthood. The protracted development of these regions and their associated functions (see Dennis, 2006, and Diamond, 2002, for reviews) reflects the importance and specificity of these functions for the life of an adult. In particular, the frontal white-matter connections develop slowly, continuing well into the adult years (Gogtay, Giedd, & Rapaport, 2002). While the basic architecture of the system is in place during infancy and early childhood, the period between ages 5 to 18 is characterized by reorganization and refinement, with emphasis on elaboration of the net of interconnecting tracts, of which the frontal connections represent a major portion (Giedd et al., 1996; Giedd et al., 1999). Brain development proceeds in sequential fashion by region, with the sensory and motor cortices maturing earlier than the parietal and frontal association cortices (Giedd et al., 1999; Gogtay et al., 2002). The delayed maturation of these regions follows a prolonged period of, first, early overproduction of gray matter and synaptic connections, peaking at puberty (Giedd et al., 1999), followed by extensive synaptic pruning (Huttenlocher & Dabholkar, 1997). These developmental anatomic changes may be related to hormonal influences, personal experience, and environmental milieu (Royall et al., 2002). Changes in synaptic density continue through adolescence and accompany increased white matter, decreased gray matter, and the corresponding increases in cerebrospinal fluid (CSF) in frontal areas (Jernigan, Trauner, Hesselink, & Tallal, 1991). Subcortical areas develop somewhat earlier than cortical regions; however, their full functional maturity awaits cortical development and the white-matter interconnections (Gogtay et al., 2002; Kinney, Brody, Kloman, & Gilles, 1988). White-matter density continues to increase in subcortical and frontal areas well into middle adulthood, with frontal lobe myelination occurring last (Jernigan et al., 1991; Yakovlev & Lecours, 1967; Fuster, 1997). Thus, later developing cognitive and regulatory processes reflect ongoing myelination, metabolic changes, hormonal influences, and environmental modifications (reviewed in Eslinger, Biddle, & Grattan, 1997).

In parallel with the structural changes described above, executive function develops well into adulthood, forming a critical scaffold for ongoing personal growth. Luria (1973) early on posited that frontal lobe functions matured between ages 4 and 7. By contrast, many neuropsychological studies find that children do not perform at adult levels until adolescence, leading to the belief that EF was a function of the mature brain, and that these cognitive control functions did not emerge until adolescence (Golden, 1981). We now understand that both views may be true depending on the nature of the task. Early emergence of cognitive EF is supported by evidence that some EF-like problem solving has been seen in infants when tested with appropriate measures (Diamond, 2002), and findings from developmental studies show that normal children achieve adult levels of performance on many cognitive tests of EF by about age 6 (see Romine & Reynolds, 2005, for a review and meta-analysis). The greatest period of development of these skills appears to be between ages 6 and 8 (reviewed in Romine & Reynolds, 2005) with continued, albeit apparently slower, development thereafter. However, many studies show that most tasks are mastered by age 12, depending on the task (Grattan & Eslinger, 1991; Welsh, Pennington, & Grossier, 1991; Levin et al., 1991; Chelune & Baer, 1986; also see Romine & Reynolds, 2005). This cognitive progression has its parallel in behavioral control. The rudiments of self-control and goal-directed behavior are evident in babies and toddlers, while the growing language skills of the young child permit more internal regulation of ongoing behavior, with increasing levels of flexibility, inhibition, and the ability to plan developing through mid-childhood (Vygotsky, 1962; Romine & Reynolds, 2005; also see Diaz & Berk, 1992). Finally, adolescence and early adulthood brings more sophistication and efficiency, increased organization, flexibility, and the capacity for self-monitoring in all cognitive and problem-solving domains (Passler, Isaac, & Hynd, 1985; Chelune & Baer, 1986; Stuss & Anderson, 2004; Romine & Reynolds, 2005).

