Computerized Attention Training for Childhood Behavior Disorders: A Non-Pharmaceutical Treatment Approach

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Preface

The present thesis contains three original manuscripts representing the scope of my Master's research. Brain training programs abound in the commercial market and are increasingly capturing the interest of clinicians and cognitive researchers as a therapeutic or rehabilitative tool. The thesis begins with a critical review introducing the concept of brain training in different populations and examining the evidence supporting or disputing the usefulness of various products (Manuscript 1). One prominent target of brain training programs is attention, a strong regulator of thought and action as well as a contributor to success in social and academic settings. By training attention in children, our study investigates the capacity to strengthen important cognitive capacities during development (Manuscript 2). In addition, because our study revolves around children with common impulse-control disorders, we examine the potential of attention training as an adjunct or possible alternative to pharmaceutical treatments. Some preliminary results of our study were presented at national and international conferences. Finally, in light of the commercial allure of these programs, we include a published commentary addressing conflicts of interest in research in Appendix D (Manuscript 3).

Contributions of Authors

Critical Review (Manuscript 1): *Training the brain: Fact and fad in cognitive and behavioral remediation*

Sheida Rabipour: Primary author, writing the manuscript.

Amir Raz: Corresponding author, commenting on the manuscript and providing guidance.

Experimental Piece (Manuscript 2): *Computerized attention training in children with impulse-control impairments*

Sheida Rabipour: Primary author, writing the manuscript and leading the research effort.

Elena Perez-Hernandez: Development of methodology, providing guidance in carrying out the research.

Alexandra Fischer: Assistance in carrying out the research, commenting on the manuscript.

Amir Raz: Corresponding author, commenting on the manuscript and providing guidance in carrying out the research.

Commentary (Manuscript 3): *Quandaries and perspectives on potential bias*

Sheida Rabipour: Primary author, writing the manuscript.

Emily Delpero: Helping form the arguments and editing the manuscript.

Amir Raz: Corresponding author, commenting on the manuscript and providing insight in building the arguments.

Abstract

Cognitive training paradigms constitute a budding field in both research and the commercial market. Engulfed in hype, computerized training programs are particularly enticing in the "Informatics Era" and have fostered the development of increasingly complex programs aiming to improve cognitive function. With the promise of enhancing skills such as attention and memory, cognitive training programs appeal particularly to atypically developing individuals as a non-pharmaceutical alternative to treatment. Such claims have led both professionals and laypersons to question the effectiveness of commercially-available products. In our critical review, we investigate the potential benefits of various cognitive training paradigms and evaluate the evidence supporting or discounting popular programs in specific populations. This investigation reveals that, while certain forms of training demonstrate benefits for improving certain cognitive skills, many programs require more rigorous scientific evaluation to validate their claims. Our experimental piece studies the effectiveness of an adaptation on one scientifically-validated form of cognitive training: computerized attention training. We seek to determine the clinical effectiveness of this type of program in children with common impulse-control disorders, including attention deficit hyperactivity disorder, oppositional defiance disorder, and conduct disorder. Findings from this study suggest that, while subjective ratings of behavior may improve as a result of training, children may require prolonged training periods to benefit on objective ratings of attention and intelligence. Future studies remain to elucidate the effectiveness and sustainability of such training programs when administered over longer periods, as well as more subtle changes detected through neuroimaging.

Résumé

L'entrainement cognitif de l'attention est un domaine qui prend de plus en plus d'ampleur à la fois dans le monde de la recherche et dans le marché commercial. Couverts de publicité, des programmes informatiques d'entrainement mettent sur pieds des logiciels de plus en plus complexes ayant pour cible le développement des fonctions cognitives. Promettant d'améliorer des aptitudes telles que la capacité mnémonique ou l'attention, ces programmes d'entrainement cognitif sont particulièrement attirants pour des individus atteints de problèmes développementaux puisqu'ils semblent offrir une alternative aux traitements pharmaceutiques. Ces promesses ont cependant conduit les professionnels de la santé, ainsi que le public, à s'interroger sur l'efficacité réelle des produits disponibles sur le marché. Dans notre revue critique, nous tentons de saisir les bienfaits que divers programmes d'entrainement cognitif peuvent apporter, et nous évaluons les preuves en faveur ou en défaveur des programmes d'entrainement cognitif disponibles sur le marché. Nos recherches indiquent que, bien que certains types d'entrainement soient source de bienfaits cognitifs, plusieurs programmes promettent des effets qui ne sont pas soutenus par des preuves scientifiques suffisantes. Dans notre projet de recherche, nous étudions l'efficacité d'une adaptation d'un programme d'entrainement cognitif ayant été validé scientifiquement : l'entrainement de l'attention par programme informatisé. Nous tentons de déterminer l'efficacité clinique de ce type d'intervention chez les jeunes enfants atteints de troubles d'habitudes et d'impulsions, entre autre chez les enfants atteints du trouble de déficit de l'attention avec hyperactivité, du trouble oppositionnel avec provocation ou du trouble des conduites. Les résultats de notre étude révèlent que, bien que l'évaluation subjective du comportement de l'enfant semble s'améliorer suite à l'entrainement de l'attention, il est possible que les enfants aient besoin de séances d'entrainement prolongées afin de démontrer des bienfaits pouvant être mesurés objectivement, tels qu'une augmentation de l'intelligence ou de l'attention. Les études à venir devront évaluer l'efficacité et la stabilité à long terme des effets de ces programmes et enquêter la possibilité qu'un entrainement soutenu provoque des changements plus précis pouvant éventuellement être détectés par des techniques d'imagerie cérébrale.

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General Introduction

(Manuscript 1)

Training the Brain: Fact and Fad in Cognitive and Behavioral Remediation

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Non-Standard Abbreviations*

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* AT = Attention Training
WM = Working Memory
FFW-L = Fast ForWord-Language
HRT = Habit-Reversal Training
IBMT = Integrative Body-Mind Training
BBC = British Broadcasting Corporation
AKTIVA = Active Cognitive Stimulation-Prevention in the Elderly
TS = Tourette's Syndrome
COI = Conflicts Of Interest

Abstract

Putatively safe and effective for improving cognitive performance in both health and disease, products purported to train the brain appeal to consumers and healthcare practitioners. In an increasingly health-centered society, these applications constitute a burgeoning commercial market. Sparse evidence coupled with lack of scientific rigor, however, leaves claims concerning the impact and duration of such brain training largely unsubstantiated. On the other hand, at least some scientific findings seem to support the effectiveness and sustainability of training for higher brain functions such as attention and working memory. In the present paper we provide a tectonic integration and synthesis of cognitive training approaches. Specifically, we sketch the relative merits and shortcomings of these programs, which often appeal to parents who must choose between side-effect-laden medication and other less conventional options. Here we examine how neuroplasticity allows the healthy as well the impaired to benefit from cognitive training programs. We evaluate the evidence and consider whether brain training can be a stand-alone treatment or an adjunct to pharmacotherapy, outline promising future prospects, and highlight what training outcomes are plausible in line with available data. Future research would determine whether the field of brain training realizes its potential to revolutionize education and rehabilitation or withers away engulfed in controversy.

Keywords: attention, brain training, cognitive remediation, computerized training programs, neuroplasticity, working memory.

Introduction

Increasingly ubiquitous, training programs foster the putative promise of enhancing or rehabilitating behavior and brain function. This trend comprises a burgeoning market of products alleged to enhance cognition, emotion, thought and action. Catering to individuals of all ages, but targeting young children and the elderly in particular, such programs claim to benefit healthy populations as well as those diagnosed with specific disorders. Many commercial programs take advantage of computerized training over the Internet, offering the comfort and privacy of home-based brain exercise. Appealing to a wide clientele – from the ambitious and healthy to the desperate and sick – brain training targets parents and professionals looking for an edge in a competitive society, symptom relief, or a potential cure.

Broadly defined, brain training refers to the engagement in a specific program or activity that aims to enhance a cognitive skill or general cognitive ability as a result of repetition over a circumscribed timeframe. Such training can produce changes measured at the behavioral as well as the neuroanatomical and functional levels. Many forms of brain training appear to improve cognitive function and emotional control, particularly programs that exercise attention (Rueda, Posner, et al., 2005). By practicing games or tasks that require choosing between two competing responses, the training of attention aims to strengthen the neural networks underlying control processes (Raz & Buhle, 2006). A strong modulator of cognition and affect, attention refers to the selective focus on specific aspects of our environment or to the concentration on specific mental thoughts and operations (Raz & Buhle, 2006). Similar to attention training (AT), many programs target working memory (WM), a system that mediates temporary information storage, modification, and protection from interference (Bledowski et al., 2010). Apart from attention and WM, studies suggest that practicing sustained attention through meditation (Tang & Posner, 2009), schooling (Diamond et al., 2007b), interaction with nature (Kaplan, 1995a), exercise (Kubesch et al., 2009), and musical training (Kraus & Chandrasekaran, 2010) can also improve cognitive ability and emotional control. The effects of such varied methods on cognitive ability and emotional stability attest to the advantages of specific exercises.

Brain training is especially relevant for developmental psychopathology. This approach has potential to ameliorate undesired symptoms of disorders such as attention deficit hyperactivity disorder (ADHD), a condition characterized by deficits in behavioral inhibition associated with cognitive processes that mediate goal-directed behaviors (Barkley, 1997). ADHD comprises a useful lens through which researchers examine the effects of training. A spectrum disorder, ADHD contains various degrees of severity that inflict mild to severe impairments, many of which relate to executive attention and may improve as a result of training (Illes & Sahakian, 2011). Currently, primary treatments for developmental psychopathologies such as ADHD often involve psychotropic medications, which sometimes show marginal effects. Even these effects, however, attenuate over time and can generate a number of unwanted side-effects. As a result, parents and clinicians are often reluctant to embrace drug-based therapy despite the scarcity of safe and effective treatment alternatives. Recent allegations add controversy to this dilemma by claiming that certain psychiatrists may have surreptitious ties with drug companies, biasing the research surrounding the production and distribution of medication for youth ("Credibility crisis in pediatric psychiatry," 2008). In light of such limitations in pharmacological-based remedies, brain training may represent an attractive adjunct to common pharmacological treatment.

The generalizability of brain training represents one of the major claims-to-fame of publicly distributed programs. With scarce data to support advertised claims, however, patrons of brain training often invest considerable resources pursuing programs that promote unsupported, arguably unrealistic, outcomes. While studies of computerized AT and working memory training (WMT) show, perhaps unsurprisingly, that trainees can improve significantly on cognitive skills related to the intervention (Westerberg et al., 2007), at least some findings suggest that training may generalize beyond task-specific skills and apply to untrained overarching abilities (Jaeggi et al., 2008; Jaeggi et al., 2010). Reported improvements sometimes extend to increased fluid intelligence, which refers to the ability to solve problems in novel situations (Buschkuehl & Jaeggi, 2010; Mackey et al., 2010). Such transfer effects may result from overlapping neural networks in the prefrontal cortex (PFC), which underlie both WM and fluid intelligence (Gray et al., 2003; Klingberg, 2010). Claims regarding the transfer of practiced skills to other untrained cognitive domains are contentious, however, because the appearance of transfer may, in fact, result from training-to-task (Snyder, 2011). Specifically, training programs may obliquely tax the very abilities that researchers subsequently test (Diamond, 2011). In addition, being the wild west of neuropsychology, many studies report experimental results using inadequate controls, if any (Papp et al., 2009). Rather than generalizability, therefore, the improvements observed throughout various programs may arise due to reasons such as training-to-task.

