Executive Functioning Theory and ADHD

7

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Attention-deficit/hyperactivity disorder (ADHD) is the current diagnostic label for individuals presenting with significant problems with attention and/or impulsiveness and hyperactivity. While the disorder has not always been called ADHD, the history of the clinical syndrome of inattention and overactivity dates back over 200 years. Across the last 200+ years, different aspects of the disorder (hyperkinesis, inattention, etc.) have been emphasized yet there has been an increasing recognition of the heterogeneity of the disorder. ADHD remains among the most common reasons that a child is referred for mental health treatment and is increasingly a common reason that adults are referred for treatment. Individuals with ADHD display considerable variation in the degree of symptoms, functional impairments from these symptoms, domains of impairment, age of diagnosis, response to treatment, and psychiatric comorbidity. While not currently a symptom of ADHD, there is evidence that executive functioning (EF) deficits may be a defining aspect of the disorder and even that its two symptom dimensions actually represent dimensions of EF. This chapter presents an overview of EF theory and ADHD.

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Executive Functions

While described far more completely in previous chapters of this book, the term executive function is a rather ambiguous one that refers to a set of various interrelated cognitive abilities that operate metaphorically as a company "executive" (Denckla, 1996) and are considered to be largely mediated by prefrontal cortical/subcortical circuits (Goldman-Rakic, 1995). Yet there remains no consensus definition of the term nor has an operational definition been provided that could easily serve to segregate executive from nonexecutive mental abilities (Barkley, 2012). The term executive function also has been used to encompass the actions of planning, inhibiting responses, strategy development and use, flexible sequencing of actions, maintenance of behavioral set, and resistance to interference (Denckla, 1996). Even more globally, Lezak defined executive functions as "those capacities that enable a person to engage successfully in independent, purposive, self-serving behavior" (p. 42) (Lezak, Howieson, Loring, & Hannay, 2004). Nevertheless, it is generally agreed that these multifaceted abilities all pertain to goal-directed behaviors.

Executive functions seem to be mediated, at least in part, by the frontal cortex (particularly the

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prefrontal cortex) and are implicated in the neuropsychology of ADHD (Castellanos, Sonuga-Barke, Milham, & Tannock, 2006; Nigg & Casey, 2005; Sagvolden, Johansen, Aase, & Russell, 2005). Among others, Barkley (1997b) has theorized that problems with executive functioning (EF) specifically and self-regulation more generally are central to ADHD and give rise to the more obvious surface behavioral symptoms represented in the DSM-5 diagnostic criteria.

Barkley's EF Theory of ADHD

The Centrality of Response Inhibition and Self-Regulation

Over fifteen years ago, Barkley proposed his EF theory of ADHD (Barkley, 1997b) which assumes that behavioral inhibition, self-control, and executive functioning are overlapping and interacting human abilities. In his theory, EF is self-regulation and behavioral inhibition is essential to its performance. The purpose of self-control and EF are inherently social—humans engage in reciprocal social exchanges and cooperative ventures as a means to their survival and must both track prior such exchanges with others and prepare for such future interactions with others. In Barkley's original theory, response inhibition was seen as a central feature of EF because it provided the delay in automatic responding that was essential to permitting the executive functions to monitor, interrupt, and otherwise guide behavior toward goals. Inhibition referred to three overlapping yet somewhat distinct and separately measurable processes: (a) inhibiting the initial prepotent (dominant) response to an event so as to create a delay in responding, (b) interrupting an ongoing response that is proving ineffective thereby permitting a delay in and reevaluation of the decision to continue responding, and (c) protecting the self-directed (executive) responses that will occur within these delays as well as the goal-directed behavior they generate from disruption by competing events and responses (interference control or resistance to distraction) (Barkley, 1997b).

From Barkley's perspective, without the initial inhibition of the dominant response, thinking and related goal-directed actions are impossible (Bronowski, 1977). The ability to inhibit the dominant response and subsequently engage in self-change for the sake of attaining a goal requires self-control. Self-control is a response made by the individual that alters the probability of their subsequent response to an event and in so doing thereby changes the likelihood of a later or delayed consequence related to that event (Skinner, 1953). Self-control has been defined as generally involving the choice of a larger, later reward over a smaller, sooner (Ainslie, 1974). However, this general definition does not consider the self-directed actions in which the individual must engage so as to value the delayed over the immediate reward and then to pursue that delayed consequence. Four steps appear involved in adequate self-control: (1) the inhibition of the prepotent response directed toward some environmental event and (2) the directing of actions (both cognitive and motoric) toward oneself, (3) which will result in the alteration of the subsequent response from what it would have been had none of these self-directed actions been, and (4) that leads to the change in the likelihood of a delayed (future) consequence that arises as a function of this change in the behavior that will be employed.