The developmental trajectories of noncognitive (e.g., social-emotional) functions, those associated with the VMPFC, are much less well studied, but recent progress has been made (see review by Fernandez-Duque, Baird, & Posner, 2000). It appears that young children already possess the regulatory underpinnings of noncognitive control associated with the OFC and ACC, while the cognitive EFs, associated with the maturation of the DLPFC, develop through childhood and adolescence (Stuss & Anderson, 2004; Hongwanishkul, Happaney, Lee, & Zelazo, 2005). Case studies of children with brain damage inform us that early damage to these regions is associated with disruptions in social skills (including empathy), which may have greater implications for long-term functioning than cognitive changes (Eslinger 1996). Noncognitive functions also appear to have a protracted developmental course (Eslinger, 1996; Hongwanishkul et al., 2005). A recent study in young children highlighted that these functions also develop rapidly during the preschool years and that they may follow a somewhat different time course than the cognitive executive functions discussed above (Hongwanishkul et al., 2005; Kerr & Zelazo, 2004). Thus we see that the developmental course of the different regulatory functions is variable, with skills emerging sequentially through childhood, adolescence, and early adulthood. This progression reflects the continued development of the anterior cognitive systems (Denkla, 1996) and, in particular, the development of inhibitory controls (Barkley, 1997).

Having reviewed the development of the relevant structures and their function, we shall now examine the interplay of the components of control and regulation.

Executive Function and Self-Regulation

Unlike most traditional models of EF, which stress cognitive control, many newer models separate EF into cognitive and social-emotional subfunctions. Dennis (2006) outlines a multilevel system that includes traditional EF (working memory, inhibition) and social-emotional processing. Powell and Voeller (2004) describe three domains of self-regulation: cognitive, behavioral, and emotional regulation. Similarly, Gioia and colleagues (Gioia, Isquith, Guy, & Kenworthy, 2000) also define three dimensions for EF: (a) the *metacognitive* factor (working memory, initiate, plan/organize, task monitor), which reflects cognitive problem solving; (b) the *behavioral regulation* factor (inhibit, self-monitor), which captures inhibitory control of behavior; and (c) the *emotional regulation* factor (emotional control, shift), which encompasses emotional control of behavior. Their instrument—the BRIEF (Behavioral Rating Inventory of EF; Gioia et al., 2000)—rates the behavioral expression of EF (as distinct from the cognitive expression; Gioia, Isquith, Retzlaff, & Pratt, 2001; Gioia, Isquith, Retzlaff, & Espy, 2002). Eslinger and Grattan (1993) posit a "social executor" as a coordinated circuit operating with (as opposed to entirely independent) of EF. In this model, cognitive and metacognitive strategies are within the purview of the EF system, while an emotional regulation system controls affective responses between the person and the environment, social interactions, motivation, and empathy. In the context of attention-deficit disorders and development, Barkley (1997) has also argued that EF is inherently social and that the EF system is unique to humans because of the evolution of increased social complexity.

By contrast, Stuss has argued persuasively that, rather than contain the social-emotional dimension, EF lies within a hierarchy of self-organization that includes self-awareness (Stuss & Anderson, 2004). In this model, self-awareness includes the components motivation and metacognition (the capacity to reflect on one's mental processes or "flexible access to one's own mind" (Dennis, 2006, p. 142) and is mediated by the OFC (particularly in the right hemisphere). The OFC system is involved in the appreciation of humor, theory of mind, moral evaluation, and regulation of social behaviors, and deficits in these areas are borne out in both lesion and imaging studies (Stuss & Anderson, 2004). In Stuss' view, EF is at the middle level, receiving input from and, in turn, modulating more basic domain specific processes below, and receiving modulatory input from the OFC system above (Stuss, 1992, 2007). Thus, Stuss places EF in the middle between the basic processes and the "self," the latter being involved in motivation and values (Stuss, 2007). Nonetheless, this model emphasizes the important interplay between the cognitive and noncognitive elements in the regulatory scheme.

One additional recent dichotomy is that of "hot" versus "cool" executive functions. The cognitive components discussed above in association with the DLPFC have been termed "cool," as distinct from the "hot" EFs linked anatomically with the orbitofrontal and ventral aspects of the frontal lobes (Happaney, Zelazo, & Stuss, 2004; Kerr & Zelazo, 2004; Geurts, van der Oord, & Crone, 2006). Hot EFs subsume social rules of behavior, emotional saliency and reward processing, and emotional control (Rolls, 2004). Regulatory tasks would include self-determination, self-awareness, self-monitoring and flexibility, and choice of goals and prioritizing, with damage to the corresponding brain areas leading to difficulties in motivation and affective decision making (Rolls, 2004). This dichotomy underscores further the two separate properties of the regulatory system: the cognitive and the affective/motivational.