Apparent from adequately controlled studies, brain training is a groundbreaking approach with potential to transform the panorama of non-pharmacological therapy. Despite the mounting prevalence of such products, the immense potential of such interventions for various populations, and the increasing evidence both supporting and disclaiming the effectiveness of training, no other article, to our knowledge, has thoroughly amalgamated the evidence surrounding cognitive programs and the populations that may benefit from training. In the present article, we critically evaluate the validity of claims regarding various brain exercises and cognitive remediation approaches. In an attempt to elucidate the effectiveness of brain training, we examine the impact of these programs in both healthy developing individuals and pathological populations. We further investigate the potential use of such training as an adjunct – or possible substitute – to current drug-based therapies for children with psychopathologies. We conclude by discussing specific conflicts that may hinder the advancement of research in this field and outline plausible outcomes of brain training with regards to factors that may alleviate or aggravate undesirable childhood behavior.

Neural and behavioral basis of brain training

Attention plays a central role in social behavior and academic performance. Due to brain plasticity, training can alter the neural correlates of attention and improve attentional control. In this section, we focus on a current, widely recognized model that subdivides attention into three separate systems. We discuss the function of these systems as well as their related neural networks, and delineate how these systems control behavior throughout development. Ultimately, we underline why attention is a suitable faculty to train in both children and adults.

Neuroplasticity and training

Brain training thrives on the lure of neuroplasticity, a change in neural structure and function in response to experience or environmental stimulation (Shaw et al., 1994). Research suggests that both genetic and environmental factors impact the development and physical structure of the brain (Lenroot & Giedd, 2008). Investigations of executive attention in children have uncovered notable disparities associated with socio-economic status, even when performance levels are comparable (Hackman & Farah, 2009; Mezzacappa, 2004). Other studies report that severe stress and maltreatment experienced early in life can severely impact neuroanatomy, showing reduced volumes and attenuated development of several neural structures (Teicher et al., 2003). Taken together, these findings indicate that the developing brain is susceptible to change in response to environmental stimuli.

Evidence suggests that neuroplastic processes are present in the adult brain. Repeated practice of skills required for a profession, for example, appears to induce lasting changes within neural structure; London taxi drivers display larger grey matter volumes in neural areas associated with spatial memory (Maguire et al., 1998; Maguire et al., 2006), professional typists undergo greater development of neural regions related to the programming of motor tasks (Cannonieri et al., 2007), and musicians appear to acquire increased cortical representations of their digits (Elbert et al., 1995) as well as enlarged motor, auditory, and visual-spatial regions (Gaser & Schlaug, 2003). Even among the elderly, neuroplasticity continues to facilitate changes leading to improvement in cognitive function (Calero & Navarro, 2007). These studies indicate that the greatest changes occur through repeated practice of a skill over an extended period of time, even when learned in adulthood. In addition, extensive training or practicing a specific new skill may modify neural structures and functions over a relatively short period of time; magnetic resonance imaging (MRI) reveals increases in grey matter volumes of regions associated with the processing of complex visual motion in young adults, following three months of training on a juggling task (Draganski et al., 2004). Diffusion tensor imaging, furthermore, indicates changes in white matter configuration after just four weeks of juggling (Scholz et al., 2009). Another study reported changes in the grey matter density of medical students, following three months of extensive studying for a medical school exam (Draganski et al., 2006). Recent studies show, moreover, that increases in grey matter volume may occur following as little as one week of training in a particular task (Driemeyer et al., 2008). Functional and morphological changes in the adult brain may therefore arise as a result of expertise in a field as well as mastering novel skills.

Attention Networks

Attention encompasses distinct neural processes that mature independently, at different stages of life. Fundamental to cognitive function, attention begins to develop during childhood (Posner & Rothbart, 2007b) and contributes to self-regulation, the ability to regulate our thoughts and actions (Karoly, 1993; Raz & Buhle, 2006; Rueda, Posner, et al., 2005). William James first proposed that attention may contain multiple “varieties” (James, 1890), deviating from long-held theories of attention as a unitary system. A century later, Michael Posner further elaborated on this idea by putting forth a theory in which attention consists of three highly connected yet independent networks (Posner &

Petersen, 1990). This attention trilogy comprises the alerting, orienting, and executive attention systems (Posner & Rothbart, 2007a).

The alerting and orienting networks constitute the more primitive components of attention; the alerting system denotes sustained attention, vigilance, or alertness, and refers to response readiness in preparation for an impending stimulus (Raz & Buhle, 2006). Sometimes considered the foundational form of attention, the alerting system may continue developing well into adulthood (Rueda et al., 2004). The orienting network, on the other hand, involves selecting specific information from multiple sensory stimuli (Raz & Buhle, 2006). Believed to develop fully by the age of four, this network mediates shifts of the sensory organs to bring objects of interest into focus (Posner & Rothbart, 2007b).

Of the three attention networks, executive attention is most pertinent to brain training. Also termed supervisory or selective attention, executive attention mediates voluntary control and activates in situations requiring the monitoring and resolution of conflict between computations in separate neural areas (Raz & Buhle, 2006). These conflicts may include planning or decision-making, error detection, execution of new or ill-acquired responses, involvement in stressful conditions, regulation of thoughts and feelings and overcoming of habitual actions. Executive attention involves processes of self-regulation that include effortful control, the ability to suppress a dominant response in favor of a subdominant response (Kochanska et al., 2000), as well as inhibitory control, the termination of an ongoing response (Schachar et al., 1993). Accordingly, measures of this system often involve conflict-related tasks such as the Stroop task, which requires participants to name the ink color of a color-word by suppressing the tendency to read the word itself (Stroop, 1935). In addition, executive attention plays a role in emotional regulation, the control of emotional responses based on actions of the self or others (Raz & Buhle, 2006). Neural correlates of executive attention lie within the lateral PFC, the ACC, and the basal ganglia, and draw on the dopaminergic system (Posner & Rothbart, 2007b). The ACC itself is believed to have several functionalities. While theories initially implicated the dorsal portion in cognitive conflict and the ventral-rostral portion in emotional conflict (Bush et al., 2000), recent evidence suggests that the dorsal ACC may integrate negative affect, pain, and cognitive control to facilitate appropriate action based on punishment-related information (Shackman et al., 2011). Furthermore, genes that modulate the dopaminergic system strongly influence executive attention and also appear to associate with impulse-control disorders such as ADHD (Fan et al., 2003; Fossella et al., 2002). With rapid development commencing at four years of age, the executive attention network may not change significantly after the age of seven (Rueda, Posner, et al., 2004; Rueda, Fan, et al., 2004). This early development in executive attention appears to have strong potential for environmental modification, including targeted training (Rueda, Rothbart, et al., 2005). By developing executive attention, children learn to regulate cognition and behavior, and gradually conform to societal norms.

Executive attention strongly links to WM in situations requiring attentional control and focus. Similar to attention, WM is a modular system and is recruited during processes such as reading and language comprehension, learning, and reasoning (Baddeley, 1992; Daneman & Carpenter, 1980; Tsianos et al., 2010). Originally hypothesized to mediate executive attention, WM is now believed to draw upon this network in order to maintain and prioritize temporary stores of information (D'Esposito, 2007; Jarrold & Towse, 2006). Neuroimaging studies in humans and nonhuman primates consistently correlate the use of WM with activation patterns involved in executive function, a faculty that encompasses executive attention, including circuits within the lateral PFC (D'Esposito, 2007; Klingberg, 2010). These findings suggest that WM and executive attention rely upon one another’s functionality to control and monitor specific neural processes.

Attention and brain training: Transfer of behavioral control

Studies suggest that the attention networks exert differential control over behavior, with specific networks contributing more strongly at certain stages of life (Gupta & Kar, 2009; Rueda, et al., 2004). Whereas the executive attention network plays a critical role in many adult pursuits, the orienting network most strongly dictates behavior at earlier developmental periods. In infants as young as three months of age, visual and auditory distraction can temporarily dampen distress (Posner et al., 2011). This early reliance on the orienting network may underlie the relative novelty of environmental stimuli for infants and children and often provides refuge for caregivers seeking to soothe a distressed baby by using a distracter. Similar effects have also been reported in adults (Harman et al., 1997). Whereas infants rely most strongly on the orienting network to carry out attentional shifts, adults incorporate the executive attention system in addition to the potent orienting signal (Kanske et al., 2011). Scientists are unsure, however, when the precise shift from orienting to executive control occurs. Studies report the presence of rudimentary forms of control through executive attention in the form of cautious approach to novel stimuli (Sheese et al., 2008) and behavioral inhibition during conflict at 40 months of age (Jones et al., 2003). By three to four years of age, children recognize errors and begin to display physical control strategies to inhibit inappropriate responses, although verbal self-regulation of behavior tends to manifest later in life (Jones, et al., 2003). The gradual development of executive control in children foreshadows its eventual control over behavior, although the stage for this transfer of control between the orienting and executive attention networks remains elusive.

The overwhelming tendency of infants to attend to novel stimuli in their external environment may serve an evolutionary purpose and simultaneously facilitate the development of executive attention (Posner & Rothbart, 2011). Whereas children – and certainly infants – are not expected to make executive decisions in daily life, adults require a strong command of executive function to thrive in society. Dependence on the rapidly-maturing orienting network during early life allows infants to explore their surroundings and become acquainted with their new environment. Activation of the orienting network may also play a key role in the maturation of the executive network through their complementary activation in response to presentation of novel stimuli (Posner, et al., 2011). In this fashion, caregiver interactions may promote self-regulatory processing through regular activation of the executive network.

The control of emotion and behavior may occur through altered planes of consciousness such as hypnosis. Scientists recognize that children are considerably more hypnotizable than adults (Kohen & Olness, 2011). This observation may arise from a natural tendency to delegate control to the orienting network of attention, where an external source – the child's caregiver, for example – becomes the source upon which children depend to regulate their behaviors and emotions. Similarly, the hypnotic state promotes an external source of control – this time, by the hypnotist. In such a way, the hypnotic state may promote an increased reliance on the orienting system for behavioral control, rather than the more commonly used executive system (Posner & Rothbart, 2011). In adults, who presumably have fully-developed attention systems, hypnosis affords the opportunity to achieve different states of awareness, to experience emotional realizations, and to perform neural computations that may otherwise have been difficult to achieve. Highly hypnotizable adults, for example, demonstrate elimination of conflict-related interference on the Stroop task after receiving posthypnotic suggestion (Raz, 2004). Altered mental states may therefore induce differential control over attentional networks and may prove important for modulating behavior and emotion.

