CHAPTER 26

Executive Function Training for Children with ADHD

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The growing numbers of innovative, nonpharmacological treatments developed for children with attention-deficit/hyperactivity disorder (ADHD) in recent years reflect an emerging synergy between basic and applied science, and symbolizes how they reciprocally inform and advance the field. This chapter examines executive function training, one category of these emerging treatment interventions that has garnered widespread interest among clinicians, mental health professionals, and parents of children with ADHD. We summarize the accumulating evidence from neuroimaging studies initially to provide fundamental insights into why children with ADHD continue to experience significant impairment across a wide range of functional outcomes despite receiving the most efficacious treatments available over an extended time period. The ensuing section highlights the evolving literature on *executive functions* (EFs) and the extent to which particular EFs and/or their component processes are deficient and related to core clinical features (inattention, hyperactivity–impulsivity) and functional outcomes in children with ADHD. Afterward, we describe two broad categories of EF training programs, *facilitative intervention training* (FIT) and *mindfulness*. We focus on these two particular training programs because they share two common tenets: (1) that many of these children's behavioral, cognitive, interpersonal, and learning difficulties are outcomes of underdeveloped or poorly regulated EF processes, and (2) that these EF processes can be strengthened or corrected through training and extended practice.

Recent meta-analytic reviews of FIT and mindfulness are examined in a later section to examine the extent to which training results in significant gains within and across two types of outcome measures. The first of these involves the extent to which training specific EFs and/or integral attentional processes transfers to untrained tasks that rely on nearly identical cognitive processes (i.e., *near-transfer effects*). Training children's short-term memory (STM) with an adaptive digit span task and demonstrating that training improves performance on a word list recall task is an example of a near-transfer training effect. Documenting these effects is necessary to ensure that improvement is associated with training as opposed to task-specific factors associated with practice or expectancy effects, and it also helps to validate the mechanisms responsible for potential transfer to more distal (i.e., *far-transfer ef-*

fects) cognitive and behavioral outcomes (Shipstead, Redick, & Engle, 2012). Demonstrating far-transfer effects, however, is by far the more critical training objective given that the goal of FIT and mindfulness is not to improve children's scores on laboratory-based EF tasks, but to improve specific cognitive abilities and the myriad functional outcomes dependent upon these abilities. Far-transfer effects represent post-treatment improvements in abilities or behaviors that depend on the trained cognitive abilities and involve overlapping brain regions (Unsworth & Engle, 2007) but are assessed using dissimilar and qualitatively different tasks than used during training. Training children's working memory (WM) and demonstrating that training improves academic performance and/or interpersonal functioning that relies on WM are examples of far-transfer training effects. Theoretically, the degree of improvement on far-transfer measures is limited to a considerable extent by two factors: the magnitude of documented near-transfer change and the extent to which improvement on far-transfer outcome measures rely on these newly trained abilities (Redick et al., 2012). Stated differently, if a training program results in limited or insignificant improvement on tasks that are highly *similar* to those used during training, there is no obvious theoretical reason to expect improvement on far-transfer measures that require a combination of trained and untrained cognitive processes for successful performance. The degree to which a far-transfer outcome measure requires cognitive processes similar to those being trained can be estimated by examining the magnitude of the relationship between the two tasks or outcome variables. For example, if training focuses on improving visuospatial WM, and a fluid reasoning measure such as the Raven's Progressive Matrices is selected to assess far-transfer training effects, very little improvement would be expected even if visuospatial WM training were highly effective. This is because the type of fluid reasoning necessary to perform well on the Raven's Matrices only partly reflects a child's WM ability, as evidenced by the limited relationship (*r* = .42, or less than 18% of shared variance) between the two constructs in past investigations.

In the final section, we summarize extant evidence supporting FIT and mindfulness interventions. We also discuss what we believe represents the most critical issues that must be resolved to enable these types of interventions to bring about fundamental and lasting changes in the cognitive abilities and associated functional outcomes in children with ADHD.

WHY CURRENT TREATMENTS FAIL: INSIGHTS FROM NEUROIMAGING STUDIES

Children with ADHD are in dire need of innovative and effective treatments in light of the disheartening results of the Multimodal Treatment of ADHD study (see Chapter 28) documenting significant and continued impairment across a wide range of clinical, educational, and interpersonal outcomes after 3–8 years despite receiving the most potent, evidence-based treatments available for the disorder for an extended time period (Jensen et al., 2007; Molina et al., 2009). The failure of these treatments (individually titrated psychostimulant medication alone, intensive parent training and classroom contingency management alone, or their combination) to significantly improve the long-term functioning of children with ADHD is not altogether unexpected. Neither treatment was based on a theoretical framework of the disorder. Psychostimulants were discovered serendipitously by an astute physician noting improved concentration and reduced motor activity in children administered Benzedrine who suffered postpneumoencephalography[1] headaches. Contemporary parent and classroom contingency management (behavioral) therapies, in contrast, were appropriated from the widespread application of operant conditioning principles for individuals with developmental/intellectual disabilities beginning in the 1960s. When administered in their most potent forms and monitored carefully, psychostimulant medication alone and combined with behavioral treatment is associated with large-magnitude acute reductions in inattention and hyperactivity–impulsivity symptoms (effect size range = 1.53 to 1.89) that may last for up to 24 months if treatment is sustained (Van der Oord, Prins, Oosterlaan, & Emmelkamp, 2008). In contrast, psychosocial intervention used alone is associated with more moderate reductions in core symptoms (effect size range = 0.31 to 0.87; Fabiano et al., 2009; Van der Oord et al., 2008). These impressive reductions in core behavioral symptoms and impairment ratings, however, are not accompanied by significant or sustained improvements in ecologically valid academic and learning outcomes such as quiz and test grades, overall grade point averages, grade retentions, high school graduation rates, and standardized achievement test scores (Molina et al., 2009; Van der Oord et al., 2008). In addition, no study has demonstrated sustained maintenance of medication or psychosocial treatment-related behavioral changes beyond 24 months of therapy (Jensen et al., 2007; Molina et al., 2009).

The relative impotence of psychostimulant and intensive behavioral treatment to provide lasting improvements in academic and learning outcomes in children with ADHD once treatment is withdrawn warrants consideration if the field is to progress in designing innovative therapies for the disorder. Psychostimulants such as methylphenidate act primarily as dopamine and norepinephrine reuptake inhibitors, and to a lesser extent, as direct agonists that stimulate the release of dopamine and norepinephrine into the synapse. The well-documented finding that both processes promote the availability of these neurotransmitters in cortical–subcortical pathways involving the frontal/prefrontal cortex, temporal lobe, and basal ganglia is of particular relevance for the treatment of ADHD (see Dickstein, Bannon, Castellanos, & Milham, 2006, for a meta-analytic review). These anatomical structures play a critical role in supporting EFs, an umbrella term for higher-order cognitive processes such as WM, set shifting, and inhibitory control that enable goal-directed behavior and novel problem solving (Garon, Bryson, & Smith, 2008; Miyake et al., 2000). EF deficits are implicated in most contemporary models of ADHD (Barkley, 1997, 2012; Rapport et al., 2008; Willcutt, Doyle, Nigg, Faraone, & Pennington, 2005) and associated with adverse educational (Jensen et al., 2007), interpersonal (Kofler et al., 2011), and occupational outcomes (Barkley & Murphy, 2010).

Although psychostimulants usually result in moderate- to large-magnitude improvements on non-EF measures such as regulation of attention and response speed, smaller magnitude and nonsignificant effects are reported for tasks with a prominent executive component (Bedard, Jain, Hogg-Johnson, & Tannock, 2007; Epstein et al., 2006; Kobel et al., 2009; Rhodes, Coghill, & Matthews, 2006). These results suggest that actuating the anatomical structures underlying those EFs typically assessed by cognitive testing improves important aspects of the attentional and motor response elements related to children's task performance but fails to improve essential component processes related to more meaningful functional outcomes such as learning and academic performance.

Empirically supported behavioral treatments, in contrast, are based on the underlying assumption that ADHD-related impairment in school performance/learning and interpersonal relationships reflects inadequate social learning histories and/or underlying volitional control deficits that can be managed through the contingent application of learning principles such as reinforcement and response cost. Treatment contingencies focus conventionally on increasing attention, compliance, and academic productivity, and decreasing excessive gross motor activity and impulsive behavior. These selected targets are based on the expectation that strengthening and weakening desirable and undesirable behaviors, respectively, will result in enduring behavioral change. Extensive evidence supports the efficacy of operant techniques for acutely improving a wide range of behaviors in children with ADHD while contingencies are actively implemented (for a review, see Pelham & Fabiano, 2008). No study to date, however, has demonstrated sustained maintenance of conditioned behavioral changes over an extended time frame after treatment is withdrawn (Jensen et al., 2007; Molina et al., 2009) or the transfer of effects to EF-related cognitive performance outcomes, even when accompanied by inordinate incentives (Dovis, Van der Oord, Wiers, & Prins, 2012). Collectively, our current and most potent evidence-based therapies provide effective, short-term reductions of externalizing symptoms and improve some areas of functional impairment while treatment is active, but they minimally affect the EF deficits and adverse learning outcomes common to ADHD, especially once treatment is withdrawn.

Accumulating evidence from neuroimaging studies provides important insights into this enigma. Widely distributed hypoactivity in frontal–prefrontal cortical regions implicated in EF is well documented in children with ADHD (see Dickstein et al., 2006, for a meta-analytic review; see Chapter 14), and the relations among central nervous system (CNS) arousal, increased activity level, and task performance are well established (for reviews, see Barry, Clarke, McCarthy, Selikowitz, & Rushby, 2005; Rapport et al., 2008). The near-normalization of attention and gross motor activity observed with psychostimulants and incentivized behavioral interventions likely reflects the impact of these treatments on arousal-regulating mechanisms needed to activate EF-supporting structures within these brain regions (Cortese et al., 2012). Repeated resonance scans acquired prospectively from children with ADHD, ages 5–15, however, reveal a nearly 3-year delay in attaining peak cortical thickness in these same prefrontal–frontal regions relative to typically developing children (Shaw et al., 2007). Activating these regions is therefore unlikely to improve children's cognitive functioning and related learning outcomes due to the ontogenetically underdeveloped structures themselves and the EFs these structures support.

