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Problems with the Concept of Executive Functioning

The basis for the concept of executive functioning (EF) arose in the 1840s in the initial efforts by scientists to understand the functions of the frontal lobes generally and the prefrontal cortex (PFC) specifically (Harlow, 1848, 1868; Luria, 1966). Indeed, the concept predates the term "EF" by more than 120 years. The concept of EF was at first defined by default as what the prefrontal lobes do (Pribram, 1973, 1976); they are, as Pribram said, the executive brain. The term "EF" came out of these earlier efforts to understand the neuropsychological functions mediated by the prefrontal or premotor regions of the brain. This history has led to a conflating of the term "EF" with the functions of the PFC and vice versa.

Over time, this conflation has led to a circularity of reasoning in that the functions of the PFC are said to be EF while EF is then defined back to the functions of the PFC. It has also led to a slippage in the discourse on EF between two separate levels of analysis (Denckla, 1996). One is the neuropsychological level involving thought (cognition), emotion, and verbal or motor action (behavior); the other is the neuroanatomical level involving the localization of those neuropsychological functions to specific regions of the brain and their physiological activity. But EF is not exclusively a function of the PFC given that the PFC has various networks of connections to other cortical and subcortical regions as well as to the basal ganglia, amygdala and limbic system, and cerebellum (Denckla, 1996; Fuster, 1989, 1997; Luria, 1966; Nigg & Casey, 2005; Stuss & Benson, 1986). The PFC may well engage in certain neuropsychological functions that would not be considered to fall under the umbrella of EF, such as simple or automatic sensory–motor activities, speech, and olfactory identification, to name just a few.

Thus, despite an extensive history concerning the nature of EF and of the functions of the PFC, several significant problems continue to exist in the definition of the term "EF," its conceptualization, and its measurement. EF is a term describing psychological functions and is therefore a construct at the psychological level of analysis. If our understanding of EF is to advance, the concept of EF and its nature must be defined separately and specifically at the psychological level without reference to the neurological level being an essential part of that definition. Such a cross-referencing of levels is of interest to neuropsychology in determining what specific brain regions engage in what specific functions. But this activity requires that we have such functions properly defined at the psychological level first before we can determine what brain networks give rise to that psychological function. If EF and its larger purposes in human life are not well defined and developed, only confusion can reign at the neurological level as one searches for the neural networks that supposedly underlie a vaguely defined and poorly crafted psychological construct, perhaps in vain.

This book was written to address four related problems that currently exist in the concept of EF. First, there is neither a consensus definition of EF nor an explicit operational definition of the term that can simply, clearly, and efficiently determine which human mental functions can be considered executive in nature and which ones cannot be so classified. Simply put, What is EF? When definitions are too general or vague, as is EF, they leave considerable opportunity for misinterpretation as well as for including within the term's conceptual realm excessive semantic baggage that would easily have been pared away had the definition had greater clarity and precision.

The first problem leads to the second. How is EF to be assessed? If the term is not defined operationally then anything goes; any measure or test can be declared to be executive in nature by mere assertion alone or through its alignment with any of 33 constructs attributed to it (Eslinger, 1996). As a case in point, my colleagues and I declared the Simon game to be a test of EF in one of our studies on adult attention-deficit/hyperactivity disorder (ADHD) (Murphy, Barkley, & Bush, 2001). This game requires one to replicate increasingly longer sequences of musical notes by depressing keys corresponding to each note. We asserted that this was a test of EF because it assessed nonverbal working memory and that it was similar to that of digit span in the verbal domain; this assertion went unquestioned in reviews of our paper. Granted, working memory has been defined as holding information in mind that is used to guide subsequent behavior, and this game seems to fulfill that definition. But then why is holding information in mind (working memory) itself an executive function? As a consequence of lack of definitional clarity, many tests and measures have been declared to be executive functioning tests without much basis for challenge. And so we cycle back to the first problem—the absence of an operational definition of EF, which then spawns the use of any variation of a test a researcher or clinician wishes to use to measure EF. To make the tautology complete, models of EF are then empirically developed based on tests of EF. Yet if there are problems in the choice of what measures assess EF, then these problems carry forward to create problems in the theories constructed upon them. Not the least of these problems is that of method variance—the theory will largely reflect the types of tests used to construct the model rather than being based on conceptual clarity and operational definition.

This state of affairs is actually related to a third larger problem this book intends to address: the lack of a coherent theory of EF. Theories are not just constructs, but mechanisms, which is to say explanations of relationships among constructs. They address the questions of How does EF work? or What does it do? Without a coherent theory of EF, constructs have multiplied to the extent that 33 or more have been claimed to be involved in this "metaconstruct" or umbrella term (Eslinger, 1996). The relationships among these various constructs have only been vaguely explained. For instance, are response inhibition and planning and problem solving related to each other? If so, in what way are they interactive? If not, why not, given that they have all been considered to be EF? So they must have some relationship to each other or else combining them under the umbrella construct of EF is nonsensical. If our goals are precision of thinking and definition as well as utility of prediction, this situation is patently unacceptable. Prediction requires explanation or understanding, and that requires propositions about how things relate to each other. Listing a set of constructs that are presumed to make up an umbrella, family, or metaconstruct will not suffice. There must be some operational definition as to what makes that list executive in nature and just how the constructs being labeled as EF relate to each other. In the absence of such an explanation, there is no theory of EF.

All three of these problems pertain to a much larger fourth problem. That issue is contained in the question Why EF? (Barkley, 2001). This is a different question from those raised above. Without answering it one is likely to get only partial answers to the other questions. To answer why humans developed EF, one must think about ultimate ends. For what purposes does EF exist? What is it accomplishing? What problem(s) in human daily existence does this mental mechanism, or more likely suite of mental mechanisms, exist to solve? The only explanation for that question comes out of evolution. Thus, this book will take an evolutionary or "adaptationist" stance in addressing the question Why EF?

This book seeks to address all four of these issues. Each will now be discussed in more detail to support the contention that these *are* serious problems even if 160+ years of history has made it seem as if they had been resolved. If there is to be further advancement of our understanding of the concept of EF, these problems stand in our way.

What Is EF?: The Lack of an Operational Definition

Sidebar 1.1 lists a variety of definitions of EF. There is much cross-referencing among many of them, but this does not clarify or operationalize the term any better; it just sidesteps the problem and kicks the conceptual can further down the road. To illustrate the point, consider one of the most popular definitions appearing in the literature on EF, particularly in research on normal children and people having ADHD (Hinshaw, Carte, Fan, Jassy, & Owen, 2007; Martel, Nikolas, & Nigg, 2007; Rhodes, Coghill, & Matthews, 2005; Wilding, 2005; Willcutt, Doyle, Nigg, Faraone, & Pennington, 2005). While many of the authors citing this definition attribute it to Welsh and Pennington (1988), the latter authors credit it to Luria (1966). But Luria credits it to Bianchi (1895, 1922) as well as to the writings of Bekhterev (1905–1907). The definition states:

> Executive function is defined as the ability to maintain an appropriate problem-solving set for attainment of a future goal. (Welsh & Pennington, 1988, pp. 201–202)

Neither this definition nor any of those in Sidebar 1.1 indicate which mental function or tests of that mental function would be considered "executive" and which would not qualify for that distinction. Clearly this is not a single "ability." Welsh and Pennington (1988) went on to specify the components of EF as being

> a) an intention to inhibit a response or to defer it to a later more appropriate time; b) a strategic plan of action sequences; and c) a mental representation of the task, including the relevant stimulus information encoded in memory and the desired future goal-state. (p. 202)

SIDEBAR 1.1. A Sampling of Definitions of EF

The frontal cortex is critically involved in implementing executive progammes where these are necessary to maintain brain organization in the face of insufficient redundancy in input processing and in the outcomes of behavior. (Pribram, 1973, p. 301)

The executive functions consist of those capacities that enable a person to engage successfully in independent, purposive, self-serving behavior. They differ from cognitive functions in a number of ways. Questions about executive functions ask *how* and *whether* a person goes about doing something (e.g., Will you do it and if so, how?); questions about cognitive functions are generally phrased in terms of *what* or *how much* (e.g., How much do you know? What can you do?). (Lezak, 1995, p. 42)

The executive functions can be conceptualized as having four components: (1) volition; (2) planning; (3) purposive action; and (4) effective performance. Each involves a distinctive set of activity-related behaviors. All are necessary for appropriate, socially responsible, and effectively self-serving adult conduct. Moreover, it is rare to find a patient with impaired capacity for self-direction and self-regulation who has defects in just one of these aspects of executive functioning. Rather, defective executive behavior typically involves a cluster of deficiencies of which one or two may be especially prominent. (Lezak, 1995, p. 650)

The term "executive functioning" generally refers to the mechanisms by which performance is optimized in situations requiring the operation of a number of cognitive processes (Baddeley, 1986). Executive function is required when effective new plans of action must be formulated, and appropriate sequences of responses must be selected and scheduled. (Robbins, 1996, p. 1463). [Robbins goes on to identify working memory, inhibition, and monitoring of behavior relative to internal affective and motivational states as likely components of EF.]