Origins and evolution of brain training

Whereas various cultural practices have influenced states of attention for centuries, the implications of altered mental states on cognitive function were sparsely documented before the late 20th century (Jevning et al., 1992). Studies in the 1960s and 1970s on relaxation therapy and early forms of AT were among the first research efforts leading to modern behavioral modification paradigms (Douglas et al., 1976; Paul, 1969; Pressley, 1979). This era of research witnessed neuropsychological AT, which initially aimed to maximize the functional independence and adjustment of individuals with brain damage (Park & Ingles, 2001). The learning model of recovery (Stuss et al., 1999) triggered theories relating experience, practice, and environment to the restoration of impaired capacities, substantiating the use of AT-like programs for cognitive rehabilitation. Following an early description concerning the therapeutic value of self-monitoring and self-control (Kanfer, 1970), a vast literature has emerged regarding improving self-control in children, a population known to be ill-equipped at maintaining composure in situations that may provoke inappropriate behavior (Pressley, 1979). The potential to improve self-control in children prompted scientists to explore these techniques as non-pharmaceutical treatment alternatives for children with impulse-control impairments. A program aiming to improve inhibitory control in hyperactive children (Douglas, et al., 1976) included self-reinforcement strategies as well as verbalization techniques. After teaching children to cope more effectively and independently when faced with cognitive problems in social and academic situations, the program facilitated significant improvements in performance on standardized intelligence tests. Following such reports, scientists began to appreciate the implications of training behavioral control in children.

Research has increasingly focused on training the attention systems as a means of altering behavior. Specific emphasis on AT originated with Attention Process Training, a cognitive rehabilitation method through which scientists trained individuals with neurological impairments to employ specific subtypes of attention (Tamm et al., 2008). In one promising study, individuals suffering from brain injury showed significant improvements in attentional processing which lasted as long as eight months following training (Sohlberg & Mateer, 1987). In another study, patients with unilateral neglect verbally regulated the sustained-attention network by engaging in an analogous AT program (Robertson et al., 1995) and displayed improvements in untrained tasks of sustained attention and neglect after the five-hour training period. These studies corroborate the use of targeted AT in individuals with specific functional deficits in their attention networks. In the spirit of rehabilitation, Benedict et al. (1994) created a 15-hour program to remediate the attentional ability of schizophrenic patients using tasks aimed at increasing information processing capacity. Although the schizophrenic population improved performance on trained tasks, observed enhancements in attention remained below the attentional baseline of controls (Benedict et al., 1994). A later study, however, reported that schizophrenic individuals with comparable baseline measures as controls improved in vigilance, distractibility, and psychiatric status following 18 AT sessions (Medalia et al., 1998). Research on AT branched out to target a variety of attention-based disorders. For example, studies in autistic children reported improved attentional capacity that generalized to untrained attention tasks as a result of training on joint-attention tasks (Whalen & Schreibman, 2003). A study examining the eight-hour Pay Attention! program (Kerns et al., 1999) found improvements in the attentive abilities and academic efficiency of children with ADHD. Research efforts have rapidly expanded the implementation of AT and similar variants to restore specific deficits in executive function and supplement these processes in typically-developing individuals. One innovative attempt modified a program used to train monkeys for space travel and created a promising AT program for children. Following five days of training, the study reported significant improvements in performance of both four- and six-year-old participants on tests of attention and intelligence (Rueda, Rothbart, et al., 2005). In addition, electrophysiological recordings demonstrated maturation of neural activation patterns associated with the executive attention network to more adult-like signals, including increased amplitude of the electroencephalographic (EEG) N2 component. The study additionally demonstrated an association between stronger effortful control, decreased extraversion, and the long allele of the DAT1 dopamine transporter gene. Thus, training programs that target attention appear to produce measurable structural and functional changes in the brain.

Culture, lifestyle, and brain training practices

Brain training has significantly impacted mainstream society. From claims of improving the negative symptoms of psychopathologies and neurological impairments to assertions of significantly boosting cognitive skills among the healthy, commercialized software and interactive programs are increasingly capturing the interest of parents, educators, students, and clinicians (see tables 1 and 2). Tutoring services (e.g., (Kumon North America, 2011; Sylvan Learning, 2011)) entice parents looking to enhance the academic success of their children. While some practices appear to produce measurable improvements in their target population, others lack scientific rigor behind their claims. Here, we discuss the data surrounding select brain training programs and techniques in randomized-controlled studies, unless otherwise indicated.

Computerized training

Computerized cognitive exercises are among the most popular forms of brain training. In a controlled study assessing the effects of computerized AT and computer-assisted instruction (Rabiner et al., 2010), children with attentional difficulties improved in measures of attention, with more severe symptoms showing larger improvements. In another study using games that activate all three attention networks, children with ADHD improved in academic skills and decreased ADHD symptomatology, compared to controls (Shalev et al., 2007).

While the effectiveness of many commercial brain training products is questionable, evidence suggests that some programs facilitate marked improvements in cognitive function. One product repeatedly demonstrated to improve WM capacity in both children and adults is Cogmed, which entails training on WM tasks for five days per week over a period of five to six weeks. Using this software, children with ADHD as well as healthy adults appear to improve in measures of WM as a result of training (Klingberg, 2007; Klingberg et al., 2005).

Another widely used program is the Fast ForWord-Language (FFW-L) software (Scientific Learning Corporation, 2011), advertised to increase brain fitness, accelerate learning, and improve test scores for children (Semrud-

Clikeman & Ellison, 2009). Experiments without a proper control group included tasks of perceptual identification and phonetic element recognition (Merzenich et al., 1996). After training for 19-28 sessions of 20 minutes over a period of four weeks, children with language-based learning impairments significantly improved in auditory perception. Thousands of public school districts in the United States incorporate the FFW-L program into their curricula, and a large number of children across North America use the product for both scholastic and therapeutic purposes (Scientific Learning Corporation, 2011). Reports published outside the peer-review scientific system suggest that this program enables educational benefits following repeated practice (Schultz Center for Teaching and Leadership, 2009). A recent study, furthermore, demonstrated that children taking part in either the FFW-L program or a narrative-based language intervention improved on time-related effects of narrative measure and non-word repetition (Fey et al., 2010). Despite these results, the participants did not display any significant inter-group variability in benefits, suggesting that the FFW-L program scarcely holds superior benefits to conventional language interventions (Fey, et al., 2010). Hence, while FFW-L appears to produce training-related gains in temporal processing of information related to language development, the program hardly fosters significant improvements in language and reading ability. Reports show, however, that training with FFW-L alongside a coach increased neural activation in regions associated with selective auditory attention – including the ACC – in children with specific language impairment during language listening tasks, compared to typically developing children who received no training (Stevens et al., 2008). These findings also extended to typically developing children, although to a lesser extents. Studies therefore suggest that the FFW-L program improves auditory perception of stimulus tones and may indirectly exercise executive attention.

Neurofeedback Training

Neurofeedback, also called EEG biofeedback, represents another computerized technique that appears to hold advantages for specific populations. This method entails training individuals to actively control and change their neural activation patterns by viewing the brainwaves they emit a few milliseconds after they occur (Angelakis et al., 2007; Hammond, 2006). Administered in research and clinical endeavors since the 1960s, neurofeedback converts EEG signals from specific cortical areas to visual or auditory representations that participants receive and subsequently attempt to regulate through training (Congedo et al., 2004). More recently, neurofeedback systems leverage the increased spatial precision of fMRI technology (deCharms, 2008).

Advertising to improve mental functioning and increase awareness of brain states, neurofeedback companies (e.g., (BrainMaster Technologies, 2009)) offer their products to individuals seeking to sharpen their cognitive skills. Studies suggest that this technique may be beneficial for enhancing cognitive function in elderly populations (Angelakis, et al., 2007) and in improving symptoms associated with epilepsy (Kotchoubey et al., 1999; Tan et al., 2009), substance abuse (Sokhadze et al., 2008), and a number of psychiatric conditions (Heinrich et al., 2007). Neurofeedback appears particularly promising for individuals diagnosed with ADHD. After training with this technology, children with ADHD appear to increase scores on tests of intelligence and continuous performance, improve cooperation and school work in the classroom and demonstrate better attentional and behavioral control (Monastra, 2005). Such benefits reportedly endure, in some cases, for several years following the intervention. Similar reviews of randomized controlled trials in children with ADHD (Fox et al., 2005; Monastra, 2005) report mixed findings; while some children showed little or no training effects, others demonstrated enhanced intelligence and significant improvements in attention, hyperactivity, and impulsivity. Studies comparing neurofeedback to medication support such training as a serious contender for non-pharmaceutical ADHD treatment. A 12-week, controlled trial comparing neurofeedback with methylphenidate treatment suggested that neurofeedback leads to similar behavioral changes, with decreased parent and teacher reports of ADHD-related symptoms in both groups (Fuchs et al., 2003). Another study found no significant difference in either treatment effects or clinical improvement of individuals with ADHD after 20 sessions of neurofeedback training or use of stimulant medication (Rossiter & LaVaqe, 1995). The sustainability of neurofeedback effects, however, remains questionable and may vary on a case-by-case basis. Similar to other forms of computerized training, long-term therapy using neurofeedback technology may prove effective for improving disease-related symptoms of developmental psychopathologies, especially when administered at childhood. Studies therefore provide compelling evidence for the potential of such training as a non-pharmacological treatment alternative for a variety of neurological disorders.

Table 1 A list of select commercial software aiming to enhance or rehabilitate specific cognitive skills in health and pathology.