Goal-directed behaviors require the ability to contemplate a future time point so as to juxtapose the "now" against the "later" and to evaluate the value or desirability of that later state vs. the current one. This capacity to consider delayed or future events requires some mental capacities for understanding time and the temporal ordering of events, for holding this information actively in mind, and for using this information to order and execute timely responses to them (Shimamura, Janowsky, & Squire, 1990). To accomplish the long chains of behavior that will be needed to bridge the delay in time between now and later, behavior must be hierarchically organized using smaller units nested within larger goals that are themselves nested within even larger goals (Badre, 2008). In Barkley's theory of EF and ADHD, executive functions represent classes of

self-directed behavior or actions that we employ for purposes of self-regulation (changing our future) (Barkley, 1997b). The key then to operationalizing EF is that all EFs are self-directed actions, the central requirement for distinguishing an executive from nonexecutive mental ability. Any executive act then achieves the requirements for self-stopping, self-management to time, self-organization and problem solving across time, self-activation to initiate them, self-motivation to sustain them toward the goal, and emotional self-regulation. Such actions may be covert yet are volitional, effortful, conscious, and self-initiated actions. Neuroimaging research suggests that this covert behavior is measurable (D'Esposito et al., 1997; Ryding, Bradvik, & Ingvar, 1996).

Response inhibition is a requirement for self-regulation because one cannot direct actions or behavior toward one's self if one is automatically responding impulsively to an immediate event. In Barkley's theory, the EFs represent the general classes of self-directed actions that humans use in self-regulation *following this delay in the immediate response* (Barkley, 1997b). Without this initial response delay, however, the EFs are poorly accessed, arise after the fact, or even fail to be utilized at all.

The EFs depend on the individual being capable of perceiving and valuing future over immediate outcomes. If there is no sense of the future, there is no self-control, and there is no point in engaging in socially cooperative behavior that requires the subordination of one's immediate self-interests to those of others to attain greater longer-term self-interests. As we develop, we become far more capable of showing a preference for larger delayed rewards over smaller more immediate ones. This development requires the capacity to sense the future, that is, to construct hypothetical futures, particularly for social consequences. It also simultaneously involves the weighing of alternative responses and their temporally proximal and distal outcomes—a calculation of risk/benefit ratios over time.

Barkley originally theorized that humans have at least five classes of action that they direct toward themselves to change themselves to improve their future. In his model, these five classes are (a) self-stopping (response inhibition), (b) sensing to the self, (c) self-speech, (d) emoting and motivating to the self, and (e) self-play (Barkley, 1997b). Barkley's model relies heavily on the work of others (Bronowski, 1977; Damasio, 1995; Fuster, 1997; Goldman-Rakic, 1995; Vygotsky, 1987) and is therefore a hybrid model.

In his original hybrid model, response inhibition sets the occasion for the occurrence of the other EFs. The other four EFs are interactive and share a common purpose: to "internalize" or more accurately privatize certain self-directed behavior so as to anticipate and prepare for the future and maximize net long-term vs. short-term outcomes.

Sensing to the Self (*Nonverbal Working Memory*). The second executive function is the nonverbal working memory, or the visual–spatial sketchpad (Baddeley, 1986, 2003; Baddeley & Hitch, 1994). In Barkley's theory, this concept represents the privatization of sensory–motor actions—sensing to the self (literally, resensing to the self). The most important of the senses to humans are vision and hearing and so this EF is chiefly comprised of visual imagery and covert audition—re-seeing and re-hearing to the self. This EF has both retrospective (sensory or resensing) and prospective (preparatory motor) elements (Goldman-Rakic, 1995) and is the mental module for sensing the hypothetical future from the experienced past. By generating the private or mental representations (images, auditions, etc.) that bridge the cross-temporal elements within a contingency arrangement (event–response–outcome), humans are able to use such mental representations to guide and sustain actions over time and manage themselves relative to time (or time management) to attain the contemplated goal.

Speech to the Self (*Verbal Working Memory*). Barkley posits that the internalization of speech (Diaz & Berk, 1992) serves as the basis for the verbal working memory system of EF (Baddeley, 1993) and transitions outer-directed behavior toward the self as a means to control one's own behavior. In Barkley's theory, Vygotsky's model of the developmental internalization of speech

(Vygotsky, 1987) figures prominently and represents what other neuropsychologists call verbal working memory. Self-speech permits self-description and reflection, self-instruction, self-questioning, and problem solving, as well as the invention of rules and meta-rules to be applied to oneself (Diaz & Berk, 1992). Self-speech contributes to self-control and provides the basis for private verbal reasoning, strategy (rule) development, verbal problem solving, and moral conduct (internalizing socially prescribed rules of conduct).