In summary, the concept of EF has evolved to either encompass or complement the growing understanding of the role of social, emotional, and self-oriented psychological processes in overall mental regulation. The details of this cognitive–noncognitive interface are the focus of ongoing research. Much research from structural and developmental studies has already pointed to the complex spatial and temporal interplay between these realms. Enough is known to encourage an integrated approach to academic learning. We now turn to a model from educational psychology that echoes these two regulatory domains, and brings noncognitive elements—and, in particular, motivation—into a framework for addressing the problems of challenged students.

Self-Regulated Learning (SRL): The Motivational Link

The theory of self-regulated learning (SRL) was introduced by educational psychologists to identify behaviors that distinguish proficient learners, to delineate processes that support effective classroom instruction, and as a framework for a program to promote educational success (Lienemann & Reid, 2006; Pintrich, 1989, 1999; Zimmerman, 2002). SRL involves self-generated processes that students use to guide, monitor, and direct the success of their performance and to manage and direct interaction with the learning environment (Pintrich, 1999; Bashir & Singer, 2006). SRL is clearly dependent on the interplay between cognitive and social-emotional processes, including affect regulation, motivation, and self-concept (Pintrich, 1999; Wolters, 2003). SRL processes work in parallel with EF, as conceived above, in the regulation of the learner's environment (Bashir & Singer, 2006). SRL theory delineates three main component processes that are used by a student to regulate behavior and control their learning environment in pursuit of (self-) identified goals. We focus on the two components most relevant to our discussion.

The first of these is a *cognitive* component that involves information processing (the what, when, and how of learning) (Pintrich & DeGroot, 1990). Students use a variety of techniques and strategies as they exercise the *cognitive* and *metacognitive* subprocesses. *Cognitive strategies* include rehearsal of information (supporting memory and working memory), followed by elaboration and organization (supporting further integration and synthesizing; Pintrich, 1999; Weinstein & Mayer, 1986). In this way, the effective student initially memorizes and learns terms and factual material from lectures, notes, and texts, then elaborates on and integrates this material with past knowledge, connects material from several sources, and formulates original beliefs and hypotheses based on this new knowledge. *Metacognitive strategies* operate on cognitive strategies in order to regulate cognitive operations and thereby direct learning. Reminiscent of the neuropsychological models reviewed above, these strategies include planning (setting goals), monitoring (comparing performance against goal), and evaluating operations and repairing as needed (adjusting behavior in line with goal; Pintrich 1999; Bashir & Singer, 2006; Boekaerts, 1999; Wolters, 2003). In this way, the student sets his or her own educational goals (for example, taking a particular course as a prerequisite for an interesting or satisfying major), monitors his or her schedule to allocate sufficient time and energy to the task (does not cram for an important exam or spend inordinate amounts of time on long-range projects when short-range deadlines are imminent), and continually evaluates and adjusts behavior according to goals (readjusts schedule to allow allocation of additional resources, locates and uses outside assistance as necessary to achieve mastery of information).

The second is an *affective* component, the most relevant aspect of which is motivation (the "why" of learning) (Bashir & Singer, 2006: Boekaerts, 1999; Zimmerman, 1986; Pintrich, 1999). This component, with its important "self" process, relates to the student's personal goals and provides the relevant emotional controls, and influences directly the cognitive and metacognitive components above. The affective component provides the sense of personal self-efficacy and the belief that the task is valuable. This has been shown to be key to maintaining academic motivation (Zimmerman, 1994; Bandura & Schunk, 1981; Bandura, 1997; Wolters, 1998, 2003). Indeed, regulating and maintaining motivation in the learning environment is a critical factor in student success (van Zile, 1999). Wolters (2003) breaks motivation down into components that include choice, effort, and persistence. In this schema, difficult or novel tasks demand a higher level of effort and a greater degree of motivation to sustain the increased effort (Wolters, 2003). Students use motivational strategies in the same way they use cognitive and metacognitive strategies. Such strategies might include self-talk (pep talks such as "I know you can do this" as well as negative performance appraisals such as "You are not going to pass this test"), environmental structuring (changing study location, eating or drinking), and self-rewards or punishments (see Wolters, 2003, for a detailed review).