[Executive functions are] a range of poorly defined processes which are putatively involved in activities such as "problem-solving," . . . "planning" . . . "initiation" of activity, "cognitive estimation," and "prospective memory." (Burgess, 1997, p. 81)

The executive functions are a collection of processes that are responsible for guiding, directing, and managing cognitive, emotional, and behavioral functions, particularly during active, novel problem solving. The term *executive function* represents an umbrella construct that includes a collection of inter-related functions that are responsible for purposeful, goal-directed, problem-solving behavior. (Gioia et al., 2000, p. 1)

(*continued*)

SIDEBAR 1.1. (*continued*)

Executive function (EF) is an umbrella term that incorporates a collection of inter-related processes responsible for purposeful, goal-directed behavior (Gioia, Isquith, & Guy, 2001). These executive processes are essential for the synthesis of external stimuli, formation of goals and strategies, preparation for action, and verification that plans and actions have been implemented appropriately (Luria, 1973). Processes associated with EF are numerous, but the principal elements include anticipation, goal selection, planning, initiation of activity, self-regulation, mental flexibility, deployment of attention, and utilization of feedback. (Anderson, 2002, p. 71)

Executive functions refer to a collection of interrelated cognitive and behavioral skills that are responsible for purposeful, goal-directed activity, and include the highest level of human functioning, such as intellect, thought, self-control, and social interaction (Lezak, 1995, p. 42). More specifically, executive functions are responsible for coordinating the activities involved in goal completion such as anticipation, goal selection, planning, initiation of activity, self-regulation, deployment of attention, and utilization of feedback. (Anderson et al., 2002, p. 231)

Executive functions is a generic term that refers to a variety of different capacities that enable purposeful, goal-directed behavior, including behavioral regulation, working memory, planning and organizational skills, and self-monitoring (Stuss & Benson, 1986). (Mangeot et al., 2002, p. 272)

EF encompasses metacognitive processes that enable efficient planning, execution, verification, and regulation of goal directed behavior. There is no single agreed upon definition of EF. (Oosterlaan, Scheres, & Sergeant, 2005, p. 69)

[Executive functioning is] an umbrella term for various cognitive processes that subserve goal-directed behavior (Miller & Cohen, 2001; Luria, 1966; Shallice, 1982). EF is especially important in novel or demanding situations (Stuss, 1992) which require a rapid and flexible adjustment of behavior to the changing demands of the environment (Zelazo, Muller, Frye, & Marcovitch, 2003). (Huizinga, Dolan, & van der Molen, 2006, p. 217)

Executive functions have been notoriously difficult to define precisely. For example, Sergeant, Geurts, & Oosterlaan (2002) note that there are "33 definitions of EF" (p. 3). However, most investigators would agree that EFs are self-regulatory functions incorporating the ability to inhibit, shift set, organize, use working memory, problem solve, and maintain set for future goals (Pennington & Ozonoff, 1996; Sergeant et al., 2002). (Seidman et al., 2006, p. 166)

[Executive functions comprise] a family of cognitive control processes that operate on lower-level processes to regulate and shape behavior. (Friedman et al., 2007, p. 893)

> The umbrella concept of "executive control" encompasses those cognitive functions involved in the selection, scheduling and coordination of the computational processes responsible for perception, memory and action (Norman & Shallice, 1986; Shallice, 1994). [EF enables] the maintenance of behavior on a goal set and calibration of behavior to context (Pennington & Ozonoff, 1996). (Ciairano, Visu-Petra, & Settanni, 2007, p. 335)
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> EF involves developing and implementing an approach to performing a task that is not habitually performed (Mahone et al., 2002). The early development of skills that support EF includes the ability to maintain problem-solving set for attainment of future goal (Welsh & Pennington, 1988), and encompasses an individual's ability to inhibit actions, restrain and delay responses, attend selectivity [*sic*], self-regulate, problem solve, be flexible, set goals, plan, and shift set (Senn, Espy, & Kaufmann, 2004; Singer & Bashir, 1999). (Mahone & Hoffman, 2007, pp. 569–570)
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> Executive functioning has been defined as a set of regulatory processes necessary for selecting, initiating, implementing, and overseeing thought, emotion, behavior, and certain facets of motor and sensory functions (Roth, Isquith, & Gioia, 2005). (Schroeder & Kelley, 2009, pp. 227–228)
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> In general, executive function can be thought of as the set of abilities required to effortfully guide behavior toward a goal, especially in nonroutine situations. Various functions are thought to fall under the rubric of executive function. These include prioritizing and sequencing behavior, inhibiting familiar and stereotyped behaviors, creating and maintaining an idea of what task or information is most relevant for current purposes (often referred to as an attentional or mental set), providing resistance to information that is distracting or task irrelevant, switching behavior task goals, utilizing relevant information in support of decision making, categorizing or otherwise abstracting common elements across items, and handling novel information or situations. As can be seen from this list, the functions that fall under the category of executive function are indeed wide ranging. (Banich, 2009, p. 89)
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> EF includes processing related to goal-directed behavior, or the control of complex cognition, especially in nonroutine situations (Banich, 2009; Fuster, 1997; Lezak, 1995). (McCabe, Roediger, McDaniel, Balota, & Hambrick, 2010, p. 222)

But why is only this set of three mental abilities included in EF and not others? Why is maintaining an appropriate problem-solving set toward a future goal considered to be the essential nature of EF? Wouldn't it be more precise and simpler to just make these three components part of the definition of EF itself? For instance, EF is the inhibition of a response or its deferral to a more appropriate time so as to develop a mental representation of the task and desired future goal, develop a strategic plan of action sequences to attain it, and maintain an appropriate problem-solving set toward that future goal.

For instance, why is it that detecting and responding to an X on a computer screen while inhibiting a response to an O is an executive function test, while reading an X when it appears is not? Or why is stating the color of ink in which a color word (i.e., "red") is printed considered an executive function but reading the actual printed word is not? Or why is pointing to a location where a picture or geometric design appeared in a matrix after it has disappeared for a few seconds an indication of EF, while pointing to the same design in the matrix while it is still present is not an EF? Why is sorting cards into categories based on your own sorting rule not an EF, while sorting them so as to discover an examiner's undisclosed sorting rule is considered an EF? Such distinctions cry out for an operational definition of the term "EF," yet none that is currently available can manage even these distinctions.

To muddy these waters even further, consider the fact that Eslinger (1996) described a conference (which I attended) held in January 1994 at the National Institute of Child Health and Human Development (Washington, D.C.) in which 10 experts in EF were asked to generate terms that would be considered executive functions. They came up with 33! The greatest agreement (endorsed by 40% or more of the participants) existed for the following six components of EF: self-regulation, sequencing of behavior, flexibility, response inhibition, planning, and organization of behavior. Why these? Using a consensus of opinion is akin to conducting science by democratic vote, fashion, or mob rule; it does nothing to advance the clarity or operationalizing of a definition of a scientific construct such as EF. As another example of the dog's breakfast of constructs that EF has become, Best, Miller, and Jones (2009) reviewed the evidence on the development of EF and identified at least 15 components in contemporary research. Among these, Best et al. (2009) settled on the most important four for their review based largely on the frequency with which they had appeared in earlier research. They argued that these components likely develop at different rates and probably in the following sequence: (1) inhibition, (2) working memory, (3) shifting, and (4) planning (which includes problem solving). Why just classify these four as EF out of the 15 identified in the review? The fact that measures of these four constructs often outnumbered those of others in the research under review does not necessarily make them important for understanding EF; it is only an indication of a psychometric popularity contest.

Again, however, one can rightly ask why these constructs of response inhibition, working memory, planning, and flexibility or set shifting are often classified as EF but visual–spatial perception, speech and language, emotion, and motor speed and coordination, among others, are not (Lyon & Krasnegor, 1996; Stuss & Benson, 1986)? Surely one can argue that the latter mental abilities help to maintain problem solving for attainment of a goal. If you cannot locate your position in space, there are many goals you are not going to be able to pursue. What is the essential nature of EF that renders the former within its domain but excludes the latter? Given such a polyglot of constructs incorporated under the EF tent, it is no wonder that the field has made little headway in its development of useful operational definitions of EF in the past 30 years. Apart from the fact that many of these EF components can be largely (though not entirely) localized to various regions of the PFC, just what makes these mental capacities or modules an EF at the neuropsychological level of definition and analysis? Are we to be stuck with mere reductionism to the neuroanatomical level as the only means of defining what constitutes EF?

How Is EF Assessed?: The Poor Ecological Validity of Psychometric Tests of EF

The second problem this book intends to address is rooted in the first problem—absent an operational definition of EF, what methods will qualify as measures of it? The field of neuropsychology seems to have answered this question by largely focusing on the use of psychometric tests as the principal or sole basis for evaluating EF deficits in clinical patients and in research studies. Indeed, it seems that the field of neuropsychology is synonymous with psychometrics. Other than convenience or tradition, why are tests given in clinical or lab settings the widespread basis for measuring EF, and not direct observations of human action in natural settings or rating scales completed by patients and others? Over the past 40 years occasional voices have been raised warning that neuropsychological tests of EF were problematic. The tests were unlikely to be capturing much of what is considered to be the essence of EF or its important features as humans use it in their daily life or to be adversely affected by injuries to the PFC (Barkley, 2001; Dimond, 1980; Dodrill, 1997; Lezak, 2004; Rabbitt, 1997; Shallice & Burgess, 1991). The warnings have largely gone unheeded as EF tests and test batteries have come to represent an inchoate gold standard for determining EF and its deficits. With very few exceptions, the vast majority of studies published on the topic of EF have used EF tests or batteries of tests to determine whether certain disorders impaired EF or how EF developed in normal samples.