Emotion to the Self (*Self-Regulation of Affect/Motivation/Arousal Emotion*). This EF may occur initially as a consequence of the first three (inhibition, private sensing, and self-speech). These mentally represented events have associated affective and motivational properties or valences (Damasio, 1995). Initially these affective valences have publicly visible counterparts—emotional displays—as when we laugh out loud in response to a mentally visualized incident. Eventually, however, these emotional displays are kept private or covert in form. In Barkley's model, private self-directed affect and its motivational properties—feeling (emoting/motivating) to the self—develop from using the other EFs above to generate the mental representations that provoke such secondary emotional states in the absence of such provocative events in the environment. The development of emotion to the self provides the self-restraint of emotion so important to cooperative social interactions. Yet it also provides the intrinsic motivation (willpower) so necessary to support future-directed behavior, especially across large delays in schedules of reinforcement or where external consequences for such future-directed action are otherwise not available in the immediate context. It also provides the motivational basis for persistence (sustained attention) toward future goals (Barkley, 1997b). These two functions of this EF, emotional self-control and self-motivation, may be partially separable or measurable given that they may be mediated by different zones of the anterior cingulate cortex.

Self-Play (*Reconstitution*). The last EF in the original theory is self-directed private (covert) play, or reconstitution. Fluency, flexibility, and generativity are other terms by which this EF is known in neuropsychology. This EF is the source of self-organization and innovation (problem solving) during goal-directed actions. In Barkley's model, reconstitution occurs through a two-step process: analysis and synthesis (Barkley, 1997b). Both are applied to the mental contents being held in the working memory systems (self-sensing and self-speech systems). In analysis, old behavior contingencies (stimulus–response arrangements and sequences) are broken down into smaller units. These units are then recombined (synthesized) into new sequences that can be tested against the requirements of the problem to be solved (Fuster, 1997). Reconstitution, or private planning and problem solving, arises from the internalization of play (both sensory–motor and symbolic) and creates the source for generating novel future-directed actions. Such novel actions will be needed when obstacles to a goal are encountered (problems) in order to overcome them and successfully attain the goal.

Theoretical Amendment. More recently, Barkley (2012) has amended this original model in three important ways. First, he has argued that there is a sixth self-directed action, or EF, which arises in conjunction with inhibition during developing and that is self-awareness (self-monitoring). Self-awareness arises like the other EFs through a process of self-directing a pre-executive function, in this case attention. Thus, self-directed attention codevelops with inhibition as neither makes any sense in the absence of the other. One cannot inhibit an automatic action if one is not aware of or attending to his or her own behavior, and there is little point to self-monitoring more automatic behavior if it cannot be inhibited or interrupted so as to make it more consistent with a longer-term goal. Second, neither self-monitoring nor self-inhibition provides much of any benefit if there is not a mental capacity to contemplate the future generally or goals specifically and alternative means to attain it. This requires the nonverbal working memory or self-directed sensory–motor

EF above in which the future is being contemplated. Therefore, in the more recent iteration of this theory, Barkley now argues that inhibition, self-awareness, and self-directed sensory–motor actions likely codevelop as a unity to form the initial level of EF as it likely evolved in human evolution. It has subsequently been expanded to include self-directed speech, emotion/motivation, and play (planning/problem solving).

Third, Barkley now explicitly shows how this initial instrumental self-directed or cognitive level of EF expands over time to link up with methodical–self-reliant behavior and the next higher level in a hierarchy of EF functioning in daily life. Cognitive EFs extend their effects outward to guide self-regulatory behavior and daily adaptive functioning more generally creating executive actions. EF = executive cognition (EC) + executive actions or behavior (EA or EB). This linkage between instrumental and self-reliant levels of EF is part of what Barkley argues as an extended phenotype of EF into daily and lifelong effective social functioning. He then goes on to elaborate to additional levels of this extended phenotype model of EF in which the effects of EF lead upward (outward) to socially reciprocal actions with others to accomplish goals (the tactical–reciprocal level) and eventually to socially cooperative ventures (the strategic–cooperative level). At the latter level, groups form to accomplish mutual goals that no single individual can attain alone or through mere reciprocity or exchange. With each new level in this hierarchy, additional mental faculties may be needed, such as theory of mind and vicarious learning through the mirror-neuronal system of the prefrontal cortex (PFC). Larger social networks are also required as is a greater reliance on cultural devices and methods to form the external scaffolding needed to boost EF upward to these higher levels of human social life across major domains of activities. In this way, EF can now be linked not only to daily adaptive or self-reliant activities but also outward to ethics and morality, social exchange and economics, law and criminality, and even government and politics through such extended phenotypic effects. All have in common the essential requirement to be capable of contemplating the future, or the later versus the now. EF disorders like ADHD therefore result in a weakening or even collapsing of this hierarchy downward resulting in serious social and adaptive impairments.

Further Implications. Each of the EFs noted above is also hypothesized to contribute to developmental shifts in the sources of control over human behavior from (a) external events to mental representations related to those events, (b) control by others to control by the self, (c) immediate reinforcement to delayed gratification, and (d) the temporal now to the conjectured social future. Across development, individuals progressively become more guided by covert representations that permit self-control, deferred gratification, and goal- and future-directed actions. In Barkley's model, these five EFs provide a powerful set of mind tools that greatly facilitate adaptive functioning in anticipation of the future (Barkley, 1997b). These EFs permit the private simulation of actions that can be tested out mentally for their probable consequences before a response is selected for public execution. This constitutes a form of mental trial and error learning that lacks real-world consequences for one's mistakes.