EFs AND FUNCTIONAL OUTCOMES

The clinical model of psychopathology, and by extension, the WM model of ADHD (Figure 26.1), hypothesize that interventions aimed at improving suspected underlying neurological substrate(s) and core psychological/cognitive features of ADHD should produce the greatest level and breadth of therapeutic change (Rapport, Chung, Shore, & Isaacs, 2001). Conversely, those aimed at improving peripheral behaviors should show limited generalization upward to core features, and minimally affect other peripheral symptoms. Novel interventions are therefore more likely to be successful if they target aspects of EF that not only are deficient in ADHD but also related to the primary behavioral, learning, and interpersonal difficulties associated with the disorder. In the ensuing sections, we summarize the empirical basis for designing novel treatments targeting each of the three, higher-order EFs (namely, *WM*, *behavioral inhibition*, and *set shifting*) and related attentional components, evidence for and against ADHD-related deficits in each EF, and research examining the role of each EF in ADHD behavioral symptoms and functional impairments.

Working Memory

Of the 25 cognitive training studies included in the Rapport, Orban, Kofler, and Friedman (2013) meta-analysis, 68% describe WM as a primary target for remediation, a finding that is consistent with mounting evidence documenting functional relationships among WM deficits and a broad range of behavioral and functional impairments in children with ADHD. As will become apparent, however, nearly all of these protocols primarily target STM rather than WM.

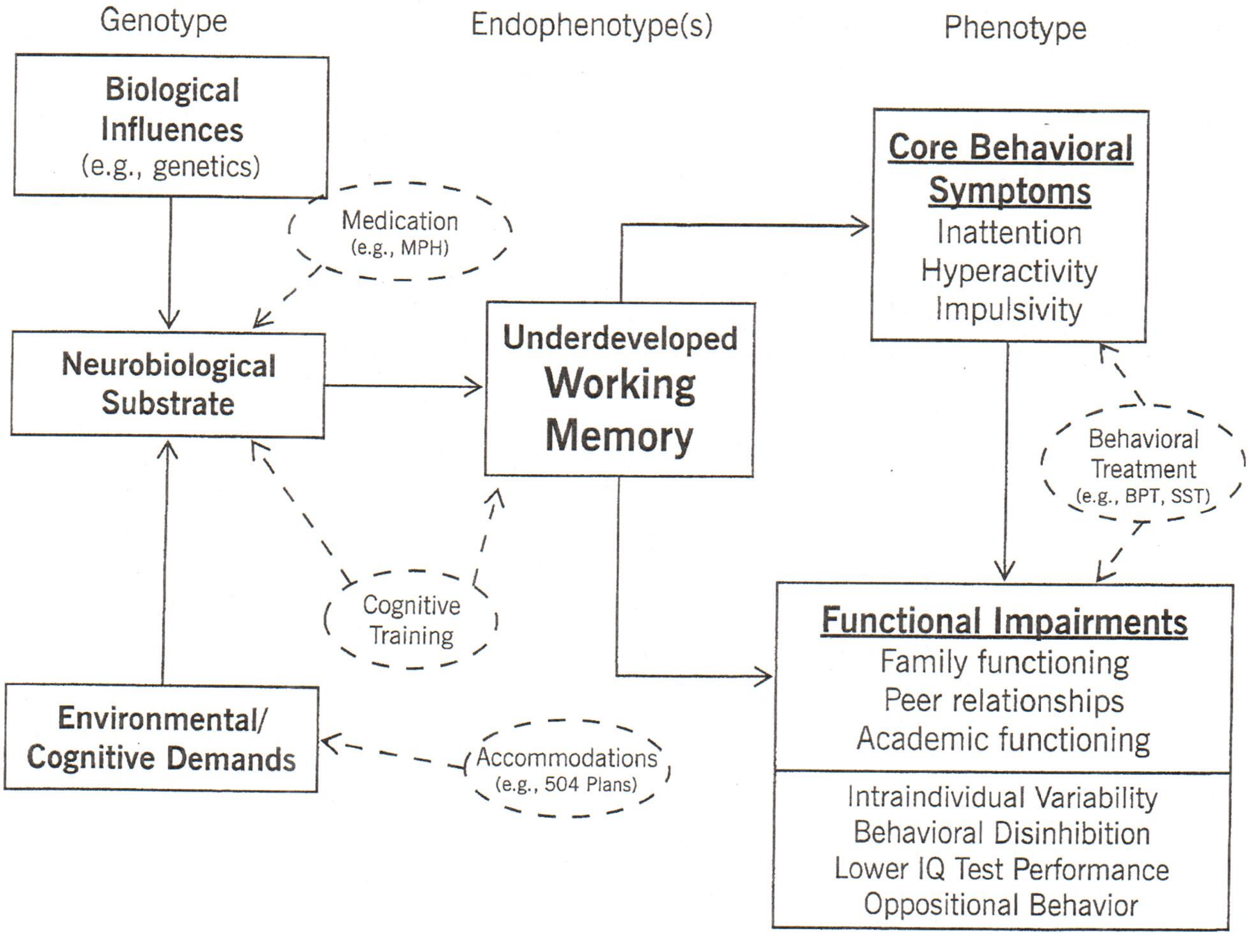

FIGURE 26.1. Visual schematic of the functional working memory (WM) model of ADHD. BPT, behavior parent training; MPH, methylphenidate; SST, social skills training. From Rapport, Chung, Shore, and Isaacs (2001). Adapted with permission from Mark D. Rapport, PhD.

WM is a limited-capacity system responsible for the temporary storage, rehearsal, processing, updating, and manipulation of information held internally. This multicomponent system plays a critical role in guiding everyday behavior and underlies the capacity to perform complex tasks such as learning, comprehension, reasoning, and planning. The *working* component of WM involves mental processing, updating, and reordering information held internally for use in guiding behavior. The terms used to describe these processes differ across neurocognitive models, and includes labels such as "central executive," "internal focus of attention," and "secondary memory." No memory/storage functions are ascribed to the *working* component of WM; instead, it functions to process or manipulate the information currently held within the two anatomically distinct short-term storage–rehearsal components: the *phonological* and *visuospatial* subsystems. These subsystems handle verbal and nonverbal (visual and spatial) information, respectively (see Figure 26.2).

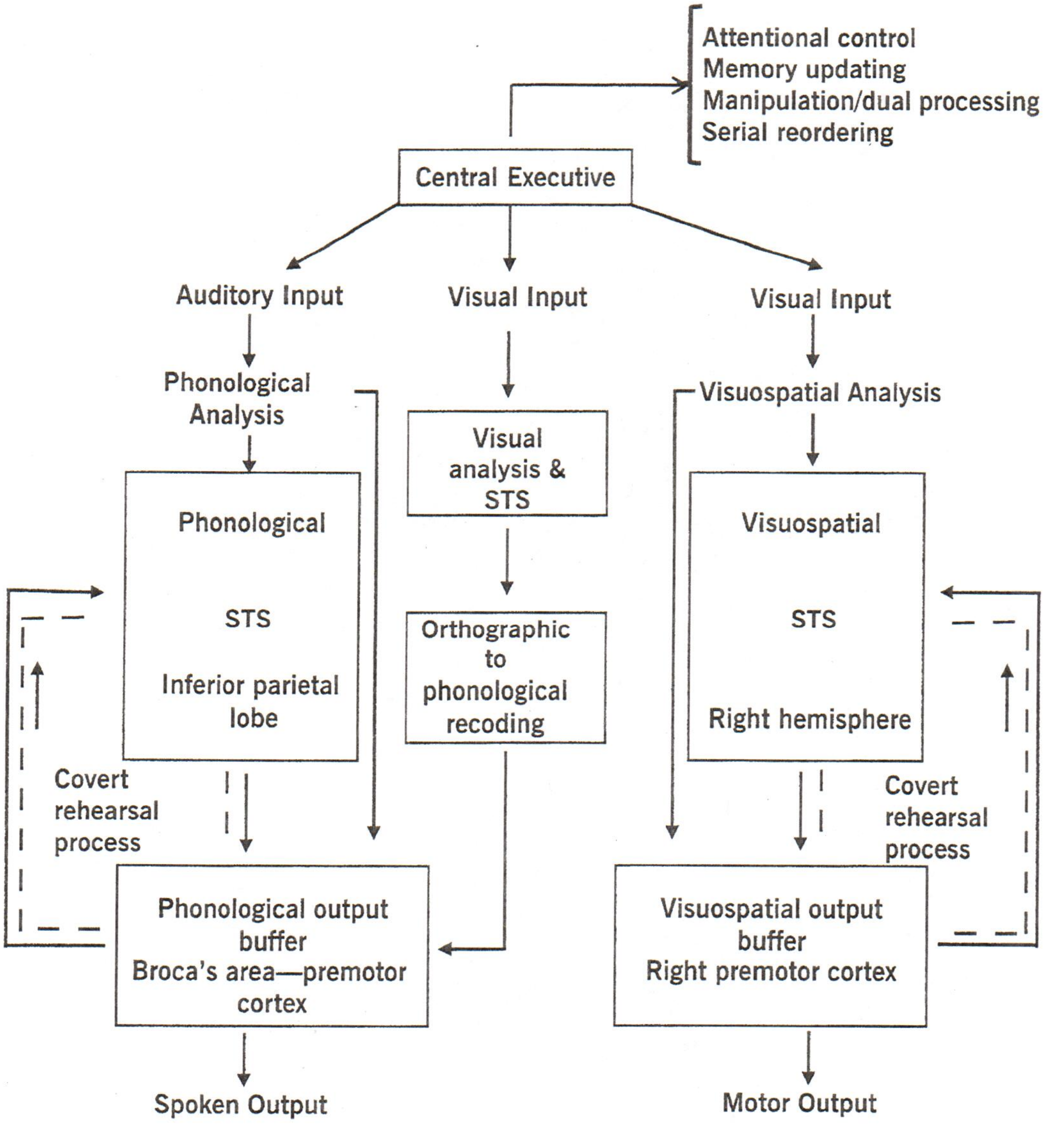

FIGURE 26.2. Visual schematic of an expanded version of Baddeley's (2007) working memory model and associated anatomical loci. Highlighted are the primary processes associated with the domain-general central executive (CE) and two (phonological, visuospatial) storage/rehearsal subsystem components. STS, short-term store. From Rapport et al. (2008). Adapted with permission from Mark D. Rapport, PhD.