This would be fine if these tests were highly reliable and well validated. But they are not. Research consistently shows such tests to be of only moderate or lower reliability (Lezak, 2004; Rabbitt, 1997). They are also of limited utility for detecting PFC injuries (Dodrill, 1997). For example, only a minority of patients experiencing frontal lobe injuries or those with ADHD known to have a frontal lobe disorder score in the impaired range on these measures. In contrast, consider the fact that the vast majority of such patients place in that range of impairment on ratings of EF in daily life activities or in direct observations of EF performance in natural settings (Alderman, Burgess, Knight, & Henman, 2003; Barkley & Murphy, 2010; Burgess, Alderman, Evans, Emslie, & Wilson, 1998; Gioia, Isquith, Kenworthy, & Barton, 2002; Kertesz, Nadkarni, Davidson, & Thomas, 2000; Mitchell & Miller, 2008; Wood & Liossi, 2006). This tells us that people with PFC disorders and injuries have EF deficits in their daily life activities even if the EF tests do not detect them. And it is the deficits occurring in daily life, not those manifested on tests, that are the most important to understand and to clinically assess and rehabilitate or manage.

This leads to the second problem with EF tests. They have little or no ecological validity. In other words, these tests do not correlate well, if at all, with more ecologically valid means of assessing EF in everyday life circumstances. This has been evident repeatedly in studies of these tests in comparison to systematic observations, structured interviews, or ratings of daily self-care and adaptive functioning, and to behavior ratings of EF in adults (Alderman et al., 2003; Bogod, Mateer, & MacDonald, 2003; Burgess et al., 1998; Chaytor, Schmitter-Edgecombe, & Burr, 2006; Mitchell & Miller, 2008; Ready, Stierman, & Paulsen, 2001; Wood & Liossi, 2006). The same problem is evident in children with frontal lobe lesions, traumatic brain injuries (TBI), or other neurological or developmental disorders (Anderson, Anderson, Northam, Jacobs, & Mikiewicz, 2002; Mangeot, Armstrong, Colvin, Yeates, & Taylor, 2002; Vriezen & Pigott, 2002; Zandt, Prior, & Kirios, 2009). This is also the case in both adults with ADHD and children with ADHD followed to adulthood (Barkley & Fischer, 2011; Barkley & Murphy, 2011). If a primary clinical aim is to predict how well an individual will do with executive functioning in the real world of their daily life activities, then EF tests are of minimal or no help.

The results of these various studies usually reveal that any single EF test shares just 0–10% of its variance with EF ratings or observations of

EF in daily adaptive functioning. The relationships are frequently not statistically significant. Even the best combination of EF tests shares just 9–20% of the variance with EF ratings or observations as reflected in these studies (Barkley & Fischer, 2011; Barkley & Murphy, 2011; O'Shea et al., 2010; Ready et al., 2001; Stavro, Ettenhofer, & Nigg, 2007; Zandt et al., 2009). If IQ is statistically removed from the results, the few significant relationships found in these studies between EF tests and EF ratings may even become nonsignificant (Mangeot et al., 2002). Yet these two methods are supposed to be measuring the same construct—EF. In contrast, research has noted moderate relationships between EF ratings and measures of daily adaptive functioning in children with various disorders including TBI (Gilotty, Kenworthy, Sirian, Black, & Wagner, 2002; Mangeot et al., 2002), in adults with ADHD (Barkley & Murphy, 2011; Biederman et al., 2007), in children with ADHD followed to adulthood (Barkley & Fischer, 2011), in people with frontal lobe disorders (Alderman et al., 2003), in college undergraduates (Ready et al., 2001), or in other populations (O'Shea et al., 2010). Something is terribly amiss here if different methods of measuring the same construct are so poorly related to each other and lead to such disparate findings and hence conclusions.

There is also the problem with the low and often nonsignificant predictive validity of EF tests. If EF is such an important, if not *the* most important, mental faculty of humans, as some have argued (Luria, 1966; Stuss & Benson, 1986), then tests of EF or its deficits should be significantly predictive of impairments in various major life activities such as occupational functioning, educational history, driving, money management, and criminal conduct. But they are not or are very poor at doing so (Barkley & Fischer, 2011; Barkley & Murphy, 2010, 2011).

The totality of findings to date concerning the relationship of EF tests to EF ratings and of each to impairment in daily life indicates that EF tests are largely not sampling the same constructs as are EF ratings or direct evaluations of EF in daily life (Alderman et al., 2003; Shallice & Burgess, 1991). It also provides a basis for not accepting EF tests as the primary or sole source for establishing the nature of EF deficits in various disorders or of its development in studies of normal samples. In sum, EF tests should not serve as the gold standard for evaluating EF.

This significant failure of EF tests to relate well to EF ratings, daily life activities, or impairment in major domains of life could well indicate that the tests are not assessing EF. This seems arguable given that many of these tests have been shown to index activities in various regions of the PFC that largely underlie EF. But it is surely unlikely to be the case that EF ratings are not actually evaluating EF. After all, their item content has been drafted directly from various descriptions of EF and from lists of putative EF constructs in the literature as well as from observations and clinical descriptions of patients with PFC lesions believed to manifest the "dysexecutive syndrome" (Barkley, 2011a; Burgess et al., 1998; Gioia, Iquith, Guy, & Kenworthy, 2000; Kertesz et al., 2000). Moreover, as noted above, these ratings are substantially related to impairment in various daily life activities and various domains of adaptive functioning, such as work, education, driving, social relationships, and self-sufficiency, in which EF would surely be operative.

Adding insult to injury in this field of research, the nearly slavish devotion to the use of EF tests as the sole or gold standard for its evaluation has resulted in some serious logical errors in various research studies on EF and reviews of that literature. For instance, my own area of clinical and research specialization is ADHD. The following current situation in this field represents this error:

- The PFC is the "executive" brain (Pribram, 1973).
- ADHD is a disorder arising largely from structural and functional abnormalities in the PFC (Bush, Valera, & Seidman, 2005; Valera, Faraone, Murray, & Seidman, 2007).
- ADHD is largely *not* a disorder of EF (Boonstra, Oosterlaan, Sergeant, & Buitelaar, 2005; Jonsdottir, Bouma, Sergeant, & Scherder, 2006; Marchetta, Hurks, Krabbendam, & Jolles, 2008; Nigg, Wilcutt, Doyle, & Sonuga-Barke, 2005; Willcutt et al., 2005).

The last conclusion was reached because the studies cited above and others (Barkley & Fischer, 2011; Barkley & Murphy, 2011; Biederman et al., 2008) demonstrated that the majority of individuals with ADHD are not impaired on EF tests, even if groups of ADHD cases differ in mean scores from control groups on many such tests (Frazier, Demareem, & Youngstrom, 2004; Hervey, Epstein, & Curry, 2004). So if EF tests are to be the sole standard for assessing the presence of EF deficits, then most cases of ADHD do not have such deficits. Ergo, ADHD is not a disorder of EF in most cases. This logical error has been repeated countless times with other disorders. For instance, a recent study concluded that the risk for developing a substance use disorder in adolescence or young adulthood is unrelated to the presence of EF deficits in childhood or adolescence—a conclusion reached solely on the basis of EF tests (Wilens et al., 2011). Such studies of disorders and the role of EF in them that relied exclusively on the psychometric approach to evaluating EF obviously now have their conclusions greatly restricted by the qualifier "as measured by EF tests." The same caveat applies as well to studies of the normal course of development of EF. These studies will need to be redone using other approaches to evaluate EF before any conclusions about EF involvement in these disorders or normal processes have any validity and generality and so can be taken seriously.

In short, why are putative EF tests so insensitive to injuries of the executive brain—the PFC? Why are they so poorly related to EF ratings and direct observations of EF-related activities in daily human life? And why are these tests so much worse at predicting impairment in adaptive functioning and major life activities than are the EF ratings? A second aim of this book is to bridge this gap between these psychometric versus ethological methods of assessing EF to show how this state of affairs could arise, what it means for conceptualizing EF, and how to resolve it.

How Does EF Work?: The Limitations of Current Cognitive Models of EF

The third problem that arises and contributes to the first two above lies in how EF works. As noted earlier, we can conceptualize EF as a construct or set of constructs. But to know how it works we must propose relationships among constructs and explain how they operate—we must have a theory. The functions of the PFC, or the executive brain, have been the subject of medical and scientific scrutiny for more than 160 years. Initial efforts to elucidate these functions relied largely on the study of the symptoms and deficits evident in individuals who had suffered serious injuries to this region of the brain. Among the first and most famous of such cases was that of Phineas Gage, the railroad foreman who suffered a penetrating head wound that destroyed a large portion of his PFC. This led to drastic alterations in his behavior, personality, and social conduct (Harlow, 1848, 1868). Like Gage, patients with PFC damage studied in these early years demonstrated a lack of initiative or drive, a curtailing of their circle of interests, profound disturbances of goal-directed behavior, a loss of abstract or categorical behavior, and emotional changes, such as a proneness to irritation, emotional instability, and indifference toward their surroundings, often superimposed on depression (Fuster, 1997; Luria, 1966; Stuss & Benson, 1986). Impulsive actions, trivial jokes, and even euphoria were noted to arise from lesions that involved the more basal aspects of the PFC. Just as likely was an adverse impact on moral conduct, independence and self-reliance, financial-economic self-support, effective occupational performance, and socially cooperative activities that all require the capacity for evaluating the longer-term consequences of one's actions as noted in the initial report on Gage (Harlow, 1848).