COMPANY (WEBSITE)	PRODUCT NAME	PRODUCT TYPE (as specified on website)	TARGET POPULATION	SCIENTIFICALLY PUBLISHED EVALUATIONS
BrainMaster Technologies, Inc. (www.brainmaster.com/)	BrainMaster – Neurofeedback Systems	Neurofeedback training	Individuals of all ages	(Martin & Johnson, 2006)
Brain Train (braintrain.com/)	Captain's Log, SoundSmart, SmartDriver	Cognitive training	Individuals of all ages with ADHD, head injuries, Learning Disabilities, schizophrenia, and other cognitive impairments	(Angelakis et al., 2004) See also: www.braintrain.com/main/ivaplus_research_bibliography.htm www.braintrain.com/main/cognitive_training_research.htm
	TNT Reading			
	SmartMind 2			
Cogmed (www.cogmed.com)	Cogmed JM	WM training for children and adults with attention deficits, learning disorders, brain injury or stroke, and adults experiencing	Ages 4-6	See: www.cogmed.com/references
	Cogmed RM		Ages 7 and up	
	Cogmed QM		Adults	

		"information overload" or the natural effects of aging		
Cognifit (www.cognifit.com)	Individualized Training System	Cognitive training	Individuals of all ages	See: www.cognifit.com/science/scientific-validation
HAPPYneuron (www.happy-neuron.com/)	Various games	Exercising memory, attention, language, visual-spatial and executive function skills	Individuals of all ages	(Croisile, 2006)
Lumosity (www.lumosity.com/)	Various games	Exercising memory, attention, processing speed, and problem-solving skills	Individuals of all ages	(Kesler et al., 2010)
MindHabits, Inc. (www.mindhabits.com/)	MindHabits	Exercises to decrease stress and improve confidence	Individuals of all ages	(Dandeneau & Baldwin, 2004)
Nintendo (www.brainage.com)	BrainAge	Training with math- and literature-related activities	Individuals of all ages	
Posit Science (www.positscience.com)	Brain Fitness	Auditory training	Older adults	See: www.positscience.com/science/proven-in-labs
	InSight	Visual training		
	Drive Sharp	Cognitive training for driving skills		
Scientific Learning Corporation (www.scilearn.com)	Fast ForWord	Language and reading training – adjuncts to classroom material	Kindergarten – grade 12 students	(Merzenich, et al., 1996) (Fey, et al., 2010)
	Reading Assistant		Children and adults wishing to build vocabulary, fluency and comprehension.	
Timocco (site.timocco.com)	Growing with Timocco	Training motor and cognitive skills	Children with cerebral palsy, ADHD, Developmental Coordination Disorder, and Learning Disabilities	
Unique Logic and Technology (www.playattention.com)	Play Attention	Attention training, memory	Children with ADHD	

		training, cognitive skill training, social skills training, motor skills training, behavior shaping		
Your Baby Can, LLC. (www.yourbabycanread.com)	Your Baby Can Read	Language training	Infants	

Applied attention as school-based interventions

Student attentiveness is essential to a positive and productive classroom dynamic and plays a fundamental role in shaping scholastic performance (Duncan et al., 2008). Assessments of learning approaches reveal that child attentiveness is positively associated with academic competence and achievement, as well as relations with both teachers and peers (Li-Grining et al., 2010). Variability in attentiveness may account for differences in child learning speed or the amount of information children can extract from an event (Ruff & Rothbart, 1996). Studies on children with ADHD, moreover, reveal comorbidities between the disorder and a number of learning difficulties, especially pertaining to reading ability (Carlson et al., 1997; Willcutt et al., 2005; Willcutt et al., 2007). An uncontrolled European study in 3 cohorts of children with ADHD not only supported the association between scholastic impairment and ADHD symptomatology, but reported a two- to ten-fold increase in impairments of reading, writing, and mathematics in children with symptoms related more strongly to inattention (Rodriguez et al., 2007). Thus, abounding evidence presents attention as an integral component in the academic success of children.

Theories surrounding school readiness stipulate that children must attain social-emotional competencies by practicing effortful control in order to grasp the lessons learned in both social and academic settings (Liew, 2011). With fundamental roles during social interactions, effortful control and emotional regulation draw upon executive function to exert attentional and inhibitory control and help children develop inter-personal relationships (Kochanska, et al., 2000; Liew, 2011; Ruff & Rothbart, 1996). At the start of grade school, children exhibiting strong effortful control are more likely to express social competence and have fewer behavior problems, whereas those who struggle to control attention and behavior tend to develop impaired relationships with teachers and peers, and have greater risk of developing academic difficulties (Liew, 2011; McClelland et al., 2007). Studies further show that the manifestation of effortful control and other self-regulatory skills in elementary-age children correlates with higher grades, and may improve early mathematical and literacy prowess (Liew, 2011). Likewise, individuals with attention-related disorders such as ADHD are generally impaired in social, academic, familial, and occupational areas of life (de Boo & Prins, 2007). As a result, school-based programs often involve AT to bolster effortful control and emotional regulation (Kring & Sloan, 2010), critical to success among peers in academic and other environments involving interpersonal relations.

School-based interventions may particularly aid children of lower socio-economic status – a population with marked deficits in control through executive function (Bierman, Nix, et al., 2008; Hackman & Farah, 2009; Noble et al., 2007; Stevens et al., 2009). Programs such as "Tools of the Mind" (Barnett et al., 2008; Diamond, et al., 2007b) and the "Promoting Alternative Thinking Strategies" curriculum, tested in the absence of matched-controls (Kelly et al., 2004), for example, appear to decrease behavioral problems and improve emotional understanding, executive function, and academic performance in children with disadvantaged socio-economic backgrounds. Similarly, studies assessing the school-based "Head Start Research-based Developmentally Informed" curriculum (Bierman, Domitrovich, et al., 2008) demonstrate enhanced academic skills as well as improved behavioral and emotional control in children. With increased awareness of the importance of attentional processes in academic and social settings, researchers are beginning to pool more resources into developing effective training programs in schools. Such programs may particularly benefit disadvantaged children and minimize their disparities in cognitive ability.

Acquiring proper social skills during childhood is essential for shaping appropriate behavior and ensuring healthy development (de Boo & Prins, 2007). Training children to exhibit effective social skills appears to improve their social knowledge and assertiveness, and may further generalize to the school setting (McBurnett & Pfiffner, 2008). Social skill training may be particularly relevant for children with impulse-control disorders such as ADHD, who often experience peer rejection and social isolation due to aggressive behavior and lack of inhibitory control (DuPaul et al., 2001; McBurnett & Pfiffner, 2008). Although individual parameters such as extent of play and teaching strategies remain widely debated in American school districts (Barnett, et al., 2008), social skills training appears to promote constructive peer interactions among children.

Table 2 A list of select programs aiming to enhance specific skills related to academic performance in children.

PROGRAM NAME (WEBSITE)	**DESCRIPTION**	**SCIENTIFICALLY PUBLISHED EVALUATIONS**
Arrowsmith School (www.arrowsmithschool.org)	Cognitive exercises to improve learning dysfunctions that impact learning and social skills	
Brain Gym International (www.braingym.org)	Specific set of movements aiming to improve concentration and focus, memory, reading, writing, math, test-taking, physical coordination, relationships, self-responsibility, organization skills, attitude	
Center for Applied Special Technology (www.cast.org)	Universal Design for Learning program that includes principles for curriculum development to provide equal opportunities to learn for all individuals	See: http://www.cast.org/research/index.html
Kumon Learning Centers (www.kumon.com)	Math and reading enrichment programs for children	
Strategic Learning Centre (www.strategiclearning.ca)	One-on-one teaching center to help children with learning disability, ADHD, dyslexia become better and more confident learners	
Sylvan Learning (tutoring.sylvanlearning.com)	Tutoring in various academic subjects for children	
Tools of the Mind (www.toolsofthemind.org)	Preschool and kindergarten curricula to improve self-regulation and executive function	See: http://www.mscd.edu/extendedcampus/toolsofthemind/about/effectiveness.shtml
University City Children's Center (uccc.org)	Early care and education system for values & character development, psychodynamic development, early literacy development	

Bilingualism

Contrary to the belief that bilingual education hinders cognitive ability and dampens intelligence, proficiency in two languages appears to enhance the development of cognitive control systems relating to attention. Bilinguals develop the capacity to independently process two languages, which requires selection of the correct lexical representations of one language while suppressing the representations of the other (Costa et al., 2008). Although scientists scarcely understand the mechanisms underlying this ability, bilingual individuals may employ the executive attention system to suppress an unwanted linguistic response much like inhibition during the Stroop task (Bialystok, 2010; Green, 1998). This process enables control over competing neural networks and communication in the intended language, thereby promote development of the underlying neural systems. Indeed, research reveals that bilingual individuals perform better at nonverbal problem solving tasks requiring inhibition of irrelevant responses and the formation of new conceptual representations compared to monolinguals (Bialystok & Martin, 2004). Bilingual individuals, moreover, display quicker response times in attention-related tasks – including trials involving conflict resolution – as well as more efficient use of their alerting and executive attention networks (Costa, et al., 2008). As early as childhood, bilinguals appear to perform better on non-linguistic tasks requiring attentional control (Bialystok & Majumder, 1998) and develop the ability to exert selective attentional control earlier than monolinguals (Bialystok, 1999). Such advantages of bilingualism grow increasingly powerful at old age, with research indicating that elderly bilinguals have significantly greater inhibitory control compared to monolinguals of the same age group (Bialystok et al., 2006). Continuously switching between two languages may further promote the capacity to maintain two sets of instructions in mind and select the correct response in a particular situation – another ability that is stronger in elderly bilingual populations (Bialystok, et al., 2006). Thus, having command of more than one language appears to enhance executive function similarly to participation in training programs. Bilingual education may therefore represent a favorable tool for the development of executive control in children and the further strengthening of this system throughout adulthood.

Music Training

Stemming in part from the widespread "Mozart effect" myth (Steele et al., 1999) – which suggests that spatiotemporal abilities increase after listening to music composed by Mozart – musical training increasingly captivates the public. Despite the fallacy of the Mozart effect, evidence suggests that musical training does produce significant improvements in faculties such as verbal memory (Chan et al., 1998; Ho et al., 2003) and general intelligence, as demonstrated in children randomly assigned to either music training, drama, or no-training controls (Schellenberg, 2004). Requiring a high degree of repetition, concentration, and devotion over many years of continuous practice, this form of training shares many of the qualities possessed by more structured cognitive training programs. Furthermore, music training generates positive emotions, which have been linked with improved plasticity (Altenmüller, 2009). Following six months of piano keyboard training, children have demonstrated enhanced spatiotemporal reasoning compared to children receiving private computer lessons or no training (Rauscher et al., 1997). Studies also show enhanced development of visuospatial WM ability and nonverbal reasoning, in addition to increases in child IQ scores as a result of musical training (Bergman Nutley, 2011). Musicians have also displayed superior control in certain auditory tasks compared to non-musicians (Bialystok & DePape, 2009). Recent research further links musical proficiency to enhanced executive control during conflict-related tasks unrelated to music (Bialystok & DePape, 2009). Considering the attentional and WM load as well as the knowledge of specific acoustic and syntactic rules that music requires (Kraus & Chandrasekaran, 2010), this association is not surprising. The widespread interest in musical training as a tool for general cognitive enhancement therefore appears to have scientific merit.

Due to the cognitive demands of musical practice, music training may facilitate changes that enhance the functionality of regions related to auditory perception as well as executive attention. The behavioral benefits of music training are accompanied by structural modifications within specific brain regions, as well as changes in grey matter volume (Gaser & Schlaug, 2003; Munte et al., 2002). In addition to the structural changes, music practice appears to alter neural activation patterns that underlie auditory discrimination and executive attention. Musicians show more pronounced neural signals in response to irrelevant sound signals and can better detect meaningful information such as speech amid a noisy background (Kraus & Chandrasekaran, 2010). Neuroimaging studies further reveal an association between neural areas related to WM function and parietal brain regions during sight reading of musical notes (Bergman Nutley, 2011). Hence, the complex process of learning to play a musical instrument has influences on neural function and anatomy that cannot be attributed to pre-existing qualities, and may constitute another promising form of brain training.