Distinguishing between *working* (central executive) and *memory* (storage–rehearsal) deficits is critical for treatment development given the differential relationships among central executive processes, short-term storage processes, and ADHD-related functional impairments. For example, recent meta-analytic results indicate that children with ADHD and typically developing children differ by more than two standard deviations in core central executive abilities, or, stated differently, that at least 81% of children with ADHD have deficits in the *working* component of WM.[2] In addition, these underdeveloped central executive abilities appear to be functionally, if not causally, related to inattention (Kofler, Rapport, Bolden, Sarver, & Raiker, 2010), hyperactivity (Rapport, Bolden, et al., 2009), impulsivity (Raiker, Rapport, Kofler, & Sarver, 2012), and social problems (Kofler et al., 2011). In contrast, children with ADHD typically have medium-magnitude impairments in phonological and visuospatial storage–rehearsal (*memory*) processes, and these STM deficits are unrelated to or contribute minimally to core symptoms or important functional outcomes. The *working* (central executive) component of WM is also intricately involved in a wide range of academic and intellectual abilities, ranging from math, reading, listening comprehension, and achievement to complex learning and fluid reasoning. In contrast, the *memory* components of WM are associated with more limited roles in learning outcomes (see Sarver et al., 2012, for a review).

Inhibition

Behavioral inhibition (BI) is hypothesized as a cognitive process that subserves behavioral regulation and EF, and underlies the ability to withhold (*action restraint*) or stop (*action cancellation*) an ongoing response. BI deficits are frequently cited as a core underlying deficit responsible for ADHD (Barkley, 1997), and children with ADHD often underperform on BI tasks relative to typically developing (TD) children. The results of recent meta-analytic reviews, however, indicate that the suboptimal performance observed in children with ADHD on BI tasks is more parsimoniously explained by difficulties with basic attentional, performance variability, and/or WM processes (Alderson, Rapport, & Kofler, 2007; Lijffijt, Kenemans, Verbaten, & van Engeland, 2005).

Evidence supporting a link between BI and ADHD symptoms is similarly modest. For example, studies of community samples report a modest (r = .30) relationship between performance on an inhibition task and parent–teacher ratings of ADHD symptoms. In contrast, most ADHD clinical studies report nonsignificant relationships between inhibition and both subjective and objective measures of classroom hyperactivity, impulsivity, or inattention. In addition, experimentally manipulating demands on inhibition exerts no discernible effect on objectively measured motor activity in children with ADHD (Alderson, Rapport, Kasper, Sarver, & Kofler, 2012). Collectively, these studies suggest that previously reported BI deficits, as reflected in psychological tests and reported to exist in children with ADHD, may occur secondarily to other cognitive process deficits and are weakly or unrelated to ADHD behavioral symptoms, including those of hyperactivity–impulsivity.

Set Shifting

"Set shifting," or cognitive flexibility, refers to the ability to flexibly switch between tasks or mental sets. Tasks commonly used to assess set shifting require children to mentally hold two response sets simultaneously and switch between these response sets according to prespecified criteria (e.g., every other trial), or to monitor their performance and change response sets based on performance feedback. Meta-analytic reviews reveal moderate-magnitude set shifting deficits in children with ADHD and indicate that approximately 25–35% of children with ADHD have deficits in this aspect of EF (Frazier, Demaree, & Youngstrom, 2004; Willcutt et al., 2005). Extant evidence that set shifting deficits are related to ADHD symptoms, however, is limited. We were able to locate only two studies that examined this relationship. One reported a moderate correlation (r = .61), and the other reported a more modest (r = .17) relationship between set-shifting performance and ADHD symptoms. Collectively, few studies have examined set shifting in children with ADHD, and the limited evidence available indicates that set-shifting performance deficits, if they exist at all, are related weakly to moderately to ADHD symptoms.

Attention

Several cognitive training protocols for children with ADHD directly target one or more components of attention. The empirical rationale for targeting attention is based on compelling evidence of parent–teacher reported attentional problems in children with ADHD, coupled with large-magnitude impairments in objectively observed classroom attention (Kofler, Rapport, & Alderson, 2008; Rapport, Kofler, Alderson, Timko, & DuPaul, 2009). Attention is also considered an integral component of all EFs, and attentional resource limitations are often assumed to reflect WM and other EF deficits. These perspectives suggest that targeting attentional processes in children with ADHD may result in generalized performance improvements across EFs.

Identifying the specific cognitive components of attention that are impaired in ADHD has been considerably more challenging. Among the diverse models of attention, studies of childhood ADHD frequently focus on four components of attention: *orienting/alertness* (the ability to enhance one's activation level following a stimulus of high priority), *selective/focused attention* (the ability to facilitate the processing of one source of environmental information while preventing the processing of others), *divided attention* (the ability to attend and respond to multiple tasks or multiple task demands simultaneously), and *vigilance/sustained attention* (the ability to maintain a tonic state of alertness during prolonged and sustained mental activity).

Converging evidence indicates that approximately 33 to 55% of children with ADHD demonstrate vigilance/sustained attention deficits. In contrast, orienting/alertness processes appear to be intact in ADHD. The evidence is mixed with regard to selective/focused attention and divided attention. Children with ADHD have been reported to perform worse, similar to, and better than children without ADHD on indices of these two attentional components.

The relationship between vigilance/sustained attention and ADHD behavioral and functional impairments is similarly complex. Performance on vigilance/sustained attention tasks is correlated weakly to moderately with both parent and teacher ratings of ADHD behavioral symptoms, and objectively observed classroom attention. In addition, deficient sustained attention is associated with poorer academic performance, lower grades and standardized test scores, and higher rates of special education placement and comorbid learning disabilities. In contrast, treatment-related improvements in sustained attention generally fail to result in improved learning or academic performance in approximately 50% of treated children (Rapport, Denney, DuPaul, & Gardner, 1994), highlighting the multifarious link between attention and ADHD-related functional impairments.

Summary

A substantial literature indicates that many children with ADHD have significantly underdeveloped central executive (the *working* component of WM) and vigilance/sustained attention abilities. In addition, these two cognitive functions consistently predict myriad behavioral and cognitive outcomes, rendering them highly credible targets for innovative treatments. The evidence supporting inhibition, set shifting, STM (the storage/rehearsal components of WM), and other attentional components, in contrast, is more limited.

FIT PROGRAMS

FIT programs were designed and introduced in the early 2000s to foster the development of ontogenetically underdeveloped brain structures that support EFs and related attentional processes in children by engaging them in challenging, progressively more difficult, computer-based (or automated) training exercises. A central tenet of these programs is that lasting, quantitative improvement in the development and/or efficiency of EF-related neural substrates can be accomplished by means of extensive training involving repetition, practice, and feedback. Resulting improvement in EF, in turn, is expected to generalize or transfer to other tasks, activities, and abilities to the extent that they rely on these trained neural networks. Examples include enhanced general cognitive functioning, learning, academic performance/achievement, behavioral functioning, and interpersonal relationships. As a result, the success of these programs rests to a considerable extent on the expectation of training-induced *neuroplasticity*—the brain's ability to create new pathways (neurogenesis) and rearrange and expand existing ones (synaptogenesis) for purposes of neural communication. This critical assumption of FIT programs differs in important ways from traditional CBT strategies (see Chapter 31) that rely on teaching regulatory and problem-solving strategies as compensatory change agents rather than augmenting the development of hypothesized underdeveloped neurological substrates.

Many of the FIT programs are available commercially and assert that their computer-based cognitive training exercises provide significant and lasting improvement in attention, impulse control, interpersonal functioning, academic performance, and complex reasoning skills for children with ADHD. The meta-analytic results summarized in the ensuing sections examine the veridicality of these claims.

FIT Program Descriptions and Examples

Currently Cogmed® and BrainTrain's® Captain's Log MindPower® are two of the most widely used FIT programs for children with ADHD. The former is described as a "computer-based solution for attention problems caused by poor WM" (*www.cogmed.com/program*, May 12, 2014), and incorporates a wide range of visuospatial and verbal activities to train the two anatomically distinct, modality-specific WM subsystems described in Baddeley's model (2007; Figure 26.2).

For example, one of the tasks intended to improve visuospatial WM involves a panel of small lights arranged in a four-column by four-row format, wherein a predetermined number of lights are illuminated one at a time in a random order (Figure 26.3). The child's task is to reproduce the order immediately by clicking on the bulbs in the same order in which they were illuminated.

Children typically begin at a low set-size level (e.g., three stimuli), which requires them to hold briefly and recall the observed location of a limited number of the visuospatial stimuli. Following a preestablished number of successful recall trials, they advance to the next level, which requires them to correctly recall four stimuli. The training exercise continues in this manner and reflects what is referred to as "adaptive training"—an instructional approach similar to Vygotsky's (1978) "zone of proximal development" concept, in which children's learning is thought to advance most efficiently when they are required to engage in activities they have not mastered fully. The training exercise, however, is more accurately described as a visuospatial STM task rather than a visuospatial WM task—children are tasked with holding the location of visuospatial stimuli temporarily in STM without any corresponding processing requirements.