Luria (1966) gives a fine account of the subsequent history of the study of the functions of the frontal lobes. From him we learn that Hughlings Jackson is said to have viewed the PFC as "the highest motor centres" being "the most complex and least organized centres" (Luria, 1966, p. 221). According to Luria (1966), Bianchi (1895) voiced similar views independently of Jackson, arguing that the frontal lobes contained the most complex forms of reflex activity organized hierarchically into a series of levels that "bring about the widest coordination of sensory and motor elements, utilize the product of the sensory zones to create mental syntheses, and play the same role in relation to the sensorimotor (or kinesthetic) zones that the latter play in relation to the subcortical nuclei" (Luria, 1966, p. 221). This was the integrative function first attributed to the prefrontal lobes. Both Bekhterev (1905–1907) and later Pavlov (see Luria, 1966, p. 222) observed that damaging the prefrontal lobes resulted in a disintegration of goal-directed behavior, which they saw as the principal function of the PFC. This later became the basis for the Welsh and Pennington (1988) definition of EF, as noted above.

Additional subsequent research noted other deficits evident in individuals with damage to the PFC. These included being "easily distracted by extraneous stimuli" (Luria, 1966, p. 224) including extraneous thoughts or patterns of irrelevant mental associations (Luria, 1966, p. 286), and being unable to develop or sustain a readiness for action or intentional quality to their actions. Patients were frequently noted to be hyperactive as a consequence of the poor inhibition of the lower, more automatic forms of behavior. Studies of animals whose PFC had been intentionally ablated manifested similar symptoms and deficits. Hence the integration and execution of goal-directed behavior, the inhibition of more automatic actions and reactions to extraneous stimuli (distractibility), the production of delayed reactions, the evaluation of one's goal-directed actions relative to the external environment, especially in novel circumstances, and the overall intentionality or purposive quality of behavior were all functions attributable to the PFC.

Luria goes on to state that "besides the disturbance of initiative and the other aforementioned behavioral disturbances, almost all patients with a lesion of the frontal lobes have a marked loss of their 'critical faculty,' i.e., a disturbance of their ability to correctly evaluate their own behavior and the adequacy of their actions" (1966, p. 227). Impaired here was a faculty of relational comparisons between the patients' goals, their current actions relative to those goals, their actions relative to others while in pursuit of those goals, and the environmental feedback as to the effectiveness of those actions vis-à-vis the goal. This is similar to the observations of Freeman and Watts (1941) that the frontal lobes are concerned with self-awareness, that is, with foresight and the relation of the self (current) to the self (future). PFC-injured patients also demonstrated a marked impairment in voluntary movement and activity. Such movements are unique to humans. They are a response to either verbal instruction from others or the formation of an intention of their own translated into a self-instruction. Today, these would be considered forms of rule-governed behavior (Hayes, 1989; Hayes, Gifford, & Ruckstuhl, 1996) or what Luria called the regulating functions of speech (1966, p. 250).

Damage to the PFC was typically accompanied by a release of more automatic forms of behavior. For instance, this might be seen in the inappropriate utilization of an object for its intended purposes in the wrong context as described by Lhermitte, Pillon, and Serdaru (1986). It would also be manifest in the perseveration of actions, despite a change in the context that should have led to a termination of those actions, and in impulsive responses to irrelevant events (Luria, 1966). The totality of this pattern of deficits came to be known as a frontal lobe syndrome. Later, when Pribram (1973, 1976) referred to the functions of the PFC as "executive" in nature, this would subsequently lead to the frontal lobe syndrome being known as a "dysexecutive syndrome" (Wilson, Alderman, Burgess, Emslie, & Evans, 1996).

Some contemporary theories of EF are briefly summarized in Sidebar 1.2. My intent here is not to comprehensively review such models or discuss each in detail. But such theories are all fraught to varying degrees with a set of problems. Briefly elucidating those problems will suffice to show that further theory-building about EF is in order.

The Disparity between Models of EF and Deficits in Patients with PFC Disorders

Recall the array of cognitive, behavioral, emotional, social, economic, and moral impairments associated with damage to the human executive brain discussed above and as evident in any neurology or neuropsychology clinic that specializes in their care. Now contrast them with contem-

SIDEBAR 1.2. A Sampling of Theories of PFC (EF) Functioning

Stuss and Benson's Hierarchical Model of EF

A commonly cited early conceptualization of EF was that specified by Stuss and Benson (1986) in their book on the frontal lobes:

> Executive control functions, called into action in nonroutine or novel situations, provide conscious direction to the functional systems for efficient processing of information. . . . The executive function represents many of the important activities that are almost universally attributed to the frontal lobes which become active in nonroutine, novel situations that require new solutions. These behavioral characteristics have been described by many authors and include at least the following: anticipation, goal selection, preplanning (means-end establishment), monitoring, and use of feedback (if–then statements). (p. 244)

In this model, EF refers to four components (anticipation, goal selection, preplanning, and monitoring). In their diagram of PFC functions, Stuss and Benson place these EF components above two other frontal modules that they are said to govern: Drive (drive, motivation, and will) and Sequencing (sequence, set, and integration). In this model, drive and sequencing are not EF. Drive, motivation, and will comprise the first (Drive) of the two modules governed by the EF control system (p. 243). In it, drive refers to basic appetitive states that are basic energizing forces. Motivation is conceived as being more mental/intellectual control of drive states. And "will" is undefined but is implied to be an even higher state that governs motivation, most likely representing consciously conceived wants or desires.

The second of these modules (Sequencing) is said to be involved in organizing and maintaining bits of information into meaningful sequences, such as in the temporal integration and sequencing of behavior. Stuss and Benson cite Fuster's work in support of the existence of this module (see Fuster, 1997). Fuster argued that three subordinate functions are needed to organize and integrate behavior across time: anticipation (the prospective function), provisional memory (working memory), and control of interference (the inhibitory function). To these functions, Stuss and Benson added the synthetic capacity to form sets of related information that allows the production of new, more complex information from available sequences of data. With this also goes the capacity for the integration of a number of related and unrelated sets of information into novel knowledge and hence novel action (see pp. 241–242).

These two modules (Drive, Sequencing) govern the nonexecutive posterior/basal functional systems, such as attention, alertness, visual–spatial, autonomic emotional, memory, sensory/perception, language, motor, and cognition. Interestingly, perched above the EF level and atop all of these components is Self-Awareness, believed to be the highest attribute of the frontal lobes (see Figure 17.4 in Stuss & Benson, 1986). It is viewed as separable from EF and is hierarchically placed above it (pp. 246–247). Noteworthy from this perspective is that self-awareness is implied, if not declared, to be the central executive that determines the activities of the lower level functions, including the EF level.

Fuster's Theory of Cross-Temporal Organization

A widely cited theory of PFC functioning that similarly deals with goal-directed behavior is Fuster's (1997) model of cross-temporal synthesis or integration. Cross-temporal synthesis is based on three PFC components: (1) working memory, which is a temporally retrospective function; (2) anticipatory set (planning), which is a temporally prospective function; and (3) interference control (a form of attention that involves resistance to distraction), which inhibits the disruption of goal-directed behavior by events or behavior that are irrelevant to or incompatible with the goal. Fuster argues that the overarching purpose of these three EF components is "the cross-temporal organization of behavior" (1997, p. 157). This is achieved by a *temporal synthesis* or integration that represents the "formation of *temporal structures of behavior* with a unifying purpose or goal—in other words, the structuring of goal-directed behavior" (p. 158). Like Stuss and Benson (1986), Fuster includes in his concept of EF the self-regulation of motivational, emotional, and other drive states in the service of goal-directed behavior.

Central to this model of PFC/EF is the need to appreciate that goal-directed actions often involve significant delays among events (E), responses (R), and goals and their attendant consequences (G/C). Such lengthy delays require an internal means of temporal structuring or binding together the components of this contingency. This, Fuster argues, is done by mentally representing the E-R-G/C arrangement. Goal-directed behavior is achieved through the guidance of behavior by these internal representations, and those representations arise from his three components. To Fuster, EF "is closely related, if not identical, to the function of temporal synthesis of action, which rests on the same subordinate functions. Temporal synthesis, however, does not need a central executive" (p. 165). Fuster does not put a ghost in the machine or homunculus in the mind. All along, it is the individual organism that is selecting what goals it will pursue within the constraints of its time horizon or capacity for retrospective and prospective functions.

While Fuster acknowledges that PFC-injured patients display an inordinate degree of concreteness in their daily behavior, he believes that this is largely, if not solely, a temporal concreteness. "The patient suffers from an overall constriction of the scope and complexity of behavior and of the thinking behind it" (p. 165). Behavioral patterns that are not well established are anchored in the present, devoid of temporal perspective, for the past as well as the future, and have an air of temporal immediacy dominated by immediate needs and stimuli or the here and now. In this model, once a desire, want, or goal comes into mind, the temporal integration or synthesis activities of the frontal lobes serve to construct the cross-temporal chains of behavior necessary to its attainment and, if thwarted, the problem-solving mental manipulations that may be needed to surmount the obstacle. Deficits in any of the three can result

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SIDEBAR 1.2. (*continued*)

in deficient temporal integration of behavior, or EF, and thus lead to different forms or origins of EF deficits. EF (temporal synthesis) depends on all three of Fuster's components, and hence deficits in any component give rise to a distinct disorder of EF.

Duncan's Theory of Goal Neglect

A less complex theory of the functions of the PFC is that of goal neglect by Duncan (1986). It essentially argues that human behavior is organized around a list of goals and subgoals against which individuals are comparing their ongoing behavior to maintain behavior directed at these goals. Frontal lobe damage results in an inability to retain these goals in mind and thus greater disorganization of behavior.