Physical exercise

Aside from advantages to physical health, exercise appears to have a beneficial impact on cognitive function, particularly in children (Hillman et al., 2008) and elderly individuals (Colcombe & Kramer, 2003). The relatively recent infatuation with sedentary lifestyle seen in developed countries creates the precedent of minimal physical activity throughout a typical school or work day. With childhood obesity on the rise and an increasing prevalence of weight-related health conditions such as diabetes, educational and public health campaigns attempt to heighten public awareness about the importance of exercise to physical health. Studies report that as little as 30 minutes of aerobic exercise per day significantly enhance children's capacity for creativity and the capacity to deduce several correct answers in response to a given question (Tuckman & Hinkle, 1986) – a measure of cognitive flexibility (Diamond & Lee, 2011). Studies further indicate that aerobic exercise may significantly enhance executive function, improve performance in mathematics, and increase activity in the PFC (Davis et al., 2011). In addition, a meta-analysis of fitness training programs revealed that fitness programs encompassing aerobic exercise may enhance executive control and visuospatial ability in healthy but sedentary elderly adults (Colcombe & Kramer, 2003). The evaluated studies further reported improvements in all of types of cognitive tasks and following all methods of training, with combinations of strength and aerobic training producing greater benefits than aerobic exercise alone. Critics have nonetheless pointed out that many fitness training studies do not adequately control for experimenter involvement and, in some cases, lack control groups altogether (Green & Bavelier, 2008). Therefore, while aerobic exercise may promote the development of various cognitive abilities in children and the elderly, proper controls are necessary to discern the scientific validity of such claims.

Interaction with Nature

Perhaps surprisingly to fervent believers in circumscribed training programs, regular interaction with nature appears to facilitate improvements in cognitive function and behavioral control. Proponents of the beneficial effects of nature strive to increase outdoor exposure lost to the industrial ideals of modern society, offering nature retreats, environmental awareness workshops (Charles et al., 2009; Civic Results, 2008), and even university courses that teach students to harness nature as a context for therapeutic interventions (Naropa University, 2011). Some academic programs, moreover, educate children outdoors rather than in traditional classrooms (Denison Pequotstepos Nature Center, 2009; Forestry Commission Scotland, 2009) and, according to teacher reports, appear to improve interpersonal work habits, classroom behaviors, and engagement with the learning process. Many of these programs stem from the attention restoration theory, which posits that nature has the capacity to relieve the attention system of its functional load in order to restore effectiveness in cognition (Kaplan, 1995b). According to this theory, nature provides a medium that requires less inhibition of competing stimuli, giving executive function a chance to rest. Controlled and uncontrolled studies suggest, for example, that leisurely outdoor activity may relieve ADHD symptomatology in children (Faber Taylor & Kuo, 2009; Taylor et al., 2001). In addition, children who have greater exposure to nature from their home environments appear to attain superior attentional control (Wells, 2000) and to react better in response to stressful life events, experiencing lower psychological distress and higher perceptions of self-worth (Wells & Evans, 2003). Studies suggest that walking in natural environments as opposed to urban areas or viewing pictures of nature may improve executive attention (Berman et al., 2008), and that having near-home views of nature may improve concentration, inhibition, and self-discipline (Taylor et al., 2002). Interacting with natural environments may therefore enable more efficient executive function and benefit attention as well as self-control.

Meditation Training

Often regarded as methods of relaxation and mental clarity alone, meditative practices aim to train attention and awareness as a means of increasing control over mental processes (Walsh & Shapiro, 2006). Meditation training programs often include one or a combination of focused attention and open monitoring, two common Buddhist techniques that target specific cognitive processes (Slagter et al., 2011). Focused attention meditation involves voluntarily sustaining focus on a given object, whereas open monitoring consists of non-reactively monitoring the content of an ongoing experience, to become aware of the nature of associated cognitive or emotional patterns (Lutz et al., 2008; Raffone & Srinivasan, 2010; Slagter, et al., 2011). Mindfulness is another common contemplative technique related to open monitoring (Raffone & Srinivasan, 2010) and constitutes one of the most widely studied meditative practices (Walsh & Shapiro, 2006). One definition describes mindfulness as the practice of purposefully and objectively attending to thoughts, emotions, and daily actions

(Allen et al., 2006; Tang & Posner, 2009). Meditation therefore represents another technique that fosters the development of cognitive and attentional capacity.

Studies have shown that training with open monitoring or focused attention can trigger neural processes underlying the executive attention system. Reports of activity in the ACC and in both the medial and lateral areas of the PFC (Lutz, et al., 2008; Raffone & Srinivasan, 2010) suggest that meditation training (e.g., practicing focused attention) improves conflict processing as well as emotional- and self-regulation, with experienced meditators showing increased activation in these areas compared to non-meditators (Hölzel et al., 2007). In addition, focused attention and open monitoring both associate with neural adaptations such as increased regional blood flow and glucose metabolism in the PFC and ACC (Baijal & Gupta, 2008). Accordingly, studies show that meditators who practice methods of either focused attention or mindfulness can better sustain their attention (Valentine & Sweet, 1999) and demonstrate improved performance on a number of conflict-related tasks. These include superior perception during binocular rivalry tasks (Lutz, et al., 2008), reduced semantic processing required for lexical decision tasks (Pagnoni et al., 2008), decreased response variability for dichotic listening tasks (Lutz et al., 2009), and increased mismatch negativity for auditory tones (Raffone & Srinivasan, 2010). Neuroimaging studies additionally reveal that regular meditators who practice open monitoring or focused attention may activate attention-related neural regions more efficiently in response to conflict (Kozasa et al., 2011). The beneficial effects of these meditative practices may be sustained throughout aging; experienced meditators show fewer age-related declines in grey matter volume of certain neural regions and display higher volumes of several brain regions, including the PFC (Ott et al., 2011). Thus, specific forms of meditation can invoke activation of the executive attention system and may thereby improve its functionality over time.

Recent evidence suggests that mindfulness meditation may enhance the neural processes underlying attention and WM. In light of such findings, scientists are now considering the clinical implications of meditation training, particularly for conditions that involve broad aspects of psychological well-being (Chiesa et al., 2010). Studies indicate that mindfulness training may improve cognitive functioning and reduce stress, anxiety, negative affect, and the symptoms associated with various diseases (Chiesa, et al., 2010; Creswell et al., 2007). Adults and adolescents with ADHD, furthermore, have demonstrated improvements of behavioral and neurocognitive impairments following a mindfulness group-training program (Zylowska et al., 2008). This program may have an additional favorable impact on the development of inhibitory control and self-regulation. While experience may increase the benefits of meditation, short-term training also appears to promote observable effects. A school-based mindfulness program in elementary-aged children, for example, demonstrated improvements in behavioral regulation and executive function after a mere eight hours of training, administered over a period of eight weeks (Flook et al., 2010). By promoting a heightened state of concentration that triggers activity of the attentional networks, meditative practices such as mindfulness training may improve behavior (Jha et al., 2007) and prove useful – at least as ancillary treatment – for individuals with attention-specific deficits.

Despite the promise of meditative practices in improving cognitive function, research surrounding this form of training has yet to unearth optimal protocols and administration strategies that are most beneficial in various populations (Burke, 2010). A number of factors contribute to this ambiguity, such as the use of different scales to measure experimental findings and the scarce inclusion of active control groups in studies (Davidson, 2010). An interesting study addressing this latter issue incorporated sham meditation as part of the experimental design and reported improvements in psychological variables such as mood, depression ratings, and fatigue, following three days of mindfulness training (Zeidan et al., 2010). Observed improvements in behavior, however, may arise as a result of diverse meditative techniques. As a result, in addition to incorporating active controls, studies examine combinations of potentially beneficial training techniques with hopes of creating variants that would induce maximal benefits on attention. One such variant, a Chinese technique known as integrative body-mind training (IBMT), integrates aspects of several meditative practices (Tang & Posner, 2009). In one study, individuals randomly assigned to practice IBMT for five days demonstrated significantly better attentional capacity and control over stress compared to individuals who practiced other meditative techniques during the same period of time (Tang et al., 2007). Furthermore, a mere three hours of this training program was enough to induce an increase in activation of the ACC and improve the self-regulation of adult participants (Tang et al., 2010). Recently, Tang et al. (2010) also showed that adults who trained in IBMT for 11 hours had a higher density of cortical white matter, including a region known to connect the ACC with functionally important neural areas. Further research is nonetheless required to properly attribute the different components of meditative practices to the observed effects on cognitive ability. Future studies may glean more precise information by adequately controlling for all variables involved in specific programs to better parse the training components that promote such positive outcomes.

Parenting

One of the strongest influences on childhood behavior is the family setting, largely a function of parent or caregiver interactions with a child. Animal studies attest to the importance of parenting, with early monkey studies (Harlow & Mears, 1979) identifying the primary purpose of nursing as a way to ensure intimate body contact between mother and infant – essential for establishing sensory stimulation that facilitates neural development (Illes & Sahakian, 2011). Rodent studies further show that maternal behaviors can reduce neuroendocrine response to stress (Liu et al., 1997) and even alter the genetic expression underlying neuroendocrine and behavioral stress responses (Weaver et al., 2004). Maternal behavior also appears to promote synaptic development in the hippocampus, a structure associated with memory, and may enhance spatial learning and memory in rats (Liu et al., 2000). Such studies attest to the importance of parenting for the proper development of cognitive ability and emotional stability.

The challenges of caring for children in a typical working-class family increase for parents who have little support or assistance. Studies suggest that disturbed family environments may contribute to the development of childhood psychopathologies. A review of ADHD neurobiology, for example, identified six family-related factors that significantly correlated with the development of childhood mental disturbances, including severe marital discord, low social class, large family size, paternal criminality, maternal mental disorder, and foster placement (Faraone & Biederman, 1998). In light of such reports, a number of therapeutic programs target parents and families as a whole, and sometimes include supplemental interventions for the children. One such program, the Community Parent Education method, implements a ten-week parent education program with concurrent social skill building for children and has gathered evidence showing improved parenting skills and fewer child behavior problems (Tamm, et al., 2008). Parent training also appears to improve inattention, over-activity, conduct problems, compliance, and aggression in children (Wells, 2008). Following a 12-session mindfulness training program for mothers with no focus on behavior management, mother-child interactions improved and child compliance increased (Singh et al., 2010). Other studies suggest, moreover, that developing effortful control in children may offset the effects of negative or neglectful parenting (Liew, 2011). These findings highlight the importance of parent-child relationships and of using proper parenting methods to guide behavioral development in children.

The added difficulty of raising children with developmental psychopathologies often leads parents to resort to unjust or ineffective punitive measures. For this reason, a central feature of several parent training approaches includes proper allocation of attention and appropriate management of disorderly behavior. One study of a program for ADHD-related behavior management (Barkley, 1998) revealed that positive attention may in itself induce greater compliance in younger children and further illustrated the importance of attending to child behavior in the school setting in addition to other public environments. Expansions to this program show benefits of parent relaxation training as well as stress-management (Wells, 2008). More recent parent training paradigms have tested the effects of incorporating modern technology or interactive components into the standard program. Adding a sport or recreational component to a father-training program, for example, may enhance the typical benefits of these programs by not only improving behavior-related symptomatology and peer-interactions, but by further increasing attendance and satisfaction with the program, as well as homework compliance (Fabiano et al., 2009). Similarly, an evaluation of a program implementing internet-based training for mothers with infants at risk for poor social-emotional development found increases in mother-child interactions in addition to marginal improvements in impairments associated with interactive behavior and depressive symptomatology (Baggett et al., 2010). These studies indicate that, through training, parents can learn to interact positively with their children, thereby improving parent-child relationships and helping parents teach children proper standards of behavior.