In SRL, these processes integrate to allow the student to plan (set goals), self-monitor, self-evaluate, and change (Bashir & Singer, 2006; Pintrich, 1989). This ability is applied continually during task performance and is thought to be bound tightly to language (Bashir & Singer, 2006) and verbal self-mediation of behavior. Thus, SRL theory posits that cognitive and affective systems work reciprocally in language-based self-regulation of information processing and learning (Diaz & Berk, 1992; Vygotsky, 1962). The metacognitive component directs the use of cognitive strategies; however, this is mediated by the sense of personal choice, efficacy, and motivation that the student brings to the table, which is not central in most models of EF. Indeed, this option of choice is absent in all definitions of executive processes.

SRL and Higher Education

The integrated mental process we have described here is essential to optimal participation in higher education, especially for students with learning disorders (Reis, McGuire, & Neu, 2000; Ruban, McCoach, McGuire, & Reiss, 2003). The *self-regulated college student*, possessing this ability, uses cognitive strategies to promote deep learning of information (elaboration and organization). This student has learned how to use various metacognitive strategies (planning, evaluating, and monitoring) as an active process guided by inner speech (Singer & Bashir, 1999; Bashir & Singer, 2006; Iran-Nejad, 1990). He or she maintains intrinsic goals to support his or her investment of time and effort, and to sustain motivation in the face of difficulties. The student is aware of his or her goals and intents, and monitors and allocates available resources (internal and external) to support ongoing effort and engagement. This student knows how to direct his or her own learning process and does not rely on external support to provide structure and motivation; however, the student also knows how to access supports when needed. The student appreciates that he or she possesses the necessary abilities and skills to carry out the task successfully. Finally, this student has exercised a high degree of personal choice in task selection, believes that the task at hand is important, and perceives that his or her personal goals are of value (Bandura & Schunk, 1981).

In contrast, the *dysregulated student* appears not to have an intrinsic ability to direct his or her own learning. This student may instead depend on external support (the "prosthetic frontal lobe" aptly termed by Denkla, 1989). He or she may present as a disorganized individual who fails to sustain energy and effort or follow through with tasks, may be rigid and inflexible, and has trouble using feedback to modify the task approach. This student may have difficulties managing and structuring time, materials, and space (Wolf, 2001). The student appears to lack motivation and does not set goals or plan ahead, may have weak academic skills and less well-developed cognitive strategies (e.g., uses rehearsal to memorize but not elaboration to integrate information) and metacognitive awareness (Trainin & Swanson, 2005). This student typically lacks insight and does not reflect on self and performance. Finally, this student's goals are imposed by others (teacher, parent, etc.) rather than reflecting his or her own desires.

Diagnostic Considerations

Deficits of SRL cut across the diagnostic landscape. In other words, the characteristics of academic dysregulation under review are more likely to be descriptive than diagnostic. Many neurodevelopmental and acquired disorders have been linked with executive dysfunction and learning difficulties. One source (Powell & Voeller, 2004) listed 25 different neuropsychiatric conditions in children and adults that may be mediated by defects in frontal executive circuits. The struggling student with deficits in self-regulation might be diagnosed with a neurodevelopmental disorder such attention-deficit/hyperactivity disorder (ADHD), autism, or a classical learning disability, a psychiatric disorder such as depression or bipolar illness, an acquired condition such as traumatic brain injury (TBI), or no diagnosable disability at all. The assessment of SRL deficits is not meant to substitute for a clinical diagnosis, where appropriate, but to better understand the nature of the executive problems that might accompany these conditions, in service of remediating or accommodating the suffering student.