Borkowski and Burke's Information-Processing Theory of EF

Most of the definitions or descriptions of the PFC's functions given above arose out of clinical observations of patients with frontal lobe injuries or ablation studies of animals. An alternative perspective to EF developed in the 1990s out of information-processing theory. Typical of this was the work of Borkowski and Burke (1996) and other authors whose work they summarized in this field. Borkowski and Burke described EF as a set of three components that are directed at problem solving: task analysis (essentially defining the problem), strategy selection and revision, and strategy monitoring. Those authors also cited a different information-processing model developed by Butterfield and Albertson (1995) that views executive functioning as one of three components of cognition: cognition, metacognition, and executive functioning.

> Cognition is all the knowledge and strategies that exist in long-term memory; this reservoir of information is critical to effective problem solving. The metacognitive level is aware of this lower level and contains models of the various cognitive processes as well as an understanding of how knowledge and strategies interconnect. Executive functioning coordinates these two levels of cognition by monitoring and controlling the use of the knowledge and strategies in concordance with the metacognitive level. (Borkowski & Burke, 1996, p. 241)

Another model from cognitive psychology acknowledged by Borkowski and Burke (1996) in their review was that of Bransford and Stein (1993) and their model of the IDEAL problem solver that included EF in that model. IDEAL is the acronym for the components of the model: (1) *i*dentify an important problem to be solved, (2) *d*efine the subgoals involved in solving the problem, (3) *e*xplore the possible approaches to the problem (select a potential set of strategies), (4) *a*nticipate potential outcomes before acting on the best initial approach, and (5) *l*ook back and learn from the entire problem-solving experience. If problem solving is to be a component of EF, then this usefully makes explicit what steps are being used in that component. The steps here overlap with the Borkowski and Burke model and that of Butterfield and Albertson above. These steps are also highly similar to Scholnick and Friedman's (1993) model of *planning.* Hence planning and problem solving may be synonymous terms, although planning seems to also include a longer-term future consideration than might problem solving, which can be applied to much more near-term problems. Still, both models include a component of problem selection (choosing an important problem implies a futuristic feature perhaps) and certainly anticipation of outcomes that include some time horizon over which problems/goals and actions are to be considered.

Borkowski and Burke (1996) admit that self-regulation, planning, and EF overlap but argue that they have some distinctions. Planning, they claim, necessitates decision making, regulation, and action. They view self-regulation as a component of planning but limited to the strategies necessary to achieve desired goal states. EF, like self-regulation, is a component of planning because planning has more generality in its application, whereas EF may be less so. In their view EF only involves task analysis and related steps (strategy selection/revision, self-monitoring). These may be distinctions without a difference, or variations on a common theme of goal-directed action. Surprisingly, Borkowski and Burke (1996) do not include inhibition in their EF model and yet admit that deficiencies in it would spill over into their components of EF and be detrimental to them.

Hayes's Behavioral Theory of EF as Rule-Governed Behavior

A quite different view of EF was proposed at this same time by Hayes et al. (1996) using a more behavioral analytic model, particularly the concept of rule-governed behavior (see Hayes, 1989). Their analysis of the terms often believed to comprise EF as well as many of the tests used to assess EF led them to conclude that EF is a special subset of rule-governed (verbally regulated) behavior. Rule-governed behavior is behavior that is being initiated and guided by verbalizations, whether self-directed or provided by others. We saw elements of the importance of this type of PFC function in the work of Luria (1966) above.

Hayes et al. argued that EF tasks place people in situations where previously learned sources of behavioral regulation come into conflict with rules laid down by the task and examiner. Those task-specific rules are competing with behavior that is otherwise automatic and well practiced. Thus, the typical automatic flow of behavior must be interrupted and delayed long enough for the person to discover a new rule or select among previously learned rules that may apply in this situation. Yet interrupting a well-practiced behavior itself often requires that a rule be selected and followed that is initiating the delay in responding. And so in EF tasks individuals often have to implement a rule to inhibit their usual ongoing responding, even if it is just asking them a question about the task. They must then either select from among a set of relevant previously learned rules or generate a new one. The latter is a verbal means

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SIDEBAR 1.2. (*continued*)

by which we problem solve, as in the five steps to problem solving discussed above, which are second order rules used to discover first-order rules.

Discovering or selecting the rule is only part of the process, for the individual must now follow it, adhere to it, or "track" the rule. Pliance may occur, where immediate and artificial consequences are applied to motivate the rule following, or tracking may occur where the natural consequences have now taken over to sustain the behavior. Sometimes augmenting is also needed where verbal self-reinforcement (or statements by others) is also used for motivation, as in phrases such as "good boy," or self-statements of being right or being good in following the rule. This view of EF appeared to gain little favor among traditional neuropsychologists who seemed more comfortable using a cognitive neuropsychological or information-processing view of EF than one derived from behavior analysis. Yet features of it would be incorporated into my own model of EF (Barkley, 1997a, 1997b) through Vygotsky's model of the internalization of self-directed speech (1987).

porary definitions of EF, as shown in Sidebar 1.1, and even against several contemporary models of EF as shown in Sidebar 1.2. These contemporary views of EF rarely, if ever, refer to emotional, social, economic, occupational, or moral deficits associated with these earlier descriptions of PFC injuries or EF deficits. What one observes instead is a near exclusive focus on the rather narrower "cold" cognitive constructs that are now thought to be included within the term "EF," such as response inhibition, working memory, set shifting, sustained attention, planning and problem solving, and fluency or generativity (Castellanos, Sonuga-Barke, Milham, & Tannock, 2006; Nigg & Casey, 2005; Nigg & Casey, 2005). As noted earlier, up to 33 such constructs have been placed under the umbrella of EF in modern views of this concept. So variously defined is EF that some authors simply skip defining EF entirely (Biederman et al., 2008; Gilotty et al., 2002; Papadopoulos, Panayiotou, Spanoudis, & Natsopoulos, 2005), proceeding instead to directly listing one or a few constructs they believe to represent EF, such as response inhibition (Hale et al., 2009), and working memory, set shifting, and planning (Castellanos et al., 2006; Willcutt et al., 2005).

From these constructs, as noted above, psychometric tests are then selected for use as EF tests or test batteries, and the results of the studies are said to reflect the extent to which certain clinical disorders involve EF or to which EF may develop in normal samples. The result in my opinion has been a growing disconnection between contemporary cold cognitive research on EF and the widespread and often devastating behavioral, social, emotional, economic, occupational, and moral deficits so evident in the earlier descriptions of patients with PFC injuries or disorders. For example, how are we to see any connection between how patients perform a digit span backward, N-back, serial addition, or other task of verbal working memory and their economic life in their natural settings? Humans daily engage in reciprocal exchange and must frequently and rapidly evaluate the costs-benefits to them of doing so as each party to the transaction goes about pursuing their actions toward their future goals, no matter whether the exchange involves money, goods, or services. This is the field of economics, broadly defined. Yet where does this widespread human goal-directed activity ever enter into modern views of EF?

Consider how we are to connect the inability of PFC patients to sort cards into categories or reorganize rings onto spindles to match a sample arrangement and that individual's profound difficulties with ethical or moral conduct. What do such tasks tell us about the likelihood of the person having substantial difficulties with social relationships with others, with reciprocity and cooperation, or with participating in the community and obeying its laws? The fundamental basis of morality is awareness of one's self over time in relation to others and the future consequences of one's actions toward others and of others' toward one's self. This daily intersection of each human's goal-directed activities among those of other goal-directed humans requires rules (ethics) for making such activities run as smoothly and peaceably as possible. Where is this reflected in psychometric tests or modern cognitive models of EF? Such a myopic emphasis on short-term (minutes) cold cognitive psychometric tasks preferred by most contemporary neuropsychological studies has left a gapping chasm between the constructs sampled by these tests and the executive deficits evident in patients in their everyday life. This is the most likely reason why little or no relationship has been found between the tests and the observations and ratings of EF, adaptive functioning, and human major life activities saturated with EF, as discussed above.

When such cold cognitive models and tests based on them are then relied on to identify the dimensions or components of EF, further difficulties for theory-building can arise. Those cognitive tests further impede efforts to bridge the growing chasm between the results of modern studies into EF and the more widespread and socially devastating symptoms associated with PFC injuries and other EF disorders. Largely eschewing an attempt to operationally define the concept of EF, many authors have pursued a more empirical, atheoretical, statistical approach to understanding EF. This effort has chiefly been exemplified by attempts to factor analyze various batteries of putative EF tests to discover their underlying dimensions. Numerous such attempts have been made, with most identifying several distinct EF dimensions or factors. For instance, Miyake and colleagues (Miyake et al., 2000) used confirmatory factor analysis to determine whether the three most commonly proposed EF did, in fact, form distinct functions—these being set shifting, information updating, and inhibition. Using three tasks commonly used to assess these constructs and college students as participants, Miyake et al. found evidence for such a fractionating of EF. But Shute and Huertas (1990) also gave a battery of seven EF tasks to college students and identified four factors—flexibility/perseveration (or set shifting), perceptual–motor speed (probably not an EF), verbal working memory, and time estimation. These factors mainly reflected the tests in the battery. In Levin and colleagues' study of brain-injured children (Levin et al., 1996), five factors were identified from their battery of six EF tasks. Grodzinsky and Diamond (1992) gave a battery of 10 EF tests to their participants and found at least seven separate factors, most of which reflected the tests. Mariani and Barkley (1997) also used an extensive battery of EF and non-EF tests and identified at least four factors. Anderson (2002) described the results of several factor analyses of EF test batteries and the common factors they identified. These were planning, impulse control, and concept reasoning. A response speed factor was also found, but this would be considered nonexecutive. Anderson then goes on to develop his own four-factor model of EF: (1) attentional control (includes inhibition); (2) information processing (fluency, efficiency, and speed of output); (3) cognitive flexibility (shift response sets, learn from mistakes, devise alternative strategies, divide attention, process multiple sources of information concurrently); and (4) goal setting (develop new initiatives and concepts, plan actions in advance, approach tasks in an efficient and strategic manner).