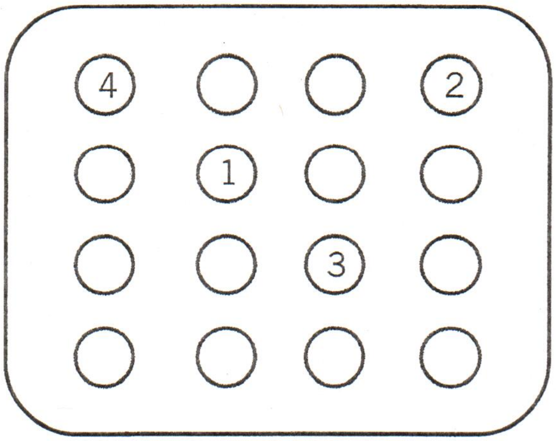

FIGURE 26.3. The figure represents a visual schematic of a hypothetical visuospatial task similar to one described by Cogmed. Numbers represent the order in which the lights are illuminated. Children are instructed to replicate the order by clicking on each of the bulbs in the same sequence in which they were illuminated.

A second visuospatial exercise described on the company's webpage involves watching rotating asteroids light up, one by one, on a computer monitor. Visuospatial recall is demonstrated by clicking on the asteroids in the same order in which they appeared. Similar to the previous exercise, children begin by recalling a limited number of stimuli, and they are required to recall increasingly more stimuli correctly as they proceed from lower to higher set-size levels. Based on the website description, this exercise also appears to be a relatively straightforward visuospatial short-term storage rather than a WM training exercise.

Several verbal training exercises are also included in Cogmed's training program and reflect the well-established finding that children with ADHD also experience moderate- to large-magnitude deficiencies in their ability to store/rehearse and process phonologically based information (Bolden, Rapport, Raiker, Sarver, & Kofler, 2012; Kasper, Alderson, & Hudec, 2012). For example, in one training exercise, children are shown a square-shaped keypad with nine consecutive, single-digit numbers in a 3 row × 3 column format. An audible digit string is emitted by the program's computer software (e.g., 4 9 2) and children are required to recall the digit string in reverse order using a manual keypad response. The exercise is highly similar to the Wechsler Intelligence Scale for Children–IV (WISC-IV) digit span backwards task, with one exception—children are able to view the number pad while hearing the numbers, which makes the exercise more of a mixed verbal–visuospatial STM task if children use both modalities to store–rehearse–reverse and recall the information.

Another verbal exercise designed to strengthen the phonological WM subsystem—termed *Stabilizer*—requires children to view a panel with 11 small bulbs located in a circular arrangement around an empty oval. A different bulb is illuminated momentarily and paired with the sound of a unique letter (e.g., T, G, and E might correspond with the second, third, and fifth bulbs illuminated as illustrated in Figure 26.4), and children must remember which letter corresponds with each of the lit bulbs. Afterwards, one of the previously articulated letters appears in the center of the panel (e.g., G), and children are instructed to identify the correct bulb that was illuminated at the time the letter was heard by clicking on its location. As with the previous example, the task appears to require a mixture of visuospatial and phonological short-term storage rather than WM, depending on how children elect to store and recall the stimuli sequence.

Mental health and educational professionals undergo training to qualify as Cogmed coaches, which enables them to offer the training package and provide ongoing supervision to children whose families can afford the cost (the fee is set by individual providers and $1,500 appears to represent the current modal training cost). Children are typically required to complete approximately eight training exercises per day (i.e., about 30–45 minutes), 5 days per week, over a 5-week training period, and engage in computer games afterwards as an incentive.

An alternative set of cognitive training exercises (Captain's Log MindPower) offered by BrainTrain, allows individuals to customize cognitive training by selecting among nine modules designed to strengthen visual and verbal short-term and WM abilities, various attentional abilities, and problem-solving skills. For example, in one of the WM skills module tasks—*Code Cracker*—children are shown visual stimulus sets that comprise letters and symbols (e.g., L, *, &, R, #), and each stimulus is matched with one of nine unique digits (1, 2, 3 . . . 9). Afterwards, a row containing the letters and symbols appears directly above a 3 row x 3 column symmetrical grid that contains the numbers 1 through 9. Children are tasked with clicking on each of the previously viewed digits associated with the letters and symbols displayed in the top row to "crack the code" and open the safe (see Figure 26.5). Despite its inclusion in the WM skills module, Code Cracker might be more accurately described as a paired associate learning exercise that requires visuospatial and/or phonological STM, depending on whether children encode the stimuli phonologically or by their shapes.

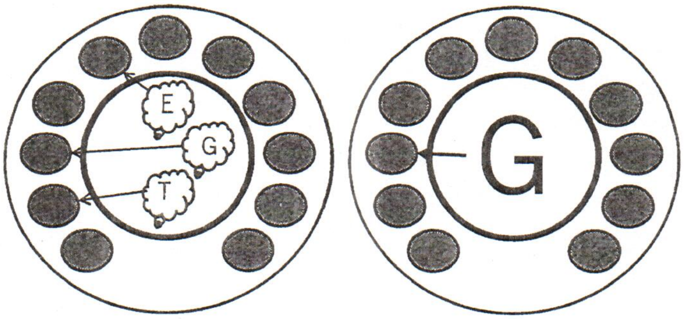

FIGURE 26.4. The figure represents a visual schematic of a hypothesized visuospatial, short-term memory training task similar to one described by Cogmed. Children hear the letters T, G, and E emitted from the computer speaker (left circle), and one of the enunciated letters appears in the middle of the screen immediately afterwards (right circle). Children are tasked with clicking on the circle that was lit up when they heard that particular letter (i.e., the circle marked G).

Turning to the Captain's Log *Attention Skills* module reveals an exercise that is described as training alternating attention and response inhibition (*Stimulus Reaction/Inhibition* or *Red Light Green Light* training exercise) to improve children's "mental processing speed" and "self-control." Children view a computer monitor and their task is to determine whether the image that appears on the screen is the same color as the screen's border, then to click the mouse button as quickly as possible following color match trials and not to click the button following color mismatch trials. Based on the website's description, the task appears to represent a relatively straightforward, simple visual matching paradigm without a clear-cut response inhibition element. For this latter element, prepotency to respond to a particular stimulus would need to be established beforehand to ensure a high degree of readiness to respond and/or difficulty withholding (action restraint) or stopping (action cancellation) a response.

A task in the Auditory Working Memory module, named Reverse Recall (*Touchdown!*), is reportedly designed to train phonological WM. In this task, children hear sequences of letters, numbers, directions, chores, sounds, and other items listed in a specific order. They are instructed to recall the items in reverse order by clicking on a visual representation of each item (see Figure 26.6). Reversing auditory stimuli in this manner, however, is similar to the WISC-IV digit span backwards task, which loads on the same dimension as digits forward (Colom, Abad, Rebollo, & Shih, 2005; Swanson & Kim, 2007) and is considered a measure of phonological short-term storage rather than WM.

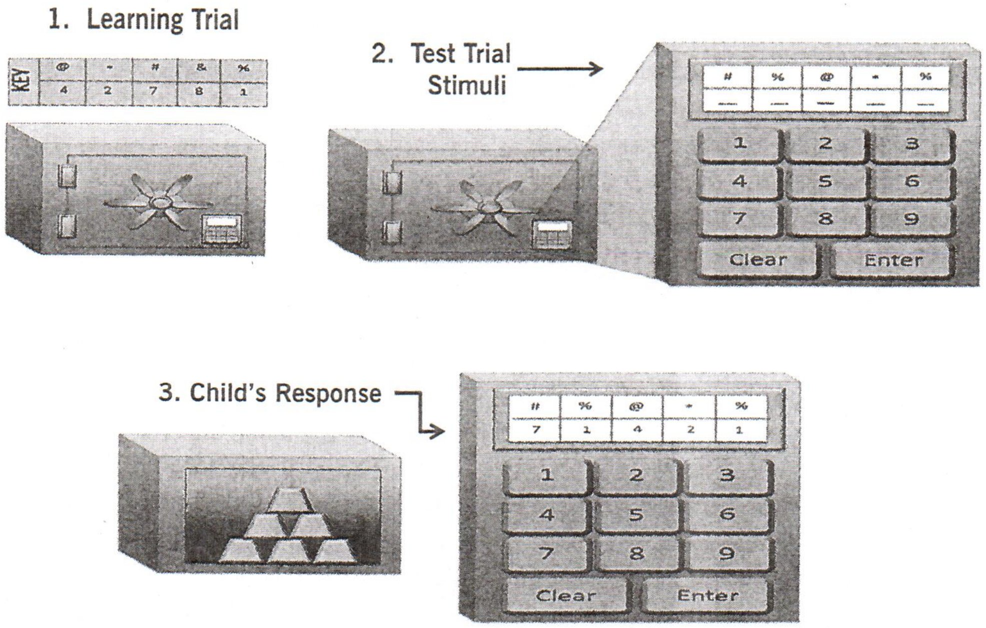

FIGURE 26.5. Visual schematic of a hypothesized combined phonological/visuospatial short-term memory training task similar to one described on the BrainTrain website. Children undergo a learning trial (1), are shown the letters and symbols of stimuli to be learned (2), and enter the correct "code" to open the safe (3).