The Impact of ADHD on Self-Regulation

Behavioral inhibition is a central problem for those with ADHD (Nigg, 2001). Barkley's theory originally asserted that a deficit in inhibition associated with ADHD would result in a cascading of secondary deficits into the remaining EFs. Behavioral disinhibition leads to nonverbal working memory deficiencies and therefore (1) forgetfulness (forgetting to do things at certain critical points in time), (2) impaired ability to organize and execute their actions relative to time (e.g., time management), and (3) reduced hindsight and forethought, (4) leading to a reduction in the creation of anticipatory action toward future events. As a result, the capacity for the cross-temporal organization of behavior in those with ADHD is diminished, disrupting the ability to sequence together complex chains of actions

directed, over time, to a future goal. In its most recent iteration, however, Barkley now concedes that since self-awareness, self-restraint (inhibition), and self-sensory–motor actions (nonverbal working memory) may codevelop as a unity, all become the primary deficits in ADHD and the starting point for understanding the symptoms associated with the disorder (and its two-dimensional structure). Research does show that not only inhibition but also nonverbal working memory, timing, and forethought are deficient in ADHD (Frazier, Demaree, & Youngstrom, 2004; Rapport et al., 2008). The greater the degree to which time separates the components of the behavioral contingency (event, response, consequence), the more difficult the task will prove for those with ADHD. Thus, Barkley now argues that working memory, especially nonverbal, may be as much a primary deficit in ADHD alongside that of poor inhibition and diminished self-awareness rather than the latter being secondary effects of the inhibitory problem, consistent with more recent research on this issue (Rapport et al., 2008). In sum, inhibition, self-monitoring, and working memory are interactive with deficits in each being likely to adversely affect the others. Indeed, Barkley now suggests that the very process of self-directing and eventually internalizing (privatizing) the instrumental EFs may be a more general developmental deficit in ADHD.

In addition to deficiencies in working memory, the privatization of speech should also be delayed in ADHD, resulting in greater public speech (excessive talking), less verbal reflection before acting, less organized and rule-oriented self-speech, a diminished influence of self-directed speech in organizing and controlling one's own behavior, and difficulties following the rules and instructions given by others. Research supports this hypothesis (Berk & Potts, 1991; Winsler, Diaz, Atencio, McCarthy, & Chabay, 2000). Verbal working memory tasks such as digit span backward, mental arithmetic, paced auditory serial addition, paired associated learning, and other tasks believed to reflect verbal working memory are difficult for those with ADHD (Frazier et al., 2004; Hervey, Epstein, & Curry, 2004).

These deficits lead to a third problem—impaired emotional/motivational self-regulation. Those with ADHD will display (1) greater impulsive emotional expressions in their reactions to events, (2) less objectivity in the selection of a response to an event, (3) diminished social perspective taking as the individual does not delay his or her initial emotional reaction long enough to take the view of others and their own needs into account, (4) greater difficulties in self-soothing the initially strong emotional reaction, (5) greater problems with self-distracting and otherwise modifying their attention to the emotionally provocative event so as to diminish its ongoing impact, and (6) a diminished ability to construct more socially appropriate and moderate emotions in place of the original emotion that are more supportive of their long-term welfare or social interests. ADHD should also impair the capacity to induce drive and motivational states in the service of goal-directed behavior. Those with ADHD remain more dependent upon the environmental contingencies within a situation or task to determine their motivation than do others (Barkley, 1997a).

Barkley's EF model further predicts that ADHD will be associated with impaired reconstitution, or self-directed play, evident in a diminished use of analysis and synthesis in the formation of both verbal and nonverbal responses to events. The capacity to mentally visualize or verbalize, manipulate, and then generate multiple plans of action (options) in the service of goal-directed behavior and to select from among them those with the greatest likelihood of succeeding should, therefore, be reduced. This impairment in reconstitution will be evident in everyday verbal fluency when the person with ADHD is required by a task or situation to assemble rapidly, accurately, and efficiently the parts of speech into messages (sentences) so as to accomplish the goal or requirements of the task. It will also be evident in tasks where visual information must be held in mind and manipulated to generate diverse scenarios to help solve problems (Barkley, 1997a). In general poorer self-organization and problem solving in support of one's goals or assigned tasks should result.

Evidence for a deficiency in verbal and nonverbal fluency, planning, problem solving, and strategy development more generally in ADHD is limited, but what exists is consistent with Barkley's theory (Clark, Prior, & Kinsella, 2000; Klorman et al., 1999).