The effectiveness of training practices: Examining the evidence

In this section, we provide a critical examination of the impact of cognitive training in both healthy and pathological individuals. We investigate the generalizability of training and whether specific exercise can transfer to other domains of cognitive function.

Generalizability and Transferability: Improving overall function or just specific skills?

As brain training rises in popularity, mounting skepticism challenges the effectiveness of such programs on cognitive ability. While brain training programs may improve performance on a specific subset of skills or tasks, the benefits may not generalize to other domains. One such example is the Bates Method, a behavioral approach to improving visual acuity by altering attentional states through practices such as hypnotherapy (Marg, 1952; Raz et al., 2004). Once considered a groundbreaking technique for visual correction, the Bates Method was disproved by studies suggesting that attention can only influence the priority or processing preference of the fovea, which can impact parameters such as visual detection or reaction time without improving visual acuity *per se* (Raz, et al., 2004). Similarly, a number of reviews have evaluated the quality and robustness of training effects in an effort to determine the transferability of different brain training methods to other cognitive or behavioral functions. Recent evidence has led many to believe that perhaps they should not expect much from these methods. A group of British scientists, in collaboration with the British Broadcasting Corporation (BBC) television program "Bang Goes the Theory", stunned participants and viewers of the program with the allegation that computerized brain training does not benefit general cognitive ability (Owen et al., 2010). Employing the largest sample size ever used in cognitive-training research, the study reported no significant increase in general cognitive performance following six-weeks of online training in WM tasks, apart from improvement in the practiced tasks. In response to this negative outcome, countless media articles suggested that brain training likely represents wasted effort. Notwithstanding this gross generalization, largely circulated by public media reports, a close examination of the parameters used in the study reveals several limitations. Weak environmental controls, insufficient training duration, and a questionable study population limit possible conclusions. Furthermore, the study involved a sample of healthy individuals, although research suggests that individuals with lower baseline scores may benefit more from such training. This study nonetheless accentuates the need for more properly controlled studies, thorough analysis of the available data, and careful interpretation of results, to determine the capacity for transfer of computerized brain training programs.

The question of transferability is perhaps most relevant for commercial products. The Cogmed program – advertised as effective in both healthy and pathological populations, both young and old – is among the most thoroughly studied of these products. In an inaugural study, children with ADHD and healthy adults who trained with components of the Cogmed program showed generalized improvements in cognitive control and general fluid intelligence, with additional reduction in symptoms related to ADHD in the pathological population (Klingberg et al., 2002). The findings were later replicated in healthy adults (Olesen et al., 2004; Westerberg & Klingberg, 2007), although both studies were unclear about the possibility of improvements due to test-retest effects (Shipstead et al., 2010). A subsequent study in children with ADHD demonstrated significant improvements on measures of attention and intelligence compared to controls, which persisted three months after completing 25 sessions of visuo-spatial, backward-digit, and letter-span tasks from the Cogmed program (Klingberg, et al., 2005). Notably, however, children randomly assigned to the control group displayed increased scores at the three-month evaluation period, which may indicate insufficient level of difficulty in the testing measures used (Shipstead, et al., 2010). Furthermore, parent – but not teacher – reports indicated reductions in ADHD symptoms (Klingberg, et al., 2005). Following 20 sessions of training with Cogmed, children with low WM capacity showed enhanced WM performance that persisted for six months, relative to controls (Holmes et al., 2009). Although this study appeared to demonstrate generalizability to cognitive domains unrelated to the training, the participants did not improve on measures of intelligence, reading, or mathematical reasoning, and follow-up measures did not include comparisons to the control group (Shipstead, et al., 2010). A replication of Klingberg et al. (2005) showed that, compared to no-treatment controls, adolescents with ADHD displayed improvements in inattentiveness and executive function, as well as symptoms related to the disorder, as indexed by parent reports (Beck et al., 2010). These effects persisted at the four-month follow-up assessment, and were mirrored by near-significant findings based on teacher reports. Studies therefore suggest that certain commercial brain training products may improve specific skills, although evidence remains scarce regarding the transferability of training to unrelated domains of cognitive function.

While computerized programs show promise along the short term, studies often carry a number of caveats that restrict possible interpretations of the experimental findings, and scarcely demonstrate sustainability of more than several months. In children with ADHD, for example, a program exercising verbal and visuo-spatial short-term memory in addition to WM facilitated improvements on measures of the trained abilities that lasted six months (Holmes et al., 2010). Limitations of this study, however, include a lack of control groups, direct ADHD measures, and transfer to IQ scores (Shipstead, et al., 2010). The transfer effects of brain training are also inconsistent in healthy populations. In one study, participants significantly improved performance on the Stroop task in addition to reading comprehension as a result of a four-week WM training program, but did not display increases in general fluid intelligence or in spatial reasoning (Chein & Morrison, 2010b). A different study reported that, after participating in a WM-training program, preschool children exhibited better performance on attentional tasks requiring monitoring, but did not show any improvements on Stroop-like, inhibitory, or problem-solving tasks (Thorell et al., 2009). After participating in 20 sessions of an adapted complex WM span task over 4-weeks, healthy individuals improved on measures of temporary memory and verbal reasoning and further increased their cognitive control, as indexed by their performance on the Stroop task (Chein & Morrison, 2010a). The participants also improved their reading comprehension, which correlated with increases in spatial WM. These findings suggest that this novel training paradigm may improve certain aspects of general attentional mechanisms, such as the management of information maintenance in concordance with other neural processes (Chein & Morrison, 2010a). Such transfer of WM training to untrained attention and memory tasks also appears in older adults (Berry et al., 2010). Although studies often report promising findings, researchers have yet to reach a consensus regarding suitable control groups, accurate measures of parameters such as sustainability, and outcomes that simply result from participation in a training program. As a result of such discrepancies in experimental parameters and measurement tools, comparisons between studies that reportedly measure the same cognitive or behavioral construct are difficult to establish.

Effectiveness without efficacy: Ulterior benefits of brain training

The advantages of brain training may reside in the nuances of effectiveness rather than efficacy. In clinical terms, efficacy refers to the ability of a substance, usually a pharmaceutical agent, to produce a desired effect through a particular mechanism of action. Effectiveness, on the other hand, refers to the practical use of a substance. Research has often revealed cases of efficacy without effectiveness (Glasgow et al., 2003); pharmaceutical agents, for example, sometimes produce side-effects that are more noxious than the condition they are meant to treat, thereby rendering them ineffective. In contrast, evidence also suggests that, in some cases, a substance may prove effective without being efficacious. Such phenomena may occur via the placebo effect, or positive effects associated with sham or irrelevant treatment (Benedetti et al., 2005). Similarly, although the improvements observed as a result of brain training may be induced due to reasons other than the training itself, such interventions may still be effective through an analogous placebo-like effect. The variety of programs that improve cognition and behavior, coupled with reports of little transferability of brain training, leads to speculation that brain training may not contain a specific mechanism of action. The act of providing treatment for a particular condition, however, may in itself decrease the associated symptoms (Kermen et al., 2010; Tilburt et al., 2008). Improvements in cognitive performance may also occur as a result of motivational factors, including active interest in individual performance (Green & Bavelier, 2008). Brain training may therefore represent an effective intervention or potential treatment for clinical populations even if research deems the specific mechanism tenuous.

Who can benefit from brain training?

Brain training programs may impact an assortment of neurological states. From the healthy to the neurologically impaired, programs aim to enhance or rehabilitate cognitive function in both young and old. In this section, we examine evidence for the benefits of brain training programs in various populations.

Brain training in typical development

Evidence indicates that brain training can enhance healthy neural development. Unlike pathological populations, typically developing children and adults train the brain to fortify skills already acquired in an effort to distinguish their abilities among peers and thrive in an increasingly competitive society. While the effects are often subtle, such training may sometimes yield dramatic results. One particularly effective technique comprises strategy training, which involves learning effective approaches to encode, maintain, and retrieve information from WM (Chein & Morrison, 2010a). One study reported the memorization of 80 digits after learning the strategy of grouping numbers into running times (Ericsson & Chase, 1982). A more recent example of strategy training is the story of Joshua Foer, the 2006 U.S.A Memory Champion (Foer, 2011). A freelance journalist with no previous experience in competitive memorizing, Foer not only defeated his competitors – experienced mnemonists – in the championship, but also broke the world record in the speed card category. His trick consisted of an age-old memorization technique by which he trained himself to associate tedious facts, difficult for the human brain to remember, with eccentric images that an individual is unlikely to forget. Neuroimaging studies suggest that competitive mnemonists and high-rankers of World Memory Championships use similar stratagems during performance of WM and long-term verbal memory tasks (Maguire et al., 2003). Despite having typical brain morphology compared to controls, this population displays increased regional activation of areas associated with spatial memory and navigation, which may underlie the learning of route strategies to recall long lists of items (Maguire, et al., 2003). Therefore, typically developing individuals may also display enormous improvements in performance following specific types of training.

Training the aging brain

With mounting evidence for cognitive decline in the elderly, brain training programs for geriatric populations seem increasingly relevant and enticing. In 2005, a global prevalence study estimated that 24 million individuals were living with dementia, of whom 3-4 million were residing in North America, and that this number would double every 20 years (Ferri et al., 2005). While the leading cause of age-related dementia is Alzheimer's disease (Ferri, et al., 2005), studies have identified a number of risk factors associated with impaired cognitive ability including decreased physical activity (Laurin et al., 2001; Yaffe et al., 2001), lack of education (Callahan et al., 1996), health conditions such as diabetes and hypertension (Kuo et al., 2005), and the presence of certain pathological (McKeith et al., 1996) and genetic traits (Duff et al., 1996). Reports of delayed cognitive decline as a result of brain training have propelled a market of products aimed at preventing or even reversing the effects of age on cognition. These programs, often administered through computerized media or video game consoles, carry varying degrees of scientific validity. The popular BrainAge program (Nintendo DS, 2007) is one prominent example among the myriad of commercialized products that holds little scientific evidence of efficacy. A recent study using this game console, moreover, suggests that elderly individuals work more efficiently using a paper-and-pencil interface, although decreased technological sophistication appears to evoke lower levels of arousal (Nacke et al., 2009). On the other hand, certain training techniques have shown promise for the delay or prevention of neurodegenerative diseases. Animal studies indicate that enriched environments may increase cognitive function (Arendash et al., 2004) and reduce pathological traits for Alzheimer's, including neural deposition of amyloid protein (Lazarov et al., 2005). In humans, training appears to improve memory in individuals with mild cognitive impairment (Belleville et al., 2011) or mild-to-moderate Alzheimer's (Zanetti et al., 1997). A recent evaluation by the National Institutes of Health found little evidence for pharmaceutical or dietary preventative measures for cognitive decline (Daviglus et al., 2010), underlining the importance of increasing research pertaining to cognitive training in such populations. With positive preliminary findings in elderly individuals with cognitive impairments, this type of training may constitute a crucial source of remediation for cognitive decline.