Assessment of the Regulatory System

The definitions of EF are inextricably bound with its measurement, to the extent that it can be argued that, like IQ, EF is what tests of EF measure (although the utility of this approach has recently been challenged; see Alvarez & Emory, 2006). Available methodology always influences research, and this is seen in the study of executive function. Indeed, Stuss and Levine (2004) argue that the cognitive components are more readily captured by neuropsychological assessment than are affective or social regulatory functions. A discussion of the merits of individual tests of EF is beyond the scope of this chapter; however, the interested reader is referred to a recent comprehensive review and critique of many of the commonly used instruments associated with "frontal lobe" functions (Stuss & Levine, 2004). Because testing of cool EFs is better developed, studies have concentrated on this aspect of the regulatory system. Consequently, less is known about the development or assessment of motivational aspects of the regulatory systems (Stuss & Levine, 2004).

In keeping with our arguments above, the assessment of a student with apparent difficulties in academic self-regulation must be multimodal in nature, combining assessments of both cognitive and motivational components. We lay out a general game plan for conducting this assessment below, which is comprised of thorough history gathering and interview; a functional assessment of strengths, weaknesses, and environmental demands (Chaytor, Schmitter-Edgecombe, & Burr, 2006); and neuropsychological testing using both a psychometric and process approach.

History and Interview

A thorough interview and history will be important for assessing certain components of SRL reflecting the hot EFs that are not amenable to testing (see Mapou, Chapter 10, this volume, for more detail). This interview should include a functional assessment—for example, how is the student functioning currently and historically in the real world? This portion of the assessment forms the basis (and arguably the most important piece) of the clinical database in neurodevelopmental disorders as the clinician begins to identify symptoms, developmental difficulties, educational preparation, family history, and so forth.

The interview should also probe the cognitive component of SRL and inquire as to what cognitive strategies are available (what does the student know) and how the student uses them. The interview should pay particular attention to planning, time management, and organizational strategies. Data about the regulatory component of SRL and EF should also be sought, including the student's goals (e.g., are they internal or extrinsic?), modes of emotional regulation, sense of self-efficacy, and competence as a learner. Particular attention should be paid to probing the student's sense of personal efficacy, locus of control, values, and choices. This portion of the assessment might also include rating scales such as the BRIEF (Gioia et al., 2000) or the Dysexecutive Scale (Burgess, Alderman, Evans, Wilson, & Emslie, 1996). An experimental measure, the Motivated Strategies for Learning Questionnaire, has been developed to capture the learning strategies and motivation of college-age students (Pintrich, Smith, Garcia, & McKeachie, 1993); however, to the best of our knowledge, this is not available as a clinical instrument. Information about changes in patterns of strengths and weaknesses over time also provides important data about these functions.

Neuropsychological Testing

Decades of studies have delineated batteries for the assessment of frontal lobe function, incorporating many of the commonly used tests familiar to neuropsychologists. Most practicing neuropsychologists (and many researchers) adhere to a restricted number of tests that they believe capture the essence of EF as they understand the concept. We do not discuss or critique this approach but encourage the interested reader to see Stuss and Levine (2004) for an excellent discussion. We do endorse a flexible approach combining well-understood and standardized instruments with a qualitative and process-oriented analysis of strategy use.

This flexibility is most critical when we attempt to assemble batteries that might measure the social or affective component of regulatory disorders, in particular, motivation. One approach is to use instruments that present risky affective decision-making tasks, such as the Iowa Gambling Test (Bechara et al., 1994; also see Manes et al., 2002) and the Everyday Test of Attention (Shallice & Burgess, 1991). Another such test is the Strategies Application Test (Levine et al., 1998) in which subjects select among target stimuli with different reward contingencies. This instrument has been shown to be sensitive to damage in the ventral areas of the OFC (Levine et al., 1998).