But all of these findings could just as easily reflect method variance. As a general rule, the more tests included in the EF battery, the more factors the study seems to identify—these factors primarily comprise the different tests. It is therefore not clear that EF is as fractionated a construct as such studies suggest; nothing requires that it be conceptualized as such. What these studies more likely illustrate is that a diversity of putative tests of EF, when factor analyzed, result in a diversity of dimensions—as diverse as the tests included in the battery. Also troubling in this empirical (statistical) approach is that typically the correlations among these various factors are relatively and disturbingly low, suggesting only 10–20% of shared variance among them. This finding is not encouraging of a central construct or general EF factor (Lehto, 1996).

As Miyake and colleagues noted (Miyake et al., 2000), however, this limited relationship among the factors could just as easily reflect the diversity of non-EF abilities that are also being sampled in the EF test batteries. These non-EF abilities would obscure the commonality that might exist among them that would represent the higher order central executive faculty lying latent across these diverse tasks. Nevertheless, this sampling of research serves to illustrate the problem. The increased reliance on the psychometric approach to EF has resulted in relatively circumscribed cognitive faculties being incorporated into the term while failing to address the significant personal, emotional, social, economic, and moral deficits that frequently arise in disorders of the EF system—the PFC.

The Missing Linkage between EF and Social Functioning

Dimond (1980) and later Lezak (1995) were correct, I believe, in noting the relatively sparse recognition in the modern views of EF of its importance for social functioning and effectiveness, or what Dimond called our *social intelligence*. A few EF researchers have noted its importance, however, such as Ciairano and associates (Ciairano, Visu-Petra, & Settanni, 2007) on the importance of EF in cooperative social behavior. Dimond referred to "the capacity to respond to appropriate social patterns, to regulate social life and to integrate adequately and successfully with others" as being so important in PFC functioning (1980, p. 510).

> As one of its major functions, the frontal lobe bears responsibility for administering the code by which the patterns of social behavior are put into operation and by which the individual integrates and regulates its conduct in respect of that of other individuals. We postulated that there is a special form of social intelligence by which the organism maintains the running, changing stream of social relationships and that the frontal lobes bear important, if not unique, responsibility for this. (Dimond, 1980, p. 507)

There is a striking social pathology associated with PFC damage, Dimond (1980) argued, that goes largely unappreciated in efforts to describe the major functions of the PFC. Perhaps this is largely because clinicians and neuroscientists nearly always study such patients in isolation (individually) and in relatively short periods of time (a few hours at most at a time) in unnatural settings (clinics and labs) and with EF measures that are largely "cold" cognitive in nature that would miss this aspect of functioning or detect only the smallest instances of its degradation. Dimond (1980) makes a special point of noting the hundreds of cases of PFC injury that did not manifest many of the changes in cold cognition or mental functioning attributed to this region by others except for marked changes in planning and social functioning (pp. 505–508).

Eslinger (1996) in particular would later take up this call for the importance of EF (the PFC) in managing the social conduct of the individual. He argued that EF contains "social executors" that each serve certain social functions: (1) social self-regulation: processes needed to manage the initiation, rate, intensity, and duration of social interactions; (2) social self-awareness: knowledge and insight about oneself and the impact of one's behavior on others in social settings; (3) social sensitivity: the ability to understand another's perspective, point of view, or emotional state (similar to empathy); and (4) social salience: regulation of somatic and emotional states that impart a sense of meaningfulness to social situations and to specific individuals within that situation (p. 390).

In contrast to most modern cognitive views of EF, Eslinger (1996) viewed the social disability arising from EF impairment as frequently being the most distinctive feature beyond just the cold cognitive impairments. He states, "Yet there is no comprehensive model of executive function that addresses the interrelationship of cognitive and social aspects of behavior, including the various impairments that can occur" (p. 389). He lists the following as some of the social deficits arising from PFC (hence EF) damage: demanding and self-centered behavior, lack of social tact and restraint, impulsive speech and actions, disinhibition (of immediate self-interests), apathy and indifference, and lack of empathy, among others.

More recently, Rossano (2011) similarly bemoaned the dearth of references to the importance of social and emotional factors in studies and reviews on cognitive control, or EF, and its evolution. He reviewed anthropological evidence on the importance of both social and emotional functioning in the evolution of cognitive control in primates and especially humans. His review indicated that "theories of cognitive control are likely to be seriously incomplete unless they incorporate relevant social/emotional factors" (p. 238).

Absent these rare voices concerning the importance of EF (the PFC) for social behavior, and the role of social/emotional factors in its evolution, one would have thought that the major deficits suffered by those with PFC injuries were largely cognitive or information processing in form. Anyone who has spent any time with patients with PFC injuries or spoken with their family members would find such cognitive deficits to be trivial in comparison to the major social impairments arising from such injuries. From this clinical (and familial) perspective, the view of EF offered by cognitive psychology or those wedded to EF test batteries is not worth having. Their contents are devoid of social relevance and context. It is axiomatic that we do not live alone—humans are a group-living social species. When we engage in EF, we do so not just aware of our long-term self-interests but with an awareness of and in the context of other self-interested self-regulating agents with whom we interact. EF occurs not only across time toward future goals but usually *among social others!*

The Overlooked Importance of Emotion and Motivation in EF

A further problem with most theories and definitions of EF is the relative dearth of attention given to emotional and motivational aspects of self-regulation, as Rossano (2011) above also noted. While this issue is certainly discussed by Luria (1966) and others who described the consequences of frontal lobe injuries in humans and primates (Damasio, 1994, 1995; Dimond, 1980; Fuster, 1997; Stuss & Benson, 1986), it has been largely ignored in most other conceptualizations of EF in the past 30 years. This is particularly so in accounts of EF using cognitive psychology and information-processing models. Exceptions have been Fuster's theory of cross-temporal synthesis (1997), Damasio's (1994) somatic marker theory, Stuss and Benson's (1986) hierarchical model, and my own hybrid model of EF (Barkley, 1997a, 1997b). None are based on the computer metaphor of brain functioning that underlies information-processing models of EF. Perhaps this neglect arises because computers do not have emotions that need self-regulating and do not have to self-motivate.

The neglect of emotion may also stem from the inherently greater difficulty in measuring emotional and motivational states relative to the enormous number of tests available for assessing the more "cognitive" features of EF, such as working memory. Emotions are motivational states that undoubtedly play an important role in evaluating and determining one's means (actions) and ends (goals) and their social appropriateness (Damasio, 1994). They will also contribute the drive, willpower, or self-motivation that will be needed to achieve them (Barkley, 1997b; Fuster, 1997; Stuss & Benson, 1986). The supposedly "cool" EF brain networks, such as working memory, planning, problem solving, and foresight, may provide for the "what, where, and when" of goal-directed action, but it is the "hot" EF brain network (Castellanos et al., 2006; Nigg & Casey, 2005) that provides the "why" or basis for choosing to pursue that goal in the first place and the motivation that will be needed to get there.

The Limitations of the Computer Metaphor of Brain Functioning for EF

The foregoing discussion suggests yet a further problem with contemporary cognitive views of EF, and especially those predicated on information-processing models of brain functioning. Using the computer as a metaphor for brain functioning has undoubtedly been of value in efforts to advance the understanding of neural circuitry and its likely functions. But it has its limits for brains. Moreover, it is, after all, just a metaphor. Appreciating some of the major differences between computers and brains is important. First, computers are designed, whereas human brains evolved; hence the architecture and functioning of each are likely to be quite different. Engineers designing computers can determine the most efficient and effective designs for both hardware and software to achieve the intended purposes to which computers are used. Natural selection, acting on brains, has no such plans and foresight to use in its sculpting of the brain. Consequently, a computer may be a marvel of efficient design. But a brain is a veritable Rube Goldberg device of adaptations cobbled together from what had been available for other functions previously but that may be diverted to another function under a change in environmental pressure (a new adaptive problem). Evolution can only work on what was previously available and gradually tweak previous mechanisms or adaptations for use in the new function to which it is being put. As such, an adaptation is a patchwork of kludges or solutions arising out of whatever pieces (functions) were around at the time, so to speak. We must therefore be prepared for the fact that the human brain may be a mixture of older or vestigial adaptive functions that may be less useful or even disadvantageous in modern environments. Yet it may also contain a mixture of new ones that may even now still be in the process of evolving toward greater efficiency and effectiveness. Not all PFC functions are likely to be presently adaptive or useful, and others may be frankly maladaptive in modern, industrialized environments.

A second major distinction between computers and brains is that computers are passive whereas human brains are not. The computer metaphor portrays the brain as if it were software and hardware; given a certain input, this "computer" moves the information through various stages of processing to produce the output that we see virtually automatically, like an automaton, industrial robot, or artificial intelligence creation. *This is a very passive view of the organism,* devoid of what makes living things unique—they are *self-interested agents!* They have basic motives preinstalled that serve to sustain their own life (appetitive and defensive/protective motives) and to reproduce (that is, to transmit their genes) into the next generation (sexuality and competition for mates). This blindness to *self-interestedness and its motives* is a glaring deficiency in contemporary EF models. A computer is not a self-interested, self-motivating, self-regulating entity; a human brain is.