Training need not be circumscribed or even deviate from typical daily activities. An interesting take on cognitive training in elderly populations, the Active Cognitive Stimulation-Prevention in the Elderly (AKTIVA) program entails engagement in leisurely activities that nonetheless provide some form of cognitive stimulation (Tesky et al., 2011). By combining cognitively demanding activities previously shown to help prevent or delay onset of dementia, AKTIVA offered a potentially fun and engaging way to promote sustainability of cognitive function throughout old age. A randomized controlled study assessing the effectiveness of this program reported significant improvements in speed of processing in participants over 75 years of age, as well as subjective ratings of age-related memory declines in participants younger than 75 years of age. Overall, however, this study revealed no significant benefits of the AKTIVA program compared to controls (Tesky, et al., 2011). While such paradigms may offer an enjoyable and convenient method for training, these findings highlight the importance of discerning what components underlie the success of effective programs.

In healthy elderly populations, brain training appears to delay the natural progression of cognitive decline by enhancing learning capacity and specific forms of memory (Buiza et al., 2009; Park et al., 2009). The Advanced Cognitive Training for Independent and Vital Elderly (ACTIVE) study (Jobe et al., 2001) – the largest randomized controlled trial to date studying cognitive decline in healthy elderly individuals – provides evidence for the effectiveness of 10 one-hour sessions of reasoning training, memory training, and speed of process training in improving performance on the specific abilities trained (Ball et al., 2002). Participants who received four additional reasoning and speed training sessions at 11-months following program completion, moreover, appeared to experience these benefits to a significantly greater extent; these booster effects were not observed for the memory training group. These effects were sustainable throughout the 24-month follow-up (Ball, et al., 2002), with later studies further reporting delays in the decline of health-related quality of life for speed-trained participants (Wolinsky et al., 2006) during the same period of time. Nonetheless, effect sizes for these benefits were small and decreased over time. Furthermore, while reasoning and speed training benefited a relatively large percentage of participants on the corresponding cognitive abilities tested, few participants improved on the memory-related cognitive abilities trained. These improvements also generalized to cognitively demanding daily abilities such as everyday processing speed and driving habits, although only for the speed training group. Despite these findings, all participants remained functionally independent throughout the course of the observation period (Ball, et al., 2002). A review of studies on cognitive training in healthy elderly individuals nevertheless concluded that while such training may effectively improve performance on tasks related to the training, little evidence demonstrates generalizability to general cognitive domains (Papp, et al., 2009). Thus, although brain training may improve specific cognitive abilities in the healthy elderly, this type of intervention does not appear to improve overall cognitive function.

Training for recovery after stroke

Cognitive training also appears to benefit the process of rehabilitation following stroke. Neuroimaging studies reveal that, once stroke recovery occurs, patients undergo structural changes within the brain that enable functional compensation for damaged neural areas (Stuss, et al., 1999). While the most common impairments experienced after stroke involve motor-related disabilities, cognitive deficits also manifest in a large percentage of patients and may persist for years following the event (Langhorne et al., 2011; Skidmore et al., 2011). Evidence surrounding the effectiveness of such interventions for stroke rehabilitation, however, remains conflicting. On one hand, certain studies report post-training improvements in functions such as alertness and sustained attention (Lincoln et al., 2000), WM (Westerberg, et al., 2007), as well as perception and spatial neglect (Langhorne, et al., 2011). One study revealed enhanced skill-acquisition in stroke patients who participated in a meta-cognitive program aimed at increasing their sense of autonomy (McEwen et al., 2010). Despite these encouraging results, the extent to which such training improves cognitive function and whether it benefits quality of life for patients is unclear. Furthermore, other cognitive functions often damaged by stroke, such as linguistic ability, do not appear to improve significantly as a result of the cognitive training techniques used (De Jong-Hagelstein et al., 2011). Cognitive remediation techniques may therefore assist the natural recovery pattern in patients following stroke, although further study remains to elucidate the most effective methods as well as the extent to which such training measurably improves daily life.

The potential of brain training for psychopathology

With the dramatic surge in attention-related disorders, parents and professionals are growing increasingly eager to optimize the system of attention both in school and at work. One example is ADHD, a disorder laced with symptoms relating to inattention, hyperactivity-impulsivity, or a combination of the two (Barkley, 1997; Steinhausen, 2009; Wells, 2008). With an approximate prevalence of 5.3% worldwide, in boys more than in girls, ADHD is the most common childhood-onset psychopathology and persists into adulthood in 30-50% of clinically-diagnosed cases (Barkley, 1997; Wallis et al., 2008). Another example is Tourette's Syndrome (TS), a neurodevelopmental impulse-control disorder (Robertson, 2003). With a brief review of some complexities surrounding the etiology and treatment of these disorders, we discuss the potential of specific forms of brain training as alternatives to medication.

The appeal of brain training to ADHD

ADHD affects neural structures associated with attentional processes. Neuroimaging studies indicate that children with ADHD have smaller global brain volumes compared to typically developing children, in addition to localized decreases in PFC, caudate, cerebellum, and corpus callosum size (Kieling et al., 2008; Steinhausen, 2009). Studies also report diminished activity in the circuits underlying executive attention, including regions of the PFC and ACC (Spencer et al., 2002), which may bring about the observed differences in cognitive control. Developmental manifestations of ADHD can be extremely pronounced and involve WM, speech internalization, modulation of goal-directed behaviors, as well as self-regulation of drive and affect (Faraone & Biederman, 1998). While these deficits may be more prominent in children, studies report analogous impairments of attention, self-control, and time estimation in adolescents with ADHD (Barkley et al., 2001).

ADHD is perhaps best recognized through the marked difficulties that children exhibit with interpersonal relationships. A study in the United States found that, among a population of children diagnosed with ADHD, over one third of parents reported significant emotional and behavioral difficulties in their children, with nearly 40% reporting deficits in aspects of daily living (Strine et al., 2006). These difficulties may arise, in part, as a result of an inferior capability to distinguish emotionally-charged facial expressions (Pelc et al., 2006). In addition, studies show peer-rejection rates of children with ADHD span 52-82%, which may be due to increased aggression, poorer social skills, and inflated self-perception (Murray-Close et al., 2010). Such reports indicate that children with ADHD stand to benefit from programs that may teach them to control their emotions and behavior.

Treatment options for ADHD are sparse and most commonly comprise psychostimulant medication, which shows marginal effectiveness. Improvements in the conduct and academic performance of medicated children (Elia et al., 1999) confirm the short term efficacy of psychostimulants, of which methylphenidate and amphetamine are most commonly prescribed. This type of medication appears to reduce characteristic behaviors associated with ADHD, including inattentiveness, hyperactivity, and impulsivity (The MTA Cooperative Group, 1999), with additional improvements in compliance, aggression, and academic achievement (Halperin & Healey, 2011). Reports further indicate varying levels of improvement in performance and reaction time on various WM and executive function tasks in individuals with ADHD taking stimulant medication (Barnett et al., 2001; Swanson et al., 2011). These studies suggest that psychostimulant medication effectively decreases ADHD symptoms.

Current ADHD medication, however, has several limitations that incite parents and professionals to demand superior treatment options. First, while short term effects of these drugs are well documented, there is ongoing debate regarding the effects of long-term psychostimulant consumption. While some studies report continued stimulant efficacy for a number of years following initial treatment in children and adults (Bejerot et al., 2010; The MTA Cooperative Group, 1999), high drop-out rates and findings of a drop-off in effect after a few years render the collective evidence inconclusive at best (Swanson, et al., 2011). Even the positive short-term benefits of psychostimulant drugs come at the price of unwanted side-effects and potential long-term risks. Both methylphenidate and amphetamine trigger similar, dose-dependent, adverse effects, of which insomnia and diminished appetite – seen in approximately 80% of children with ADHD – are the most common (Elia, et al., 1999). Reports also identify cardiovascular problems such as elevated resting heart-rate and blood pressure, in addition to stunted growth and the development of tics (Bejerot, et al., 2010; Daughton et al., 2010; Elia, et al., 1999). Another concern pertains to substance abuse, highly comorbid with ADHD and sometimes triggered by continued stimulant-use (Daughton, et al., 2010; Szobot et al., 2011). Finally, not all individuals respond to psychostimulants. Reports indicate that 70% of ADHD patients respond to the first stimulant drug administered, and an additional 10-20% respond if a second class of stimulant is tried in succession (Daughton, et al., 2010). These response rates, however, do not appear to vary with ADHD subtype (Solanto et al., 2009).

These findings clearly warrant demand for safer and more effective treatment options.

Scientists have attempted treating ADHD with alternate types of medication, including non-stimulant drugs, antidepressants, antipsychotic medication, and alpha-adrenergic agonists. While non-stimulant medications have reportedly fewer side-effects and long-term risks, their impact on ADHD symptoms is not as strong as psychostimulants (Daughton, et al., 2010). Likewise, antidepressant, antipsychotic, and alpha-agonist medications show only mild efficacy, although the findings come from small populations and include reports of adverse side-effects (Daughton, et al., 2010; Elia, et al., 1999; Ipser & Stein, 2007). Reports of death in children taking a combinations of psychostimulants and alpha-agonists, moreover, represent a clear illustration of the need to determine the ramifications of taking several classes of drugs simultaneously (Elia, et al., 1999). Such reports suggest that these types of drugs may not constitute viable alternatives to psychostimulant treatment in ADHD.

Given the potentially noxious effects of psychostimulant medication and the relative ineffectiveness of other drug types, widespread efforts aim to develop non-pharmacological therapies that would regulate unwanted ADHD symptomatology without the threat of long-term adverse effects. Currently, many studies indicate that children with ADHD strongly benefit from family therapy – with particular emphasis on parent training – as well as social skill training (Elia, et al., 1999; McBurnett & Pfiffner, 2008; Wells, 2008). Certainly, providing a more structured and supportive environment may offset conditions that play a role in triggering the onset of ADHD symptoms in children, and has potential to markedly improve the pathophysiological course of the disorder.

Cognitive treatments for ADHD entail brain training programs and show promising effects in both children and adults (Galbiati et al., 2009). Studies of programs such as Cogmed (Klingberg, 2008; Olesen, et al., 2004), report improvements in both cognitive ability and behavioral symptoms of ADHD (Halperin & Healey, 2011). Other programs appear to facilitate increased cognitive performance and attentional ability in children, although these benefits do not always extend to improvements in behavior (Kerns, et al., 1999). The effects of certain forms of training, furthermore, are comparable with the effects of medication (Klingberg, et al., 2005). Similar to pharmacotherapy, however, many of these training programs do not afford children the opportunity to develop their own self-control (Singh, et al., 2010). Cognitive training programs supplemented by interpersonal interactions may therefore allow children to receive behavioral monitoring and continual feedback, thereby teaching them to monitor their actions and respond in a situation-appropriate manner. Programs for children combining medication with cognitive training, including specific forms of meditation, reveal significant improvements in symptoms related to inattention, impulsivity, and hyperactivity, as well as enhanced self-esteem and child-parent relationships (Rubia, 2009). The reported improvements in cognitive performance and ADHD symptomatology as a result of cognitive training attest to the promise of such interventions as a component of ADHD treatment.