In general, individuals with ADHD will be more under the control of external events than mental representations about time and the future, under the influence of others rather than acting to control one's self, pursuing immediate gratification over deferred gratification, and under the influence of the temporal now more than of the probable social futures that lie before them. From this vantage point, ADHD is not a disorder of attention, at least not to the moment or the external environment, but more of a disorder of intention—that is, attention to the future and what one needs to do to prepare for its arrival. It is also a disorder of time—time management specifically—in that the individual manifests an inability to regulate their behavior relative to time as well as others of their developmental level. This creates a sort of temporal myopia in which the individual responds to or prepares for only events that are relatively imminent rather than ones that lie further ahead in time yet which others of their age are preparing for so as to be ready for their eventual arrival (Barkley, 1997a).

Other Perspectives on ADHD and EF

In viewing ADHD as a disorder of self-regulation (and its underlying executive functioning), Barkley's theory has proposed a model of how ADHD disrupts the normal structure and processes of self-regulation to produce what is known about the disorder. Barkley's theory also suggests new hypotheses about what may be disrupted by the disorder. In this way, Barkley's theory has been very influential in spurring research into the relationship between EF and ADHD.

However, some researchers have suggested that EF deficits may not be specific to the disorder and that it is more likely that only a subpopulation of individuals with ADHD experience clinically significant executive dysfunction. For example, although neuropsychological theories have implicated executive dysfunction as a main characteristic of ADHD, some researchers have questioned the role of EF as a core deficit of the disorder. In fact, some (e.g., Trani et al., 2010) have posited that evidence from neuropsychological studies suggests that only a subpopulation of individuals with ADHD experience clinically significant EF deficits. Thus, some believe that executive dysfunction is only a partial explanation of a comprehensive model of ADHD. The potential flaw in such arguments is the premise that "cold" cognitive EF psychometric measures as collected in clinical or lab settings are the sole or gold standard for evaluating EF. Barkley's recent extended phenotype model of EF shows why this is not the case and why EF tests have low or no ecological validity (Barkley, 2012).

Theories implicating executive dysfunction as a causal mechanism underlying ADHD have been tested by comparing groups of individuals with and without DSM-defined ADHD. However, it has been suggested based on reviews of the results only of psychometric EF tests that no one neuropsychological model, including Barkley's model of executive dysfunction, currently provides a complete account of ADHD (Nigg & Casey, 2005). For example, Nigg et al. (2005) reported on neuropsychological data gathered from 600 children without ADHD and 287 children with ADHD combined subtype. Of the administered neuropsychological measures, the Response Suppression Task: Stop Task was the most discriminative with approximately 50 % of the children with ADHD demonstrating clinically significant impairment. However, this suggests that nearly half of the children with ADHD were not impaired on tasks of response inhibition. Furthermore, although approximately 80 % of children with ADHD exhibited impairment on at least one EF task, so did nearly half of the control participants. Thus, because only some individuals with ADHD experienced executive dysfunction across the measured tasks, it was concluded that EF is not the only causal pathway leading to ADHD (Nigg et al., 2005).

Similarly, results of several meta-analyses have also indicated that EF deficits are likely experienced by some, but not all, individuals with ADHD. One such meta-analysis (Boonstra, Oosterlaan, Sergeant, & Buitelaar, 2005) quantitatively examined the difference between adults with ADHD and control participants across EF measures and non-EF variables. Thirteen studies were reviewed, and data from five tests of EF were analyzed. Specifically, data on participants' verbal fluency, attention and response inhibition, working memory, and mental inhibition were analyzed. Participants' performance on non-EF variables (e.g., processing speed, verbal memory) and EF tasks was also compared. Results indicated that adults with ADHD tended to demonstrate greater difficulty than control participants on measures of both EF and non-EF. Further, because average effect sizes were similar for both the EF and non-EF domain ($d = .40$ and .43, respectively), Boonstra et al. (2005) concluded that EF is not a specific deficit for adults with ADHD. Rather, the authors suggested that adults with ADHD demonstrated poorer performance than adult control participants in a variety of cognitive domains, including EF.

In another meta-analysis, Willcutt, Doyle, Nigg, Faraone, and Pennington (2005) included 83 studies that measured EF psychometrically among groups of individuals with ADHD (total $N = 3{,}734$) and without ADHD ($N = 2{,}969$). Although ADHD groups demonstrated significant EF impairment across all measured EF domains (i.e., response inhibition, vigilance, set-shifting, planning, organization, verbal working memory, spatial memory), effect sizes were moderate in size ($d = .46$–$.69$) (Willcutt et al., 2005). Others (Nigg et al., 2005) have criticized the interpretation that moderate effect sizes are evidence that a unified, core EF deficit is characteristic of all children with ADHD. Specifically, Nigg et al. (2005) argued that such effect size magnitudes suggest distributional overlap between ADHD and non-ADHD samples on EF performance and that the performance of some with ADHD falls within the normal range.

Some evidence suggests that tests of EF are sensitive but not specific to the diagnosis of ADHD (e.g., Doyle, Biederman, Seidman, Weber, & Faraone, 2000). Clinically, this means that poor scores on these tests may indicate that an individual has ADHD, but average or above-average scores cannot be used in isolation to rule out the possibility of ADHD. For example, one study (Wodka et al., 2008) examined the predictive ability of four subtests of the Delis–Kaplan Executive Function System (D-KEFS) toward an ADHD diagnosis in 69 children without ADHD and 54 children with ADHD. Results indicated that those without ADHD performed significantly better than those with ADHD on only two of the four selected D-KEFS measures. The authors concluded that this measure of EF lacks specificity in ADHD diagnosis (Wodka et al., 2008).