Another feature of animal life is locomotion—animals move and act under their own power and must frequently be attentive to refueling and maintaining their vehicles. Nature does not automatically provide for the life-sustaining needs of a human; that person must interact in such a way with that environment to produce its sustenance. Computers are not self-interested, do not self-assemble, do not compete with other computers for resources or mating rights, and do not concern themselves with the source of their own fuel or the integrity of their hardware. Such motivational considerations from biological evolution are absent in the modern concepts of EF. Only Dimond (1980, p. 504) seems to have taken note of them and given them some importance in understanding the losses that occur in PFC damage—our social intelligence that is necessary to insure our survival and reproductive self-interests. Humans have motivations that computers do not.

Some EF perspectives do acknowledge that drive, motivation, and will are prefrontal functions and are a component of or enslaved by EF (Stuss & Benson, 1986). But even these few fail to note that this is the fuel tank of all future-directed action and the EFs that contribute to that action. Humans act, and they do so with purpose (intentionality; a future-directed stance). Those actions are initiated and sustained by drive, motivation, and will and by the self-interested motives to survive, nourish themselves, and reproduce themselves into the next generation. Absent an appreciation for such motives in human action, computer metaphors of EF will prove strikingly sterile and self-limiting in helping us to understand EF or the functions of the PFC.

The Installation of a "Central Executive" or Homunculus in EF: The Ghost in the Machine

The next important problem with theories and their conceptualizations of EF, again noted by Dimond (1980) and later others (Hayes et al., 1996), is attributing "a central executive" to the PFC. This was the initial mistake made by Pribram (1973), and it has been repeated since that first appearance of the term "executive" as applied to the PFC's functions. Saying that the PFC is the brain's executive installs a *deus ex machina*, a marionette operator, or homunculus (Grafman, 1995) into the PFC that serves to explain nothing and will eventually require its own explanation. Saying that the PFC is the brain's central executive merely begs the issue of just who or what is this wizard behind the curtain that is pulling all these levers in managing the lower level nonexecutive brain systems so as to direct behavior across time toward future goals. Just who or what is even choosing these goals, and for whom are they being chosen? It is surely not some little CEO of a large corporation or a symphony conductor installed in the brain, as suggested in the analogies so often used as exemplars of EF in the trade literature. Yet most models of EF include some thinly veiled reference to some sort of "mini-me" that is doing our bidding, as Hayes et al. (1996) noted.

Since its inception by Pribram more than 40 years ago, the issue of who or what is the central executive has been kicked down the road incessantly. But it must eventually be addressed. One can temporarily sidestep this issue as is evident in decisions by working memory scientists (Baddeley, 1986; Baddeley & Hitch, 1994; Goldman-Rakic, 1995) to intentionally ignore the nature of the "central executive." Instead they focus their research on the subordinate working memory systems that serve to hold in mind the information and goals that the central executive has chosen. Or the central executive is simply inferred from the shared variance between nonverbal and verbal working memory tests without actually defining it and assessing it directly (Rapport et al., 2008). Understanding the nature of working memory is clearly a laudable and worthy research goal. However, it does not get us very far in understanding the entity to which the working memory systems are said to be slave units. Who or what is determining the contents of working memory and the goals they serve?

The Missing "Self" in EF

Strikingly absent from most views of EF other than that of Stuss and Benson (1986) is a role of *the self* in these models. In my view, the conscious self IS the central executive. Each of us develops a conscious sense of self, and it is this conscious self that is serving as the executive. It is through our self-awareness/self-consciousness that our values and wants are consciously known to us, our goals (values or what we wish to pursue) are chosen by us, and the strategies that we will employ in these pursuits are selected by us. Who chooses? *I* do. What is to be valued and pursued? What *I* choose to do. How is it to be pursued? The way *I* decide to do so. The "*I*" has been almost entirely jettisoned from cognitive theories of EF, replaced by some unknown, undefined central executive holed up in some penthouse office suite in the frontal lobes. This conscious capacity to consider who and what we are, what we will value, and how and when it will be pursued originates in our self-awareness. It is the seat of human free will as philosophy has noted (our freedom to choose among various goals over various time periods and the means to attain those goals). Stuss and Benson (1986) were absolutely correct, I believe, in making this mental capacity the apex of their pyramid of the EF system and its components.

Freedom here does not mean random or uncorrelated decision making between values (goals) and their means–ends. Freedom or free will is a conscious generation of and consideration of the variety of options available to that individual over the longer term as capable of being conceived by the individual. It also includes the selection of which goals to pursue, how to pursue them, and when to do so. This active agency of the self exists in philosophy but seems lost to or intentionally avoided by the field of neuropsychology. Perhaps this is because it is seen as unscientific or just difficult to measure. But it is neither. Instead, cognitive neuropsychology's view of humanity is frankly not worth having—an Orwellian automaton of an information processor without a sense of self.

Alternatively, constructs can be proposed in a scientific analysis of an issue on the basis of reason, experience, and logic that cannot yet be measured objectively at the moment. Objective measurement is not a precondition of scientific theorizing; rather, it is just the eventual possibility of testability of the proposal. We know that self-awareness is a brain function (Stuss & Benson, 1986), that it is largely a function of the PFC and related networks, and that it can be neuroimaged (Herwig, 2010). And we have ample evidence that this sense of ourselves as an active, thinking–choosing agent can be diminished by brain injuries, especially to the PFC. This self, however, is often spoken of in the third person, if at all, in cognitive models of EF. Even then it is not obviously a part of a living self-conscious entity as seen, for example, in statements such as the following on the nature of EF: "it monitors and controls all the steps necessary for a correct solution" (Borkowski & Burke, 1996, p. 242). *It?*

We should immediately recognize that the "it" here is actually the "I." Efforts to strip the self and self-awareness from EF are unnecessarily sterile of what every human accepts as axiomatic and as common sense: I am the agent consciously deciding what it is that I will do. Others hold that "I" accountable for its actions precisely for this reason. A software program in a computer is incapable of being held legally accountable for its choice of actions, but a human can and should be held so accountable. One chooses what he or she will do and ought to do using one's self-awareness and sense of the future—the longer-term consequences that are likely to ensue for one's self and for others given the various choices under consideration. It is time to return the self to the construct of EF.

Overlooking the Bidirectional Influence of EF and Culture

One can recognize that EF is of exceptional social importance and likely arose to meet social adaptive problems, such as social interaction and self-defense, reciprocity, cooperation, and hence survival (Barkley, 2001). But this does not in and of itself directly recognize an important place of culture in either contributing to EF or being influenced by it. Culture is shared information. It is the result of people individually and collectively pursuing their goals and discovering new and better means of doing so. These means and ends may be recorded, codified, or in other ways stored by means that endure sufficiently to be shared horizontally across people and vertically across time (generations). People both create and adopt culture. Yet it is equally true that the existing culture influences the people who are immersed within and who actively adopt it. That is, the information, products, services, and other innovations stored and transmitted from prior generations or even from others currently existing can and are used by people to provide better means by which they can pursue their goals and general self-interests. This reciprocal influence between EF and culture goes virtually unnoticed in prior views of EF. But its existence is virtually self-evident, requiring only the evidence of one's senses and very existence to affirm its validity. There are parts of the PFC that both use and create culture. Yet this exceptionally important aspect of human activity gets virtually no attention in modern models of EF.

For example, the computer on which these sentences are being composed is a product of past and current EF by other humans of which I am the benefactor. The computer, a cultural product, provides a far better means of attaining my goal (writing this book) than was the case for prior generations or even for me two decades ago. Even so, the product of this interplay between me and computer (this book) is intended to further influence the existing culture and others by its information. Save for the work of Vygotsky (1962, 1978, 1987) and a few others, the reciprocal influence of EF and culture has been utterly absent from conceptualizations of EF. Yet this interplay is in serious jeopardy of perversion, reduction, or complete loss when injuries of the PFC (and its EF system) are sustained. Some mental mechanism must exist for humans to create culture and to benefit from, adopt, or be influenced by it. That mechanism, in my opinion, is the EF system, explaining (if such explanation were needed) why only humans have culture.

Why EF?: The Importance of Evolution in the Origins and Purposes of EF

All of the above problems, as serious as they are, pale when compared to the even larger problem: Why do we have EF? I have argued elsewhere (Barkley, 2001) that virtually all of the efforts to understand the EF system and its components have ignored their likely evolutionary origins and purposes. The same has largely proven true in the literature on cognitive control (Rossano, 2011), an alternative term for EF in information-processing research. This is undoubtedly due in part to the legacy of adopting cognitive tests and their constructs in trying to study EF. It may also be the result of widespread ignorance of the theory of evolution among neuropsychologists and hence their neglect of its importance for understanding the nature of EF. But neuropsychology is a subspecialty of biology as much as of psychology, and the governing paradigm in biology is evolution. Yet one is hard pressed to find any mention of it in any treatise on EF by neuropsychologists, except vaguely by Dimond (1980) and more explicitly in a trade book by Gazzaniga (1998).