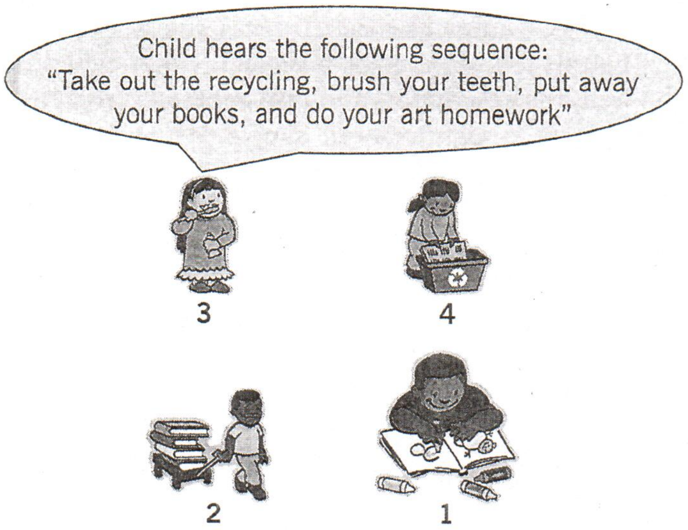

FIGURE 26.6. Visual schematic of a hypothesized phonological working memory training task similar to one described on the BrainTrain website. Children hear a sequence of chores (top of figure) and are tasked with recalling them in reverse order by clicking on the appropriate pictures. Numbers directly underneath the pictures (1, 2, 3, 4) indicate the correct reversed order in the example.

Educators and professionals can individualize treatment by selecting which modules and exercises to use during training. Similar to Cogmed, the available exercises utilize an adaptive training approach and adjust the difficulty level of the exercises to ensure that children are continually challenged by the tasks demands. Licenses for Captain's Log MindPower can be purchased through the BrainTrain website for $395 per client or $1,495 per computer station. Children are encouraged to complete 2 hours of training per week in a manner that best fits their schedules.

Key Questions

Improving the functioning of underdeveloped neurological substrates that enable goal-directed behavior is highly dependent upon the integrity of the training programs. As a result, we pay particular attention to several critical questions in the ensuing meta-analytic review of these programs (Rapport et al., 2013).

The data in Table 26.1 addresses the first of these questions reviewed earlier—namely, to what extent do extant FIT programs target the (1) empirically documented EF deficits and associated core/peripheral features and (2) functional outcomes in children with

TABLE 26.1. Executive Functions and Attention Processes Targeted for FIT

		Working memory[a]			Short-term memory[b]		Behavioral Inhibition			Attention			
Author (year)	Training target	Updating	Manipulation/ dual-task	Serial reordering	PH	VS	Motor	Cognitive	Set shifting	Orienting alertness	Vigilance sustained	Selective	Divided
Beck et al. (2010)	STM				X	X							
Dahlin (2011)	STM				X	X							
Gibson et al. (2011)	STM				X	X							
Gray (2011)	STM				X	X							
Green et al. (2012)	STM				X	X							
Holmes et al. (2010)	STM				X	X							
Klingberg et al. (2005)	STM				X	X							
Mezzacappa & Buckner (2010)	STM				X	X							
Prins et al. (2011)	STM					X							
Kerns et al. (1999)	Attention										X	X	X
Lange et al. (2012)	Attention									X	X	X	X
Semrud-Clikeman et al. (1999)	Attention										X	X	
Tamm et al. (2012)	Attention										X	X	X
Tamm et al. (2010)	Attention										X	X	X
Tucha et al. (2011)	Attention									X	X	X	X
Halperin et al. (2012)	Mixed EF				X	X	X					X	
Hoekzema et al. (2010)	Mixed EF				X						X		
Johnstone et al. (2012)	Mixed EF					X	X						
Johnstone et al. (2010)	Mixed EF					X	X						
Klingberg et al. (2002)	Mixed EF				X	X	X						
Rabiner et al. (2010)	Mixed EF					X					X		
Shalev et al. (2007)	Mixed EF							X		X	X	X	
Steiner et al. (2011)	Mixed EF				X	X				X	X	X	X
Van der Oord et al. (2012)	Mixed EF			X		X	X		X				
Kray et al. (2012)	Set Shifting								X				

Note. Studies are grouped by training target and alphabetized within grouping to permit direct comparisons of study characteristics and effect sizes in subsequent tables. PH, phonological; VS, visuospatial; STM, short-term memory; EF, executive function.

[a] All tasks require at least minimal WM/central executive resources (e.g., maintaining task instructions). Tasks are coded as targeting WM processes if these processes were targeted explicitly through adaptive training components designed specifically to increase abilities in one or more WM central executive subprocesses (updating, manipulation/dual processing, and serial reordering) by a majority of training components. All studies using Cogmed were coded as targeting STM given empirical evidence indicating that this training paradigm improves short-term but not WM processes (Gibson et al., 2011).

[b] STM refers to the storage/rehearsal components of the WM system (i.e., the *memory* components of WM).

ADHD? The significance of this question rests on the assumption that targeting nonaffected or minimally impaired substrate mechanisms/processes is unlikely to result in substantial far-transfer effects.

Table 26.1 summarizes the type and range of EFs and/or attentional processes targeted by each of the 25 FIT studies. It indicates that nine of the 25 reviewed FIT studies used Cogmed training exercises, which are intended to improve WM; however, scrutiny of these training exercises reveals that most of them require children to store/rehearse auditory and/or visuospatial stimuli for a brief time interval and do not include *working* memory processing demands such as actively updating memory, manipulating/dual processing, and serial reordering. An additional nine FIT studies focused primarily on training phonological (PH) and visuospatial (VS) STM, in addition to at least one attentional component, such as orienting, vigilance, selective attention, or divided attention. Six of the remaining FIT studies focused exclusively on training two or more attentional components, and one focused exclusively on training set shifting. Collectively, none of the reviewed FIT studies included appropriately designed tasks to rigorously train empirically established WM processing deficits in children with ADHD; however, several included components designed to train children's vigilance or ability to sustain attention over time—a well-documented deficiency in children with ADHD.

Table 26.2 provides an overall summary of the FIT interventions, including the number of children who participated in the treatment and control groups, the name of the program, the type of control group employed (e.g., waiting list, nonadaptive). It also addresses a second set of critical questions regarding the extent to which FIT programs incorporate *adaptive* training, and the relative potency or dosage effects related to training. As shown in Table 26.2, nearly all of the FIT programs incorporated adaptive training methodology, which continuously adjusts the difficulty of the training exercise based on each child's performance to ensure that the suspected underlying neurological substrate is challenged continuously. The optimal duration of sessions, number of sessions, and intensity parameters required to obtain clinically meaningful improvement in children's WM is unknown currently; however, the 25 studies reviewed include a wide range of values for each of these parameters. For example, minutes per session ranged from 15 to 60, total sessions ranged from three to 36, total training minutes ranged from 105 to 2160, and total training weeks ranged from four to 18. We examined these parameters in the meta-analysis; however, they did not prove to be significant moderators for any of the findings.

Table 26.3 addresses important methodological questions concerning the extent to which FIT programs incorporate appropriate experimental controls (e.g., inclusion of both near- and far-transfer measures; blinded raters) to ensure that any behavioral–cognitive gains realized can be attributed to the training rather than to unsystematic factors or Hawthorne effects (i.e., illusory biases). Most (68%) studies included near-transfer objective measures of cognitive performance, whereas a smaller percentage of studies (44%) included far-transfer measures of cognitive performance, and relatively few (12%) included far-transfer objective measures of academic achievement. Finally, 32% and 52% of the studies included far-transfer subjective measures of behavior change based on blinded and unblinded raters, respectively. Effect size estimates based on Cohen's *d* (corrected for sample size) are reported for near and far objective and subjective outcome variables for all 25 studies included in the meta-analysis. Cohen's *d* effect sizes are in standard deviation units, such that an effect size of 1.0 indicates a change in one standard deviation from pretreatment to posttreatment. An effect size of 0.2 is interpreted as small (detectable only through statistics), 0.5 as medium (detectable to a careful observer), and 0.8 as large (obvious to any observer; Cohen, 1988).

FIT Programs and Empirically Based Outcomes

A tiered analytic approach adopted to examine the FIT outcome studies addressed the key questions discussed in the previous section. The Tier I analysis examined 17 studies reporting posttreatment outcomes on tasks similar to the training tasks (immediate, near-transfer effects; 58 effect sizes); Tier II examined the three studies reporting long-term follow-up of near-transfer effects (long-term, near-transfer effects; 20 effect sizes); Tier III examined 21 studies (22 independent subgroups) reporting posttreatment data on outcomes dissimilar to training tasks (immediate, far-transfer effects; 233 effect sizes); and Tier IV examined the seven studies reporting long-term follow-up of far-transfer effects (long-term far-transfer effects; 125 effect sizes).

LE 26.2. FIT Study Characteristics

Author (year)	T (*n*)	C (*n*)	Program	Control group	Adaptive	Computerized	Total minutes	Total sessions	Total weeks	Minutes/ session
et al. (2010)	27	24	Cogmed	Waiting list	Y	Y	750	25	6	30
in (2011)	41	15	Cogmed	Waiting list	Y	Y	600	20	5	30
n et al. (2011)	38	—	Cogmed	None	Y	Y	600	20	6	30
(2011)	36	24	Cogmed	Adaptive	Y	Y	900	20	5	45
a et al. (2012)	12	14	Cogmed	Nonadaptive	Y	Y	625	25	—	25
es et al. (2010)	25	—	Cogmed	None	Y	Y	600	20	6	30
berg et al. (2005)	20	24	Cogmed	Nonadaptive	Y	Y	1,000	25	5	40
acappa & Buckner (2010)	8	—	Cogmed	None	Y	Y	1,000	25	5	40
et al. (2011)	27	24	Study developed	Adaptive	Y	Y	105	3	3	35
s et al. (1999)	7	7	Pay Attention!	Nonadaptive	Y	N	480	16	8	30
e et al. (2012)	16	16	AixTent	Adaptive	Y	Y	480	8	4	60
ud-Clikeman et al. (1999)	21	12	APT	Waiting list	Y	N	2,160	36	18	60
n et al. (2012)	54	51	Pay Attention!	Waiting list	Y	N	480	16	8	30
n et al. (2010)	19	—	Pay Attention!	None	Y	N	480	16	8	30
a et al. (2011)	16	16	AixTent	Adaptive	Y	Y	360	8	4	45
rin et al. (2012)	29	—	TEAMS	None	Y	N	177.5	5	5	35.5
zema et al. (2010)	10	9	Study developed	Nonadaptive	Y	N	450	10	—	45
tone et al. (2012)	40	20	Study developed	Adaptive and waiting list	Y	Y	375	25	5	15
tone et al. (2010)	15	14	Study developed	Nonadaptive	Y	Y	500	25	5	20
berg et al. (2002)	7	7	Cogmed	Nonadaptive	Y	Y	607.5	24.3	5	25
er et al. (2010)	25	27	Captain's Log	Adaptive and waiting list	Y	Y	1,400	28	14	50
v et al. (2007)	20	16	CPAT	Adaptive	Y	Y	960	16	8	60
r et al. (2011)	11	9	Captain's Log	Adaptive and waiting list	Y	Y	960	32	16	30
ler Oord et al. (2012)	18	22	Study developed	Waiting list	Y	Y	1,000	25	5	40
t al. (2012)	10	10	Study developed	Nonadaptive	N	Y	120	4	4	30

T, treatment group; C, control group; *n*, number of participants within each group; APT, attention process training; TEAMS, training executive, attention, and motor skills; CPAT, computerized ssive attention training. Training time data represent lower value of range reported by authors.