While these data suggest that EF tests are not specific to ADHD diagnosis, there are also data that suggest otherwise (Clark et al., 2000; Holmes et al., 2010). For example, Clark et al. argued that EF impairment is specific to ADHD. They found that two groups of adolescents with ADHD (e.g., ADHD only and ADHD with comorbid ODD/CD) demonstrated a significant deficit on measures of EF in comparison to adolescents with ODD/CD only and a typically developing control group. Thus, the relationship between ADHD and EF continues to evolve and may depend on how EF is being defined and assessed.

As noted above, the argument has been made (Barkley, 2012; Barkley & Fischer, 2011; Barkley & Murphy, 2010, 2011) that all such conclusions about the nature of EF in ADHD are undermined by the exclusive reliance of such research on psychometric approaches to measuring EF. When other methods, such as rating scales of EF, have been used, the vast majority (86–98 %) of individuals with ADHD are found to place in the deficient range ($\leq$ 7th percentile). The fact that EF ratings are only weakly related if at all to EF tests scores further undermines the credibility of the latter as the exclusive approach to studying EF in disordered populations such as ADHD.

Barkley's EF Theoretical Expansion

In the 15 years since Barkley first proposed his theory of EF and ADHD, much research, often conflicting, has considered the relationship between EF and ADHD (see above). As briefly noted above, Barkley (2012) recently expanded his EF theory upward to involve four additional levels beyond the level of basic cognitive EFs. A main goal of this theoretical expansion was to integrate a more traditional view of EF at the neurocognitive level with how it plays out in everyday life, referred to in Biology as the extended phenotype.

Barkley's Expanded Phenotypic Theory of EF

In Barkley's expanded theory, EF and EF subcomponents arise out of two developmental processes, the *self-direction of actions* and their *internalization*. It is the self-direction of human actions that makes an act, function, or component executive in nature. The self-directed action is being done to alter subsequent behavior from what it would have otherwise been (it is a means to an end) and that is done to alter the likelihood of future consequences for the individual (ends or goals). This constitutes the definition of self-regulation. Therefore, the initial definition of EF was clarified and made more specific as follows: *the use of self-directed actions so as to choose goals and to select, enact, and sustain actions across time toward those goals*. Although the cross-temporal nature of EF is implied in the definition of self-regulation, Barkley believed it was important to make it explicit. Humans bind current status, intermediate means, and future ends together into cross-temporal structures that are mentally represented and serve to guide goal-directed actions (Fuster, 1997).

In Barkley's expanded theory of EF, as noted above, there are now six self-directed actions rather than five that are identified as being used for self-regulation and as being self-evident in any human's existence: (1) self-directed attention to create self-awareness, (2) self-directed inhibition to create self-restraint, (3) self-directed sensory–motor actions to create mental representations and simulations (ideation), (4) self-directed speech to create verbal thinking, (5) self-directed emotion and motivation to create conscious appraisal, and (6) self-directed play (nonverbal and verbal reconstitution) to create problem solving, fluency, or innovation. Humans are using at least six forms of self-regulation in directing and sustaining action toward a goal, and each is an EF in Barkley's expanded theory.

Using Barkley's extended phenotype viewpoint, EF has radiating effects outside of and at considerable spatial and temporal distances from the organism. This leads to an appreciation for the important role of EF in the initial zone of that phenotype that respects the group living niche in which humans exist and so includes other humans as self-interested competitors and manipulators. This expansion of the EF phenotype identified fellow humans as likely to be engaging in the manipulation of others as a means to attain ends at this methodical–self-reliant level of the EF phenotype. Thus, Barkley's definition of EF was broadened to incorporate this initial social context and became the use of self-directed actions so as to choose goals and to select, enact, and sustain actions across time toward those goals usually *in the context of others*.

EF is not just indispensable for social self-defense. Rather, by adopting a longer view of one's self-interests, others can be construed as a means to goals that are symbiotically beneficial to both parties. This connected EF to the practice of social reciprocity and exchange as well as the larger field of economic behavior and formed the tactical–reciprocal level of the EF phenotype. Extending the time horizon over which one is contemplating the longer-term even further ahead, it becomes possible to demonstrate that reciprocity may be improved through cooperation (acting in unison) which itself often results in division of labor with trade. This forms the strategic–cooperative level of the EF phenotype. Understanding these extended phenotypic effects of EF led Barkley to a further expansion of the definition of EF: the use of self-directed actions so as to choose goals and to select, enact, and

sustain actions across time toward those goals usually in the context of others *often relying on social means*.