An important recent methodological contribution is the Delis-Kaplan Executive Functioning System (D-KEFS) (Delis, Kaplan, & Kramer, 2001), a new instrument that includes nine different subtests of different aspects

Table 9.1 D-KEFS Subtests

- Cognitive:
  - Sorting Test (problem solving and shifting)
  - Verbal and Design Fluency Tests (fluency in verbal and spatial domains)
  - Color Word Interference Test (verbal inhibition)
  - Tower Test (planning and impulse control)
- Conceptual:
  - Sorting Test (verbal and spatial concept formation)
  - 20 Questions Test (generating and testing hypotheses, abstract thinking)
  - Word Context Test (deductive reasoning)
  - Proverb Test (metaphorical thinking)

of EF and regulation. The D-KEFS is the first standardized battery designed for assessing multiple factors of executive and regulatory functioning in patients between ages 8 and 89. It has been conormed extensively on a large national sample, rectifying some of the interpretive problems inherent in informally selected batteries. The domains of assessment include inhibition, flexibility, planning, impulse control, conceptual and abstract thinking, concept formation, and creativity. The design of the instrument is faithful to the process approach (Kaplan, 1988) (see Table 9.1). It allows for evaluators to administer the entire battery or choose among nine carefully selected subtests as they generate and test hypotheses about performance for an individual patient. Examiners may pick and choose among tests of cognitive, inhibitory, and conceptual functions. In this way, a profile of different regulatory abilities may be elucidated, errors may be evaluated, and strategies employed in task solution may be analyzed. Because this instrument offers a choice of tests that have been conormed on the same population, the D-KEFS adds statistical rigor to the personally chosen clinical and research battery.

As discussed above, neuropsychological testing often is best suited to the cool EFs and to abstract concept formation. We stress that since so many different areas may be impacted by regulatory difficulties, testing should employ a number of different tests of the fractionated skills we have discussed, as no single test will capture all of the components. The examiner should also keep in mind that generating a score profile of strengths and weakness on a battery of EF tests alone will not be sufficient. Again, we want to emphasize that a score profile will not be diagnostic because of the lack of specificity of executive dysfunction for a particular neurodevelopmental disorder. However, the history and results of the interview, complete with a functional assessment of the subject's other strengths and weaknesses paired with the regulatory control demands of his or her environment, will serve to flesh out the profile.

It has been argued that neuropsychological testing of EFs is not valid ecologically because the structured test setting itself does not capture the real-world difficulties of patients with regulatory problems (Brown, 2006; Rabbit, 1997). For this reason, we stress that the neuropsychological assessment of such difficulties should include not only a flexible, wide battery of tests but also a qualitative or process interpretation of the cognitive testing. This approach (Kaplan, 1988) is based on the fundamental assumption that analysis of the underlying *processes* leading to a specific behavior is as important as the test data itself. Further, allowing subjects to employ different strategies to solve various problems and assessing the different ways they approach the task allows a less-structured view of the test situation itself and may increase the ecological validity of the test results.

Applying the Model

We now turn to the ways in which different defects in an integrated regulatory system give rise to the range of dysexecutive behavior seen in the different neurodevelopmental disorders.

Recent work in ADHD provides an excellent example of this reasoning. Sonuga-Barke (2003) has delineated two neuropsychological pathways in the dysfunction of ADHD. The "dysexecutive" circuit impacts effortful control and implicates anterior regions of the frontal lobe. The other "motivational" circuit involves reward processing and delay of gratification, and implicates limbic regions. Thus, two parallel pathways may underlie this one condition and may account for some of the variability in clinical presentation and in research findings (Sonuga-Barke et al., 2003; Castellanos, Sonuga-Barke, Milham, & Tannock, 2006). Castellanos and colleagues (2006) suggest that differential dysfunction in these two subsystems determines clinical subtype, with the "dysexecutive" correlating with the inattentive subtype, and the "motivational" correlating with the impulsive subtype.

Thus, one neurodevelopmental disorder may be classified according to both cognitive and motivational aspects of the disorder. These correspond to separate yet interacting neuroanatomy, related to different symptom profiles and (perhaps) different treatment needs. These systems operate reciprocally throughout development such that deficits in one may produce or modify expression of the functions of the other (e.g., motivational and reward deficits can constrain development of certain cognitive control processes and vice versa). Similarly, different disorders may be associated

Table 9.2 Executive and Regulatory Functions Relevant to College

Organize (space and materials)
Manage time (plan and prioritize)
Task initiation and follow-through
Sustain energy and effort
Flexible problem solving
Generate alternate solutions
Switch among tasks
Working memory
Monitor output (especially in relation to future goals)
Use feedback to adjust performance
Set goals and make choices
Evaluate social-emotional cues
Regulate emotions
Maintain motivation

with varying deficits of hot versus cool processing. For example, it has been suggested that autism may involve deficits in the hot areas of motivation and social emotion, while ADHD may be associated with cooler cognitive and attentional problems (Zelazo & Müller, 2002; Castellanos et al., 2006; Sonuga-Barke, 2003).