TABLE 26.3. FIT Program Near- and Far-Transfer Effects

Author (year)	Program	Training target	Control group	Effect Sizes					
				Near objective		Far objective		Far subjective	
				COG	ACH	COG	ACH	Blinded	Unbli
Beck et al. (2010)	Cogmed	STM	Waiting list	—	—	—	—	0.23	0.6
Dahlin (2011)	Cogmed	STM	Waiting list	0.85	—	—	0.41	—	–
Gibson et al. (2011)	Cogmed	STM	None	0.45	—	—	—	0.27 PH 0.09 VS	0.6 0.1
Gray (2011)	Cogmed	STM	Adaptive	0.28	—	0.49	0.03	—	0.0
Green et al. (2012)	Cogmed	STM	Nonadaptive	0.70	—	—	—	0.16	–
Holmes et al. (2010)	Cogmed	STM	None	0.84	—	0.11	—	—	–
Klingberg et al. (2005)	Cogmed	STM	Nonadaptive	0.62	—	0.42	—	0.32	–
Mezzacappa & Buckner (2010)	Cogmed	STM	None	0.99	—	—	—	—	0.9
Prins et al. (2011)	Study developed	STM	Adaptive	0.64	—	—	—	—	–
Kerns et al. (1999)	Pay Attention!	Attention	Nonadaptive	0.0*a*	—	0.31	—	0.0	–
Lange et al. (2012)	AixTent	Attention	Adaptive	0.55	—	—	—	—	–
Semrud-Clikeman et al. (1999)	APT	Attention	Waiting list	0.90	—	—	—	—	–
Tamm et al. (2012)	Pay Attention!	Attention	Waiting list	–0.03	—	0.25	—	—	0.4
Tamm et al. (2010)	Pay Attention!	Attention	None	—	—	0.18	—	—	0.4
Tucha et al. (2011)	AixTent	Attention	Adaptive	0.38	—	—	—	—	–
Halperin et al. (2012)	TEAMS	Mixed EF	None	—	—	—	—	—	0.5
Hoekzema et al. (2010)	Study developed	Mixed EF	Nonadaptive	—	—	0.0[c]	—	—	–
Johnstone et al. (2012)	Study developed	Mixed EF	Waiting list[d]	0.00	—	0.10	—	—	0.3
Johnstone et al. (2010)	Study developed	Mixed EF	Nonadaptive	0.04	—	—	—	—	0.
Klingberg et al. (2002)	Cogmed	Mixed EF	Nonadaptive	0.86	—	1.05	—	—	–
Rabiner et al. (2010)	Captain's Log	Mixed EF	Adaptive[e]	—	—	—	0.11	—	0.2
Shalev et al. (2007)	CPAT	Mixed EF	Adaptive	—	—	—	—	0.41	–
Steiner et al. (2011)	Captain's Log	Mixed EF	Adaptive[e]	—	—	–0.07	—	0.11	0.2
Van der Oord et al. (2012)	Study developed	Mixed EF	Waiting list	—	—	—	—	—	0.4
Kray et al. (2012)	Study developed	Set shifting	Nonadaptive	0.70	—	0.44	—	—	–

Note. COG, cognitive performance; ACH, standardized achievement; STM, short-term memory; APT, attention process training; TEAMS, training executive, attention, and motor skills; computerized progressive attentional training; PH, phonological; VS, visuospatial; EF, executive function. Effect sizes are Cohen's *d* corrected for sample size.

[a] Reflects a nonsignificant change on a continuous performance test; a measure of sustained auditory attention was considered an outlier ($d = 3.02$) and excluded from this analysis.

[b] Reflects within (adaptive treatment) group pre–post differences; insufficient data available for the nonadaptive control group.

[c] Authors reported no significant group differences in performance on three cognitive tasks, and did not respond to e-mail requests for unreported data for two additional measures.

[d] Two active treatment groups receiving identical treatment with the exception of one component were collapsed and compared to a waiting list group by the authors.

Immediate Near-Transfer Effects

The 17 studies reporting data on 636 individuals with ADHD were included in the analyses examining immediate near-transfer effects of ADHD FIT programs (Table 26.3). We found significant differences in effect magnitude across studies, which necessitated examination of potential moderators of these effects. Training Target was examined initially to examine the extent to which effect sizes differed systematically as a function of cognitive training target. Studies were classified into three categories: STM only ($k = 8$), mixed EFs ($k = 3$), and attention only ($k = 5$). Set shifting ($d = 0.70$, nonsignificant) was examined qualitatively but not included in the analyses due to insufficient degrees of freedom ($k = 1$). Our results revealed that Training Target explained significant between-study differences, such that no significant between-study residual differences remained after accounting for Training Target. As shown in Table 26.4, studies targeting STM only ($d = 0.63$) were associated with moderate-magnitude increases in STM. In contrast, studies targeting Attention only ($d = 0.05$, nonsignificant) and mixed EFs ($d = 0.06$, nonsignificant) failed to find significant posttreatment improvement on near-transfer measures of targeted cognitive processes.

Long-Term Near-transfer effects

Only 3 of the 17 studies reporting near-transfer effects reported data sufficient to calculate long-term follow-up effect sizes; follow-up duration ranged from 3- to 6-months across studies. Collectively, results from the three studies reporting long-term follow-up data suggest that STM gains may be maintained for up to 3–6 months; however, additional follow-up studies are needed to ensure the veracity of these findings.

Immediate Far-Transfer Effects

A total of 21 studies reporting data on 733 individuals with ADHD were included in the analyses examining immediate far-transfer effects of cognitive training for children with ADHD (Table 26.3). Despite finding that only STM training programs were associated with improvements in their training target, classifying studies by training target did not explain between-study differences in far-transfer outcomes. As a result, we examined whether the far-transfer results might depend on the type of outcome measures (i.e., objective and subjective) used in the studies. The results revealed that studies that relied on unblinded raters—and not objective outcome measures—accounted for the immediate far-transfer FIT training effects. In contrast, FIT training did not improve blinded behavior ratings or academic achievement, and it exerted a minimal impact on cognitive test scores for children with ADHD. Collectively, these results were disappointing and indicate that the significant far-transfer training benefits reported previously are in the *eye of the beholder* and consistent with an illusory bias or expectancy effect.

Long-Term Far-Transfer Effects

Seven of the 21 studies reporting far-transfer outcomes included long-term follow-up data sufficient to calculate effect sizes (total $N = 231$)—three trained STM, three trained mixed EFs, and one trained attention. Far-transfer gains reported at the conclusion of training were maintained at 1- to 9-month postassessment intervals; however, five of the seven studies reporting long-term follow-up data on far-transfer effects relied exclusively on unblinded behavior ratings and, as reported earlier, likely reflect uncontrolled expectancy effects.

Summary of Findings

The meta-analytic results revealed moderate magnitude improvement on near-transfer measures of children's cognitive performance for FIT programs targeting STM, and these effects remained evident at 3–6 months in the circumscribed number of studies ($k = 3$) that examined near-transfer maintenance. In contrast, FIT programs targeting mixed EFs (e.g., combined inhibition and STM training), set-shifting, or only attention processes were not associated with significant improvements in the trained cognitive processes. This pattern of results was consistent with expectations derived from our literature review of EF deficits in children with ADHD and their association with impaired functional outcomes with one exception: the lack of significant near-transfer effects for FIT programs targeting vigilance/sustained attention deficits. The latter finding may reflect the limited time devoted exclusively to strengthening vigilance/sustained attention abilities due to time spent training attention components that are likely not impaired in children with ADHD (i.e., inadequate potency).