The theory of evolution provides a means by which one can understand the functional mechanisms that species have evolved to deal with problems they encounter in their environment—these functional mechanisms are their adaptations. The EF system is a complex functional mechanism that seems to have been designed for a purpose—it and the PFC that gives rise to it are costly. Such costly adaptations do not arise in evolution without providing their owners with some benefit to their survival, chances of reproduction, and inclusive fitness (the likelihood that their genes and those shared with relatives get into the next generation). EF is an adaptation that has evolved to solve a problem or set of problems faced by those few species that possess it. This is not a *non sequitur*—EF may have evolved to solve social problems. Humans are a social species, and living with other genetically related and unrelated individuals poses problems (and opportunities) for members of that species. There is a daily need to look ahead and anticipate what others are likely to do in the context of pursuing one's self-interests. We can rightly ask what specific adaptive problems the EFs evolved to solve in the environmental niche in which humans live. It surely was not sorting cards. Given that the vast majority of species do not possess this adaptation, it is highly unlikely to be necessary for surviving and reproducing on this planet. If it were, many species would have converged on it as an adaptive means of addressing problems in coping with the physical environment, such as has happened with the repeated evolution of eyes. It is highly likely that the EF system exists to assist humans with their social existence and its associated problems and opportunities. To what extent it is a result of either natural selection or sexual selection, or both (Miller, 1998), is of less concern here than that it is an adaptation that enhances either survival or reproduction, or both.

The answer as to why humans have EF may come from considering other species that have rudimentary prototypes of EF. Chimpanzees and dolphins seem to have a nonverbal working memory system, as do some species of monkeys, though far less developed. One thing that these species have in common is that they are social creatures. Unlike some group-living species of mammals and insects, chimpanzees, dolphins and some monkeys live in groups with individuals to whom they are not strongly genetically related. Where genetic relationships are high, cooperation with the group and mutual self-interest can arise by genetic (natural) selection, as members of the group are virtual clones of each other and thus have a highly shared genetic self-interest. But social primates often live in groups with others to whom they may be only modestly genetically related or not at all. The particular behaviors known to exist in the social primates (and dolphins) that deserve consideration as possible reasons for EF are reciprocal exchange (trading behavior, and especially delayed exchanges), social competition, social cooperation or mutualism (social symbiosis), and the protoethics and morality that exist to facilitate it. Both delayed reciprocal exchange (giving up a resource now to be repaid later) and cooperation (acting together to achieve goals not possible by an individual) require a sense of time, a means of evaluating the discount of delayed payments or other benefits, and a means of subordinating immediate self-interests to future benefits. Without a capacity to conceive of the longer term, these volitional forms of behavior are not possible. As already noted, it is precisely such behavior that is grossly impaired in individuals with damage to the PFC.

The species that have a proto-EF system also engage to a certain extent in imitation learning (a form of experiential or behavioral plagiarism). They possess a mirror neuronal system in the PFC that is highly specialized for this purpose. In humans, in particular, there is a dominant or prepotent response to overtly imitate another's actions, and it must be actively inhibited from being publicly expressed—the neuronal firing patterns that match the actions being watched are activated, but their release to the musculoskeletal system is inhibited. This instinct to imitate the actions of another can be partially disinhibited when working memory load increases because that increasing demand on the EF system undermines the executive inhibition of the habit of spontaneous imitation (van Leeuwen, van Baaren, Martin, Dijksterhuis, & Bekkering, 2009). The instinct to imitate is also likely to be disinhibited when the PFC is damaged (Luria, 1966).

The capacity to use the witnessing of another's experiences for one's own self-improvement is a tremendously useful adaptation among social species in which members compete against each other for resources. Humans also take imitation to an even higher level, which is vicariously learning to do the opposite of what one has seen another do. Vicarious learning is a particularly useful adaptation when it comes to learning from the mistakes made by others, some of which can be injurious or even lethal. It is self-evident that more learning occurs in response to errors than to successes. This must be immeasurably more so if one can profit from the mistakes made by others by observing their actions, the consequences, and then suppressing one's own predispositions to do the same. The inability to act in opposition to information and actions perceived in the sensory fields is a classic symptom of PFC damage (Luria, 1966; Stuss & Benson, 1986). The capacity to mentally represent information (working memory) allows an individual to wrest control of moment-to-moment behaving and even to act in opposition to what is seen.

There may be other social problems that the EF system has evolved to solve (Rossano, 2011). These may include theory of mind (anticipating that another also has a mind and especially an EF system and acting accordingly) and empathy (Grattan, Bloomer, Archambault, & Eslinger, 1994). These functions may even be facilitated by or even based on covert imitation. But the functions of delayed reciprocal exchange, social competition, social cooperation, and imitation and vicarious learning may have been the initial ones that kicked off the evolutionary expansion of the PFC in primates and especially humans. Only the first would be needed to veer human evolution down the path to the others, I believe (Barkley, 1997b, 2001). They are well worth our consideration in understanding EF. Performing a digit span backward task is trivial in comparison to these social functions and is surely not the adaptive problem the EF system evolved to solve.

Why does EF exist? What is it for? Isn't this why scientists have been studying the functions of the PFC for more than 160 years? After all, when you finally figure out what the PFC does, doesn't this invite the next question of why it does those things; why it exists? Understanding the possible adaptive problems in primate and human life that the PFC/EF system evolved to solve is the only way to answer these questions. This book will make an attempt to do so. It surely will not give definitive answers to these questions, but it can suggest some likely directions worthy of further research.

Conclusions and Specific Aims

This chapter has identified at least four serious interrelated problems in the field of EF in modern neuropsychology. This book aims to address these problems. The first difficulty is that the term "EF" lacks an operational definition that can serve to determine which human mental faculties should be graced with the moniker "executive" and which should not. The view that EF is maintaining goal-directed problem solving (Welsh & Pennington, 1988) or that it is those "skills necessary for purposeful, goal-directed activity" (Anderson, 1998, p. 319) will not suffice to meet this need—not when the neuropsychological processes needed to maintain problem solving toward a goal are incompletely or poorly specified or when the word "skills" can include 15 to 33 components. Moreover, use of the term *skill* is misleading as that is something one learns, like reading and writing, not an inherent neuropsychological capacity of the individual as EF is often represented as being in the literature. An operational definition of EF will be offered here that makes this task a relatively easier one. Meanwhile, I will accept as my starting point for defining EF the most commonly agreed upon feature of it as noted in the survey of neuropsychologists by Eslinger (1996)—EF is self-regulation. I will expand on this idea in subsequent chapters.

The second problem area is that current theories of EF have drifted away from capturing the characteristics of patients with PFC injuries or disorders of this "executive" brain, including their marked problems in emotional, social, economic, and moral domains, among others. Cognitive psychometrically based models of EF are common at this time. It is the aim of this book to propose a theory of EF that can unite these various levels of symptoms and deficits. Along the way, the third set of problems characterizing modern models of EF will also be addressed. The social purposes of EF will be placed at center stage in the higher levels of the theory proposed here. The important role of emotion regulation and self-motivation will also be explained and made an equally important component of EF, as are cold cognitive components such as planning and working memory. The computer metaphor of EF possessing a central executive or ghost in the machine will be abandoned here in favor of an acting self that ponders choices, makes decisions, and enacts those decisions over extensive periods of time and large social networks. The bidirectional nature of culture, unnoticed in modern cognitive models of EF, will be a major element in the extended EF phenotype to be discussed here.

The fourth problem of why humans have EF will be addressed by taking an evolutionary stance toward EF as an adaptation or suite of adaptations necessary for solving problems that arose in human social life. Concepts in evolution will be borrowed for any insight they may give into the reasons for the existence of EF. Three such major concepts are developed in the next chapter. The first is selfish gene theory, which explains why all living things are at their core self-interested replicators. To understand EF, we will have to take the individual's self-interests into account. What does EF do for the survival and reproductive and inclusive fitness of its owner? The second equally important concept is that of the extended phenotype as opposed to the conventional view of phenotypes. The latter represents simply a physical or behavioral trait of the organism. In contrast, Dawkins (1982) discusses how organisms in biological evolution possess phenotypes that produce effects at distances over space and time well beyond their skins. Phenotypic traits have effects that impact not just the immediate spatial and temporal environment but that also radiate outward from the organism. These effects may extend far beyond the proximal physical distance and short durations typically considered in the notion of a phenotype. In some cases, these effects may radiate outward for miles and over months or even years. Such effects are subject to natural selection and may even be the basis of the various adaptations of a species. No other species has altered the physical environment to such a degree, at such great spatial distances, and over such long spans of time as have humans. Humans not only adapt to their environments as do others species, but they adapt their environments to them—and they do it using EF. Such alterations to the environment can be studied for their value as part of the human EF phenotype. The concept of the extended phenotype will be considered in detail in the next chapter along with the third important concept, "universal Darwinism." The process of Darwinian evolution is now thought to be at work in the universe wherever information about the environment is found to have accumulated. Although genetics is the level at which it is best understood, it likely extends up to five levels beyond that one.

An extended phenotypic model of EF will also be able to address the second of our problems with EF—how to assess it. That model of EF will show why putative tests of EF are largely not related to EF as used in daily life activities and are not predictive of functioning in domains of major life activities that should be rife with EF. A hierarchical model of the extended phenotype of EF can explain how this glaring deficiency in EF tests can arise. Chapters 3 through 8 detail the hierarchical levels of the extended EF phenotype and discuss how the effects of those levels radiate outward and upward.

At this time neuropsychologists and other neuroscientists, such as those working on the role of EF in ADHD, are pursuing "endophenotypyes." These are presumably those psychological functions that seem closest to the brain's neural activity and so are closest to the genes and their proteins that serve as initial and intermediate pathways, respectively, to the EF behavioral phenotype. Although this goal is commendable in that it hopes to yield a better understanding of PFC disorders such as ADHD and of the EF deficits associated with them (Castellanos et al., 2006; Castellanos & Tannock, 2002), it is incredibly limited in scope.

I am asking you to look in the opposite direction. I am encouraging you to start with a given set of human mental functions comprising EF and look outward as to how they impact the individual's behavior, daily functioning, social relations, cooperative ventures, economic transactions, and even moral, legal, occupational, child-rearing, and community activities.