This sort of analysis helps explain how we can have so many different conditions (no fewer than 33 according to Eslinger, 1996) that have been reported to involve core deficits in EF. Rather than hunt for that defective EF core for each disorder, we can begin to conceptualize neurodevelopmental disorders of regulation along separable dimensions with concomitant cognitive and social-motivational symptoms in different combinations and at different points in development. In its dimensional approach, this parallels the theory of self-regulated learning. Together, this introduces the concept of an "academic regulatory system" comprised of traditional executive functions, social-emotional functions, metacognition, academic strategy use, and personal motivation and choice (see Table 9.2). We believe that these domains likely cut across many neurodevelopmental disorders and that they be applied as a descriptor and not as a diagnostic label. We assert that skills in this area are quite amenable to remediation and accommodation; addressing weak regulatory skills may alleviate considerable academic and personal distress in the struggling student and thus foster a successful academic outcome.

Table 9.3 Parallel Regulatory Systems

Dorsolateral System (Executive Functions)

- Cognitive processing
  - Working memory
  - Set shifting
  - Perseveration
  - Integrates domain specific and sensory information with posterior cortical regions
  - Monitors output (with motor systems)

Ventromedial System (Self-Regulation)

- Social and emotional processing
- Motivation
- Self awareness
- Choice
- Participates in goal setting and affective decision making
- Processes saliency and rewards (with limbic systems)

Conclusions

The model we have outlined involves regulatory control through two interacting components: one cognitive, comprised of the familiar EF, and the other, motivational/self-regulatory (SR) (see Table 9.3). These EF and SR components may be traced to different brain regions that work together via the neuroanatomical connections between the cortical and limbic areas, which mediate interactions among cognitive, emotional, and motivational states. The broader concept of "regulatory disorders" that impact cognition, motivation, and self-awareness (as opposed to strictly cognitive "executive function disorders") is certainly not original (Stuss & Levine, 2004; also see Gioia et al., 2002). However, it has not been translated fully into a greater understanding of how deficits in cognitive EFs interact with social, emotional, and affective systems in neurodevelopmental disorders, particularly in young adults. We have discussed the dysregulated college student and have attempted to outline those regulatory functions that may be most relevant to college (see Table 9.3). As we wait for this relationship to be further elucidated, we believe that it is important to assess, remediate (where feasible), and accommodate both systems in young adults with academic difficulties of regulatory origin.

Future Directions

The logical next step is the validation of the "academic regulatory system" in college students with and without disabilities. It will be important to assess the level of motivation, choice, strategy use, and executive skill in college students with a variety of disabilities to establish: (a) the validity of the academic regulatory deficit discussed above, and (b) whether there are perhaps different profiles in different disabilities. This would enable us to design intervention programs that might target these profiles in different ways.

Noncognitive domains of regulation such as motivation and choice have been attracting more attention from basic brain researchers. Assessing these functions in students with neurodevelopmental learning problems, as well as in normal college-aged students, will be critical for dissecting the complex interactions of these parallel systems.

In terms of assessment, we have outlined a battery that includes both a standardized and a process approach to executive function and other regulatory domains. The use of this sort of battery should be validated in a variety of students with nonspecific learning difficulties as well as in the assessment of students with known neurodevelopmental disorders.

Finally, further functional neuroimaging studies, using cognitive and noncognitive probe tasks in subjects with a range of neurodevelopmental disorders, would help elucidate the underlying brain mechanisms of regulatory dysfunction in this population. This approach should enhance the understanding of individual and group differences in this population and benefit the design of more effective interventions.

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