The lack of a significant Training Target moderator effect led us to an examination of all FIT programs

TABLE 26.4. FIT for ADHD: Meta-Analytic Summary

	Near-transfer effects			Far-transfer effects		
	Immediate (Tier I) *k* = 17	Pre to follow-up (Tier IIa) *k* = 3	Post to follow-up (Tier IIb) *k* = 3	Immediate (Tier III) *k* = 22	Pre to follow-up (Tier IVa) *k* = 7	Post to follow-up (Tier IVb) *k* = 7
Cohen's *d* effect size:	0.46 (0.26 to 0.66)	0.73 (0.46 to 0.99)	–0.18, *ns* (–0.42 to 0.06)	0.38 (0.21 to 0.54)	—	—
Corrected for sampling error	0.45 (0.25 to 0.65)	0.71 (0.45 to 0.97)	–0.17, *ns* (–0.41 to 0.06)	0.36 (0.20 to 0.51)	—	—
Corrected for sampling error/publication bias	0.23 (0.04 to 0.42)	0.71 (0.45 to 0.97)	–0.20, *ns* (–0.42 to 0.01)	0.36 (0.20 to 0.51)	—	—
Cohen's *d* effect size corrected for sampling error/ publication bias						
Moderator analysis: Training target						
STM only	0.63 (0.46 to 0.80) *k* = 8	—	—	0.39 (0.13 to 0.66) *k* = 9	—	—
Attention	0.05, *ns* (–0.29 to 0.38) *k* = 5	—	—	0.33 (0.08 to 0.57) *k* = 3	—	—
Mixed EF	0.06, *ns* (–0.22 to 0.33) *k* = 3	—	—	0.28 (0.10 to 0.45) *k* = 9	—	—
Set shifting	0.70, *ns* (–0.17 to 1.57) *k* = 1	—	—	0.44, *ns* (–0.42 to 1.30) *k* = 1	—	—
Moderator analysis: Outcome type						
Cognitive performance	—	—	—	0.14 (0.03 to 0.25) *k* = 11	0.45 (0.17 to 0.74) *k* = 2	–0.003, *ns* (–0.41 to 0.40) *k* = 2
Academic achievement	—	—	—	0.15, *ns* (–0.15 to 0.45) *k* = 3	0.28, *ns* (–0.13 to 0.69) *k* = 2	0.11, *ns* (–0.30 to 0.52) *k* = 2
Blinded subjective ratings	—	—	—	0.12, *ns* (–0.02 to 0.25) *k* = 8	0.15, *ns* (–0.19 to 0.49) *k* = 2	–0.11, *ns* (–0.45 to 0.23) *k* = 2
Unblinded subjective ratings	—	—	—	0.48 (0.30 to 0.66) *k* = 13	0.52 (0.31 to 0.73) *k* = 5	0.07, *ns* (–0.13 to 0.28) *k* = 5

Note. Cohen's *d* effect sizes (95% confidence intervals [CIs] in parentheses) were corrected for sample size due to the upward bias of small-*N* studies. Effect sizes are considered significantly different from 0.0 (statistically significant at $p < .05$) if their 95% CIs do not include 0.0. Moderator subgroup effect sizes are corrected for sampling error and publication bias when significant. *ns*, nonsignificant (95% CI includes 0.0; $p > .05$). *k*, number of studies; STM, short-term memory; mixed EF, studies training two or more executive functions.

incorporating far-transfer measures across four mutually exclusive outcome categories. These included two categories each of objective (i.e., cognitive and standardized academic achievement subtest scores) and subjective outcome measures (i.e., blinded and unblinded ratings). The meta-analytic results revealed no evidence that FIT improves children's academic achievement or blinded ratings of their behavior; however, significant, small-magnitude far-transfer effects were evident among the 11 studies that included cognitive performance outcome measures. This enhanced performance, albeit marginal and detectable only by statistical analysis (Cohen, 1988), warrants scrutiny given that nearly three-fourths of the studies reporting far-transfer cognitive performance outcomes either failed to incorporate near-transfer measures (27%) or reported far-transfer effects (46%) that were of similar or greater magnitude than their near-transfer effects. For the former studies, the lack of demonstrated near-transfer improvements makes it impossible to determine the extent to which improved cognitive performance reflects random or systematic influences, such as task-specific practice and expectancy effects, rather than the assumed strengthening of cognitive functioning. The latter studies' findings are equally perplexing and incongruent with transfer theory predictions, which limit the magnitude of transfer to the multiplicative relation between near-transfer improvement (i.e., the near-transfer effect size estimate) and the established relation between the training target and far-transfer constructs. As an example, Klingberg, Forssberg, and Westerberg (2002) reported that children demonstrated larger magnitude far-transfer improvements (effect size = 1.05) relative to near-transfer improvements (effect size = 0.86) following visuospatial STM and inhibition/choice reaction time (CRT) training. However, the far-transfer measures used in the study—the Stroop task and Raven's Progressive Matrices—are predicted only modestly by visuospatial STM measures (beta = 0.18 and 0.28; Engle, Tuholski, Laughlin, & Conway, 1999; St Clair-Thompson & Gathercole, 2006). A somewhat higher correlation is reported between tasks with combined inhibition/CRT elements (e.g., stop-signal paradigm) and the Stroop task (i.e., beta = 0.49; St Clair-Thompson & Gathercole, 2006). Accordingly, the maximum far-transfer training effect size expected for this study is between 0.16 and 0.24 (attributable to visuospatial STM improvements) and 0.42 (attributable to inhibition/CRT improvements); transfer theory specifies that far-transfer effect sizes in excess of this hypothesized ceiling cannot be attributable entirely to neuronal-level improvements in the trained cognitive functions.[3]

Finally, unblinded parents and teachers reported moderate-magnitude improvement in children's behavior and/or EF in the absence of objective evidence for these changes (i.e., illusory effects). The finding that far-transfer gains were similar to or larger than near-transfer improvement in several of these studies (e.g., Mezzacappa & Buckner, 2010), despite the modest relationship (r = .18–.35) and limited variance (3–12%) shared between span measures and parent ratings (Naglieri, Goldstein, Delauder, & Schwebach, 2005), raises additional interpretative and methodological concerns that warrant scrutiny in future investigations.

MINDFULNESS INTERVENTION TRAINING PROGRAMS

Mindfulness is a meditative technique that focuses on "awareness that emerges through paying attention on purpose, in the present moment, and non-judgmentally to the unfolding of experience moment by moment" (Kabat-Zinn, 2003, p. 145). With origins in Buddhism, mindfulness techniques have been used in a secular context since the 1940s to reduce stress and discomfort in patients diagnosed with medical conditions such as chronic pain, fibromyalgia, cancer, heart disease, and arthritis and treatment-related side effects. The techniques have also been used to treat psychological symptoms such as anxiety, depression, and binge eating in recent years, and are associated with moderate physical (d = 0.42) and mental (d = 0.50) health benefits (Grossman, Neimann, Schmidt, & Walach, 2004).

Mindfulness-based meditation techniques—in addition to improving subjective ratings of medical and psychological distress—are often associated with changes in neurophysiological and immune functioning. For example, documented neurophysiological changes associated with the implementation of meditative practices include increased alpha and theta electroencephalographic (EEG) activity, particularly in the anterior cingulate cortex and dorsomedial prefrontal cortex (Ivanovski & Malhi, 2007; Lagopoulos et al., 2009), whereas improved immune response has been demonstrated by increased titer development to influenza vaccine (Davidson et al., 2003).

Changes in brain regions associated with attention and EFs following mindfulness training (namely, the dorsolateral prefrontal cortex) prompted clinical researchers to modify and adapt the techniques for typically developing children, and more recently, for children with attentional problems and those diagnosed with ADHD. The child and adolescent adaptations involve training children to be fully aware of and in the present moment—a goal accomplished by helping them develop the ability to focus on the here-and-now of any activity in which they are involved—and to process this information from various unique perspectives. The *awareness* aspect of training includes attending to the multiple sensations (e.g., sights, sounds, smells, tastes, and tactile sensations) experienced while thinking about unique ways in which to approach and/or solve a task or activity, and recognizing but letting go of nonrelevant external distractors and internal thoughts.

Although not described as such, several mindfulness training exercises target EF deficits commonly observed in children with ADHD. For example, the *awareness* exercises are clearly intended to promote and strengthen children's ability to focus and sustain their attention on only those stimuli (sensory and cognitive) relevant to performing or completing an assignment, task, or activity. Other exercises are geared toward developing and strengthening cognitive functions that are critical to holding and processing information in the short-term storage/rehearsal WM subsystems, and to inhibit irrelevant external (distractions) and internal stimuli (thoughts) that are likely to interfere with processing the information (i.e., cognitive inhibitory or interference control). As reviewed earlier, sustained attention, WM, and central executive-related cognitive inhibitory control processes represent the most promising EF component targets based on their moderate to strong associations with core symptoms and functional outcomes in children with ADHD.

Mindfulness Programs and Empirically Based Outcomes

One of the first clinical demonstrations of a mindfulness training intervention modified for children was reported by Napoli, Krech, and Holley (2005). The authors examined the effectiveness of a school-based intervention (i.e., the Attention Academy Program) developed to improve attention through the practice of mindfulness. Children assigned to the mindfulness treatment group received 24 weeks of training (45 minutes twice a month) that focused on teaching them to control their breathing and body movements, to develop sensorimotor awareness as a means to improve their attention to the present, to approach without judgment, and to view experiences in a novel manner (see Napoli et al., 2005, Appendix A, for detailed training exercise descriptions). The authors reported moderate-magnitude improvement on measures of social skills (effect size = 0.46), test anxiety (effect size = 0.39), and some measures of attention (effect sizes = 0.49–0.60), but no significant changes in sustained attention. The extent to which improvement on these outcome measures reflect mindfulness training as opposed to increased involvement with adults and expectancy was unclear, however, due to the absence of near-transfer training measures, reliance on unblinded subjective ratings, and contrasts with a passive control group. The sample of children participating in the study may also have constrained the magnitude of treatment-related effects. Participants were described as typically developing children as opposed to children with documented attention-related difficulties or ADHD, perhaps placing an upper limit on the extent to which young children who already possess appropriately developed attentional abilities can improve their attention with prolonged training.

A Limited Meta-Analytic Review

As of this writing, there are only two published studies of mindfulness training for children and adolescents with ADHD. The first (van de Weijer-Bergsma, Formsma, de Bruin, & Bögels, 2012) evaluated the effectiveness of an 8-week (1.5 hour weekly sessions) mindfulness training protocol based on adaptive versions of mindfulness-based cognitive therapy (Segal, Williams, & Teasdale, 2012) and mindfulness-based stress reduction (Kabat-Zinn, 1990) in 10 adolescents with ADHD and their parents. Adolescent and parent completed Mindfulness Attention and Awareness Scale (MAAS) measures, and two computerized sustained attention tasks from the Amsterdam Neuropsychological Tasks (ANT) battery (i.e., Sustained Attention Dots and Sustained Attention Auditory tasks) were used to evaluate near-transfer effects associated with mindfulness training. Far-transfer measures included the attention, internalizing, and externalizing subscales of the Child Behavior Checklist (CBCL), the Teacher Report Form (TRF), the Youth Self-Report Form (YSR), and the Behavior Rating Inventory of Executive Function (BRIEF) Metacognition and Behavioral Regulation subscales.