Barkley's extended phenotype model of EF also argues for an increasing use of cultural scaffolding to ratchet up the human capacities for goal-directed actions. Humans create and use culture (stored and shared information)—its knowledge, inventions, devices, and products—to bootstrap their EF capacities upward for the attaining of larger goals, extending over longer time spans, spatial distances, and social networks. Thus, the definition of EF was further expanded to recognize this fact: the use of self-directed actions so as to choose goals and to select, enact, and sustain actions across time toward those goals usually in the context of others often relying on social *and cultural means*.

Finally, to contrast forms of cultural scaffolding (principles, policies, and governments) that do and do not promote this upward ratcheting of the human ability for goal-directed action, Barkley emphasized that human EF is motivated out of self-interest, albeit over the longer term. Such self-interest can only be determined by the individual using reason. EF is motivated by subjective appraisal of longer-term self-interest and is essentially self-determination. Forms of cultural scaffolding that accept and promote these basic features of human nature allow EF to succeed, extend outward to have wider phenotypic effects, and permit human life to thrive and prosper as individuals pursue their longer-term self-interests. EF was therefore concluded to be the use of self-directed actions so as to choose goals and to select, enact, and sustain actions across time toward those goals usually in the context of others often relying on social and cultural means *for the maximization of one's longer-term welfare as the person defines that to be*.

A number of features distinguish Barkley's extended phenotypic model of EF including Barkley's belief that EF and its components have arisen out of two psychological processes: self-direction of action and internalization or privatization. EF consists of private self-directed actions (self-regulation) and is viewed as active effortful behavior-to-the-self. Barkley's theory posits that much of this initial instrumental level of self-directed activity gradually becomes private in form across development such that by adulthood it gives rise to a private and cognitive domain of behavior as distinguished from behavior that is readily observed. Humans therefore possess both a private and a public self (Bronowski, 1977).

Barkley's model of EF is presently the only model which employs the biological concept of an extended phenotype. The goal is to demonstrate how EF radiates outward to produce effects on the physical and social environment at a distance from the genotype and conventional phenotypic levels to give rise to self-reliance, reciprocity, cooperation, and social mutualism. In this way, Barkley's EF model links EF to the social interactive behavior of individuals as well as their social self-defense, reciprocity, cooperation, mutualism, and communalism. In doing so it shows how EF is essential to functioning in most major life activities (occupational, educational, financial–economic, cohabiting/marital, parental, etc.). All of these domains of human activity are predicated on a capacity to sense the future – to contemplate the likely consequences for the various actions one may choose to do in order to attain a goal.

Emphasizing and Predicting Real-World Functioning

Barkley's expanded theory of EF was developed to revise his original theory and go beyond the neurocognitive level and emphasize how EF affects everyday life and functioning, not simply performance on a laboratory measure of EF. This theoretical expansion follows a move in the fields of psychiatry and psychology which emphasizes collecting real-world information about the deployment of EF rather than relying on laboratory tests (Gioia, Isquith, Guy, & Kenworthy, 2000; Roth, Isquith, & Gioia, 2005).

As a hierarchically organized model, Barkley's theory makes obvious how impairments at lower EF levels may radiate upward to affect higher levels; yet Barkley's theory also shows that

deficits at higher levels need not always radiate downward to the detriment of functioning at the lower level. For instance, individuals may not be capable of sustained cooperative ventures (acting in unison to attain a common goal in which all share) but may still be able to engage in social reciprocity and exchange. The radiating effects of disturbances at lower levels outward to later, higher levels of human functioning can show how ADHD can have adverse effects on many fields or domains of human functioning, such as marriage and parenting, education, health maintenance, economic behavior (occupational functioning, financial management), transportation (driving), and community participation (politics and government). The impact that EF deficits may have on traditional neuropsychological tests may be trivial in comparison to those occurring at higher levels of the extended EF phenotype (Barkley & Fischer, 2011).

Implications of Barkley's Theory for Managing and Treating ADHD

Barkley's extended phenotype model of EF views EF as conscious, effortful, self-initiated, and self-directed activities that strive to modify otherwise automatic behavior so as to alter the likelihood of future consequences (longer-term goals and desires). Barkley's theory views these self-directed activities as consisting of self-directed attention, self-restraint, sensory–motor action to the self using visual imagery, speech to the self, emotion to the self, self-motivation, and self-directed play. Barkley's theory encourages those who wish to develop or rehabilitate their EF to repeatedly practice: self-monitoring, self-stopping, seeing the future, saying the future, feeling the future, and playing with the future so as to effectively "plan and go" toward that future.

The extended phenotype view of EF argues that the problems posed for those with EF deficits in major life activities have more to do with not using what they know at critical points of performance in their natural environments than with not knowing what to do. In short, information is not self-regulation. The extended phenotype model views EF as self-regulation and impairment in EF poses more of a problem with doing what one knows rather than one of knowing what to do—it is a performance vs. knowledge (skills) distinction.