The second study (van der Oord, Bögels, & Peijnenburg, 2012) investigated the potential efficacy of a nearly identical 8-week (1.5-hour sessions) mindfulness program for 18 children with ADHD and their parents, based on the same adapted versions of mindfulness training used by van de Weijer-Bergsma and colleagues (2012). No near-transfer measures were used in the study; far-transfer measures included unblinded parent and blinded teacher ratings on Disruptive Behavior Disorders Rating Scale subscales (Inattention, Hyperactivity and Impulsivity, Oppositional Defiant Disorder, Conduct Disorder).

The overall results stemming from the two mindfulness intervention studies for children and adolescents with ADHD and their parents are summarized in Table 26.5. No significant near- ($d = 0.13$, *ns*) or far- ($d = -0.01$, *ns*) transfer effects were reported by van de Weijer-Bergsma and colleagues (2012), whereas van der Oord and colleagues (2012) reported small- to moderate-magnitude improvements on their far-transfer parent ratings ($d = 0.34$). The parents completing the rating scales, however, were actively involved with their child's treatment and received an adult version of the same treatment themselves. Consequently, their unblinded ratings likely reflect the well-documented illusory biases that occur in lieu of appropriate controls for expectancy effects—an explanation consistent with the nonsignificant mindfulness training effects based on blinded teacher ratings.

SUMMARY AND FUTURE DIRECTIONS

Considered collectively, our initial meta-analytic review indicates that extant claims regarding the benefits associated with FIT programs, including improved academic achievement, cognitive performance, and reduced symptomatology in children with ADHD, are not supported by empirical evidence. It would be premature, however, to conclude that bringing about fundamental and lasting changes in the cognitive abilities of children with ADHD is unattainable given the significant design and methodological limitations characteristic of the field.

One of the most fundamental design issues entails the lack of correspondence between the cognitive functions targeted by FIT programs and extant empirical evidence. WM is a patent example. Each of the STM FIT studies identified in the literature search relied on a program that describes itself as an intervention for improved WM. A majority of its exercises, however, focus on training the least impaired aspects of WM in children with ADHD (namely, visuospatial and phonological short-term storage capacity), as opposed to the significantly larger magnitude central executive processing deficits associated with impaired functional outcomes identified in the ADHD literature.

The scant literature examining mindfulness as a potentially therapeutic technique for youth with ADHD suffers from nearly identical methodological design limitations that characterize the FIT literature. These include the need for (1) credible (adaptive) control groups, (2) objective (blind) ratings, and (3) multiple near- and far-transfer measures to allay extant validity concerns (including nontransfer measures that would not be expected to improve following treatment as an index of divergent validity). There is also a dearth of information concerning potentially critical treatment parameters for FIT and mindfulness intervention programs. Most of these center on dosage effects and include establishing the optimal duration and spacing of sessions for youth of different ages, and how long training needs to continue to ensure optimal treatment effects. Most children with ADHD have experienced difficulties with inattentiveness, impulsivity, excessive gross motor activity, and associated adverse functional outcomes, such as learning difficulties and poor peer relationships for their entire lives. Significant improvement in core symptoms and associated adverse outcomes is to a considerable extent likely to depend on whether and the degree to which empirically informed interventions can normalize identified EF deficits that govern behavior and contribute to successful academic functioning and interpersonal interactions. Given the 3-year delay in peak, frontal–prefrontal cortical maturation associated with ADHD, however, it is unlikely that training children for 30 minutes a day across 5 weeks or for 90 minutes a day for 8 weeks—the modal training parameters adopted in past FIT and mindfulness investigations, respectively—will normalize behavioral, academic, and neurocognitive functioning for children with ADHD. We remain optimistic, however, regarding the potential for future interventions to target empirically informed EFs successfully (e.g., central executive and sustained attention/vigilance) and alter the developmental trajectory of implicated brain systems. Supplementary training such as specialized, intensive academic tutoring will almost certainly be required to maximize far-transfer gains related to academic achievement.

TABLE 26.5. Mindfulness Study Characteristics

Author (year)	T (*n*)	C (*n*)	Program	Control group	Total minutes	Total sessions	Total weeks	Minutes/ session	Near-transfer ES (CI)	Far-tra ES (
van de Weijer-Bergsma et al. (2012)	10	—	Study Developed based on MBCT and MBSR	None	720	8	8	90	0.13, *ns* (−0.51 to 0.77)	−0.01 (−0.64 t
van der Oord, Ponsioen, et al. (2012)	22[a]	11	Study Developed based on MBCT and MBSR	Waiting list	720	8	8	90	—	0.3 (0.16 to
									Overall effect	
									0.13, *ns* (−0.51 to 0.77) $k = 1$	0.3 (0.09 to $k =$

Notes. T, treatment group; C, control group; *n*, number of participants within each group; ES, effect size; CI, 95% confidence interval; MBCT, mindfulness-based cognitive therapy (Segal et al. MBSR, mindfulness-based stress reduction (Kabat-Zinn, 1990).

[a] Represents the larger number of children analyzed in the posttest contrasts and includes children who initially served as waiting-list controls and later participated in the active treatment co

KEY CLINICAL POINTS

- ✓ Current empirically supported treatments for children with ADHD produce significant acute beneficial effects during treatment, yet are unlikely to generalize to improving problems in untreated settings, and children fail to maintain these gains once treatment is withdrawn.
- ✓ Working memory (central executive) and sustained attention problems are well documented in children and teens with ADHD. These problems are associated with underdevelopment and underfunctioning of various brain regions and networks. It therefore makes sense to develop FIT programs that may improve or expand these neurological regions and networks by targeting these EF deficits. Targeting empirically identified neurocognitive functioning has the potential to improve the breadth, generalization, and maintenance of treatment gains over time relative to traditional treatments for ADHD.
- ✓ However, it is essential that FIT developers understand the nature of the EF findings and focus FIT treatments on these specific deficits. For instance, evidence indicates that the most significant WM problems in ADHD may be associated with the manipulation, updating, and reordering of information (executive) rather than with the online maintenance (storage) and rehearsal of information. FIT programs targeting maintenance and rehearsal features of WM are therefore not likely to improve outcomes for children with ADHD.
- ✓ Many FIT programs, such as those utilizing Cogmed or BrainTrain, claim to target WM but appear to primarily target storage/rehearsal rather than central executive processes such as manipulation, updating, and reordering. Other programs have focused on a mixed set of EFs and others on attentional components. These studies were combined into a meta-analysis to examine their effectiveness at (1) near-transfer improvements (improved performance on similar tasks to those used in training), (2) maintenance of such near-transfer improvements over time, and (3) immediate and maintenance of far-transfer improvements on tasks less related to the training tasks, ratings of ADHD symptoms, and EF deficits in daily life, or measures of academic achievement and school performance.
- ✓ Results of this meta-analysis indicated that none of the available programs stress training WM central executive processes and that FIT programs that targeted primarily WM storage and rehearsal produced significant near-transfer improvements. Those studies that targeted mixed EF components or attention abilities were not effective. Three studies collected follow-up measures, and these indicated that the gains on the near-transfer WM measures were sustained for 3–6 months, but such evidence is limited by so few studies examining this issue.
- ✓ Evidence for far-transfer effects of training on parent and teacher behavior ratings, academic achievement, or other functional outcomes was disappointing. Significant benefits were reported only by unblinded raters and appear to reflect illusory or Hawthorne effects rather than true changes in behavior. There was scant evidence of far-transfer effects based on objective measures of functional outcomes. These results are quite sobering and disappointing, and contradict claims made by treatment developers and FIT proponents that such programs are effective for children and teens with ADHD.
- ✓ These findings further suggest that FIT programs are not targeting the areas of greatest EF deficits—sustained attention and the manipulation, updating, and reordering aspects of WM.
- ✓ An alternative cognitive training program recently developed for children and teens with ADHD is mindfulness meditation training. As of this writing, only two studies have examined the use of mindfulness meditation training, and the results again were mixed and largely disappointing. While there is some evidence that this approach improves unblinded parent–teacher ratings, parents' active involvement in both delivering and receiving the intervention strongly suggests that the effects on their ratings are largely due to expectancy effects and not to treatment itself. No evidence was found for improvements in blinded teacher ratings or other functional outcomes.
- ✓ FIT programs have not demonstrated sufficient effectiveness for improving ADHD symptoms or the important functional outcomes related to the disorder; however, some FIT programs improve STM storage and rehearsal performance on specific verbal and nonverbal WM tasks.
- ✓ Until there is greater evidence of treatment effectiveness in ADHD, we do not recommend the adoption of these treatment approaches for routine clinical practice.

NOTES

1. Pneumoencephalography, a now obsolete medical procedure used during the early 20th century, involved draining most of the cerebrospinal fluid from around the brain and replacing it with air, oxygen, or helium to enhance X-ray imaging.
2. Estimates reflect the percentage of overlap between ADHD and non-ADHD groups (i.e., only approximately 19% of children with ADHD score within the typically developing range).
3. Multiplying the near-transfer effect size (expressed in *SD* units) by the beta-weight (which gives the *SD* change in the far-transfer outcomes associated with a 1 *SD* change in the near-transfer outcome), provides the maximum expected effect size for far-transfer that is attributable to improvements in the near-transfer (trained) construct. For example, if a 1 *SD* change in STM performance is associated with a 0.18 *SD* change in Stroop task performance, then a 0.86 *SD* change in STM performance (the near-transfer effect size) could yield a maximum of 0.16 *SD* change in Stroop performance (0.86 × 0.18 = 0.16). The obtained ES could be higher, allowing for the possibility of synergistic effects, measurement unreliability, or improvements in unmeasured EF processes, but it could also be lower due to the use of all incongruent Stroop trials in the study, which nullifies its relationship with WM (Hutchison, 2011).

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