With the performance vs. knowledge distinction in mind, interventions are most helpful when they assist with the performance of a particular behavior at the *point of performance* in the natural environments where and when such behavior should be performed. The further away in space and time a treatment is from this point of performance, the less effective it is likely to be in assisting with the management of EF deficits. Conveying more knowledge does not prove as helpful as altering the parameters associated with the performance of that behavior at its appropriate point of performance.

If the process of regulating behavior by internally represented forms of information (working memory or the internalization of self-directed behavior) is impaired or delayed in those with ADHD, then they will be best assisted by "externalizing" those forms of information; the provision of physical representations of that information will be needed in the setting at the point of performance. Since covert or private information is weak as a source of stimulus control, making that information overt and public may assist with strengthening control of behavior by that information. Consequently, those with ADHD will require the provision of externalized sources of motivation. For instance, the provision of artificial rewards, such as tokens, may be needed throughout the performance of a task or other goal-directed behavior when there is otherwise little or no such immediate consequence associated with that performance. Such artificial reward programs become for the person with ADHD what prosthetic devices such as mechanical limbs are to the physically disabled, allowing them to perform more effectively in some tasks and settings with which they otherwise would have considerable difficulty.

Several EF-based cognitive behavioral therapy (CBT) approaches related to Barkley's model have been recently developed, researched, and published in manual form for clinicians

(Ramsay & Rostain, 2008; Safren et al., 2005, 2010; Solanto et al., 2010). All of these CBT protocols go beyond simply conceptualizing ADHD as a disorder of purely cognitive underpinnings. Rather, these protocols also consider the adaptive or self-reliant and higher levels of EF in Barkley's extended phenotype model (e.g., time management, self-organization, problem solving, emotional self-control, self-motivation). These CBT protocols also consider different EF levels of dysfunction. For example, deficits at the basic instrumental level of EF might be dealt with by training in self-directed inhibition, imagery, audition, and speech, among others, that is often the focus of cognitive rehabilitation (often computer based) training programs. Medications may also serve to temporarily improve or even normalize some or all of these instrumental EFs and thus be valuable supplements to such CBT programs. Adverse effects at the self-reliant level may need to focus more on helping the individual to reorganize their external environment to facilitate performance of EF, self-care, and general adaptive functioning at this level. This could also be facilitated and amplified by artificial devices such as digital memory recorders, computers, personal data assistants, or cell phones to which periodic prompts and reminders are sent, and other such environmental prostheses. Deficits at the strategic levels will likely require training and ongoing assistance with social skills, etiquette, emotional self-regulation in social settings, and other therapies aimed at the social nature of these levels (reciprocity, cooperation, mutualism).

Conclusions/Future Directions

The expanded model explains why EF tests may be insufficient to capture deficits in EF, even at the instrumental level, because their window of ascertainment of cognition may be too brief for how humans deploy EF in daily life. Such tests also focus on "cold" cognition rather than on the social purposes of the EF system, fail to evaluate the self-regulation of emotion and motivation, and do not capture the reciprocal relationship between EF and cultural scaffolding needed to operate at higher levels of EF as it occurs in human daily life activities. For centuries, individuals with disorders of the PFC have been noted to have marked changes in their personality, ethics and morality, capacity for effective occupational and educational functioning, a preference for immediate gratification, emotional dysregulation, and an adverse impact on social reciprocity and cooperation none of which are the focus of the "cold" psychometric approach to evaluating EF. Barkley's latest model integrates EF with these larger important human endeavors attempting to demonstrate why disorders of EF produce profound disturbances in human adaptive functioning across numerous major domains of daily life activities while being only partially detectable by lab tests of the EFs.

Based on such a model, it is also evident that ADHD has to be EFDD, not only because the neural networks of the PFC that give rise to the executive brain are deficient in ADHD but also because the behavioral symptoms of ADHD are dimensions of EF in daily life (behavioral regulation and metacognition) listed under other names. Moreover, ADHD has to equal EFDD given the profound deficits evident in EF in daily life activities as captured by rating scales of EF even if such deficits are only evident in a minority of cases on "cold" cognitive test batteries that only partially evaluate the instrumental level of EF cognition.

There is considerable room for future research based on this extended phenotypic view of EF and its outward extension into daily human activities, especially over time, and as applied to understanding ADHD (and other disorders of EF). New tests could be developed to improve laboratory evaluation of EF provided that they integrate social motives into their content, use more extended time intervals, evaluate self-regulation including that of emotion and motivation, and are combined with other measures of higher level EF functioning, such as rating scales of EF and direct behavioral observations across time in natural settings. New measures of EF also need to be developed to more directly capture the tactical–reciprocal and strategic–cooperative levels of the EF phenotype beyond

the value that adaptive behavior inventories, social skills ratings, general impairment rating scales, and even archival records (e.g., driving, education, work history) may have at the moment to partially detect such impairments. As Barkley emphasized 15 years ago (Barkley, 1997b), such theories of EF are always imperfect when first proposed yet they serve to provide a time-limited tool for better understanding, evaluating, and managing EF until better models can be designed based on research and experience with the earlier theory.

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