Brain training in Tourette's Syndrome

While pharmacological options exist for the treatment of TS (e.g., haloperidol, pimozide, or clonidine), general consensus posits that such therapies are suboptimal, and prominent researchers have recently lamented that medication therapies for TS are woefully inadequate (Singer & Walkup, 1991). Drug efficacy for TS is inconsistent and unpredictable, and at best, offers only symptomatic relief (Peterson & Cohen, 1998). Benefits often come at the expense of intolerable side-effects, including sedation, parkinsonism, tardive dyskinesia, cognitive dulling, dry mouth, fatigue, dizziness, weight gain, and metabolic problems (Swain et al., 2007). Most current treatments for TS are potentially toxic to the central nervous system. Moreover, those treatments tend to be terribly ineffective for many individuals and at best provide a modest reduction of the symptomatology (Phelps, 2008). Specialists hence recognize the need for alternatives and therapeutic adjuncts.

Behavioral interventions such as habit-reversal training (HRT) have been shown to be effective in ameliorating the symptoms of TS (Feldman et al., 2011; Himle et al., 2006; Piacentini et al., 2010; Woods et al., 2011). We have outlined how attentional interventions, including AT, can aid in overcoming the debilitating symptoms of impulse control disorders via improvements to this network, with a special focus on TS (Raz et al., 2007). Similar to HRT, AT reduced the symptoms of TS in a pilot study involving 12 experimental and 12 control participants. Our preliminary findings suggest that, compared to a control condition – watching popular children's videos, relaxing, and playing general video games with intermittent dialogue pauses matching for child-adult interactions – AT decreased visible tics and impulsivity in young individuals with TS and increased their ability to regulate emotions and persist with goals in the face of distractions. Findings from our pilot data further purpose that these changes translate into an increase in the quality of life (Raz, in press). Thus, tic-awareness programs, recognizing internal urges, switching to voluntary behaviors that are physically incompatible with the tic, relaxation guidance, and learning to identify antecedents of the tics, appear to be a promising behavioral approach for people with TS.

The Business of brain training and conflicts of interest

Brain training constitutes a lucrative market. Widespread concern regarding cognitive decline in the aging population and obsession with maximizing efficiency in school and at work have created a society of brain trainers that spare little expense on cognitive fitness. With individual programs costing hundreds to thousands of dollars, this industry feeds on growing consumer interest to yield enormous profit. In 2010, the Scientific Learning Corporation – developer of programs such as FFW – generated revenues over $43 million (Ernst & Young LLP, 2010). In the U.S. alone, revenues of brain fitness software attained $265 million in 2008, increased from $100 million in 2005 (Martin, 2009), and may accumulate revenues in the billions by 2015. While healthcare systems have contributed a large portion of this figure, individual consumers are playing an increasingly prominent role, as are educational systems, athletic organizations, and the U.S. military (Fernandez, 2008). In addition, programs targeting age-related cognitive decline represent a particularly profitable market, with hundreds of retirement homes now offering brain fitness products to tenants. Hence, brain training is nothing short of big business.

The brain training industry sometimes engenders conflicts of interest (COI) that could bias the scientific integrity of published work. Similarly to pharmaceutical and medical device companies (Brennan et al., 2006), distributors of cognitive exercise programs often fund studies evaluating their product or assign product testing to academic shareholders (Corporation, 2010; Pearson, 2011; Scientific Learning Corporation, 2011). Such COI may impede the objectivity of studies by provoking the omission of results unfavorable to the desired outcome or the reporting of findings that are favorable to the funding companies (Easterbrook et al., 1991; Lexchin et al., 2003; Turner et al., 2008). Alternately, authors with ties to industry (Smith et al., 2009) may overextend the interpretations of their results by emphasizing statistical significance while ignoring relatively small effect sizes that would indicate little or no clinical significance. Thus, COI potentially compromise the integrity of research.

COI are especially troubling in clinical contexts (e.g., psychotherapy, neurofeedback), where target populations may ultimately rely on biased research and thereby overlook a more appropriate remedy when searching for a treatment. Defenders of COI speculate that scientists may not obtain the funds necessary to conduct research on potentially groundbreaking treatments or programs without the benefit of commercial support (Stossel, 2007; Stossel, 2008). In a similar vein, some brain training investigators working with industry claim that separation of research and business is impractical because product distribution is less efficient outside of commerce (Merzenich, 2011); however, little, if any, evidence supports this claim. The history of clinical research, furthermore, attests to the dangers of distributing substances in need of more rigorous testing before becoming publicly available (Brody, 2008). Proponents of COI also assert that segregation between clinical goals and promotional motivation is impossible; even researchers strive to put their work in a positive light and professionals of the medical field advertise in order to attract clientele (Stossel, 2007). However, unlike such conflicts, which are inherent to human ambition, commercial COI result from voluntary choice and are therefore avoidable (Kassirer, 2009b). Furthermore, although researchers often claim that no incentive could compromise their impartiality, evidence suggests that self-serving biases occur subtly and unintentionally (Kassirer, 2009b). COI may therefore tarnish experimental findings and bias clinical practice.

The scientific community often considers disclosure to absolve the existence of COI in research. Researchers who shelter themselves behind the veil of disclosure, however, merely attest to the existence of a COI, but neither confirm nor deny the existence of partiality in their work (Kassirer, 2009a). The onus of identifying bias therefore passes to individuals who have no objective measure of the partiality of a study. In addition, disclosure may hinder the objectivity of studies by allowing scientists to retain their favorable ties with corporations so long as they make their potential partiality known to the public. Instead of merely disclosing COI in research and brushing the issue aside, a more effective stratagem may include the elimination of potentially questionable relations, the validation of scientific rigor within study design, and the independent replication of all influential findings.

Conclusion

Brain training draws on both evidence and hype. Examination of the findings reveals that consumers – largely oversold on individualized modules and programs (e.g., for ADHD) – often rely on claims that are scientifically unsubstantiated. For these programs to be clinically useful, they will have to accomplish what few interventions, if any, have achieved: generalize circumscribed laboratory and computer skills to tangible gains in the classroom, during play, and in other ecological settings. This lofty goal, however, has hardly been achieved.

Few scholars have distinguished their research efforts by providing scientific evidence to support the impact of their computerized training in both children and adults. Specific researchers have demonstrated sustainable behavioral improvements using independent programs. Following brief interventions, children have demonstrated improvements in measures of non-verbal intelligence, language development, and control over affect and executive function. In addition, electrophysiological and neuroimaging studies report a shift of signature brainwaves toward more adult-like patterns and maturation of neural modules implicated in attention, respectively. Some of these benefits further extend to both healthy and pathological adults. These programs, however, have rarely made a trailblazing breakthrough in improving symptoms and resolving impairments. In this regard, such approaches to cognitive remediation show promise, but hardly represent stand-alone treatments.

While computerized programs constitute the most accessible form of brain training, researchers have shown benefits from specific contemplative techniques and lifestyle-related practices. Programs encompassing mind-body meditative techniques in healthy adults, for example, demonstrate training-related alterations of white matter connectivity in neural areas associated with the executive attention system, and appear to alleviate feelings of stress and pain. Meditation training has also proven beneficial in adults with ADHD, enhancing their performance on conflict and inhibition tasks, and decreasing their reported symptoms related to the disorder. Other methods of training show similar benefits for improving cognitive function and behavioral control through executive attention. These include bilingualism, musical training, physical exercise, regular interaction with nature, and proper parenting. Such findings support practice in alternate forms of training that need not involve circumscribed programs.

Cognitive training in psychopathology may represent an adjunct, if not a possible alternative, to some pharmacological treatment options. Psychiatric treatment of developmental psychopathologies largely relies on drug interventions. Pharmacological approaches may engender undesirable side effects and sometimes carry only marginal benefits, especially over time. With the current credibility crisis surrounding pediatric psychiatry and pharmacotherapeutics, crafting effective drug-free treatment alternatives seems highly relevant. Current findings, although preliminary, suggest that training options are safe, fun, and provide larger gains for children who suffer from greater cognitive deficits. Combining training with medication, furthermore, appears to produce maximal benefits that exceed behavioral or pharmacological treatments alone. Thus, given extant knowledge about available treatment options, brain training paradigms may be worthy of consideration, especially for populations with specific developmental deficiencies.

Despite promising findings in both healthy and cognitively-impaired individuals, studies often contain a number of caveats that weaken the interpretations drawn from experimental results. Such limitations relate to inadequate controls and measures of cognitive function, behavior, and training sustainability. The context of brain training research, furthermore, sometimes contains COI that prompt overly ambitious conclusions. Notably, studies indicate that such training does not constitute a "quick fix" for a lifetime of impairments. Rather, long-term exposure and application of the training is likely to create lasting results. These caveats highlight the importance of skepticism concerning experimental findings as well as the possible necessity to re-evaluate current research standards in this field.

Incorporating brain training into school curricula – alongside mainstream courses such as history, language, physical education, and math – may provide the long-term exposure needed to reap the benefits. By mimicking Eastern traditions that integrate contemplative practices into daily routine, cognitive training may have some tangible benefits to offer. In this regard, brain training likely impacts parameters related to improved quality of life, including self-esteem, depression, anxiety, and stress. While further research will have to determine the forms of training that would most benefit specific populations, the effectiveness and sustainability of such programs will likely depend on training frequency and method of delivery.

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Connecting Text

Our critical review aimed to evaluate the scientific basis and validity of brain training, a rapidly budding concept in commercial, clinical, and research domains. The investigation reveals that, while a number of brain training programs may have the potential to improve specific cognitive skills, few programs live up to the commercial hype surrounding the field. One promising prospect revolves around the training of attention. With an important role in mediating contextually relevant behavior and guiding self-control, attention has become the focus of many commercialized programs targeting both typically and atypically developing populations.

Research suggests that attention training (AT) is among the most effective forms of brain training and is especially enticing in the context of childhood behavioral impairments related to attention. In light of such research, we sought to evaluate the benefits of a computerized AT program in a population of children diagnosed with attention deficit hyperactivity disorder, oppositional defiance disorder, and conduct disorder. Our experimental piece adds to the relatively sparse scientific literature surrounding this increasingly popular form of training.

Experimental Piece

(Manuscript 2)

Computerized Attention Training in Children with Impulse-Control Impairments

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Abstract

Computerized brain training programs are among the latest fads in cognitive and behavioral therapy. Advertised to improve a variety of cognitive skills in both typically and atypically developing individuals, such programs constitute a lucrative market. One of the most prominent targets of brain training programs is attention, a system of neural networks that mature throughout childhood and regulate behavior and self-control. In the present study, we evaluate the effectiveness of a computerized attention training program coupled with a motivational paradigm that we developed for children with common impulse-control impairments. Following 10 training sessions, children improved in subjective ratings of behavior related to impulse-control, as indexed by parent reports. We did not find, however, significant improvement on objective measures of attention and intelligence. These findings contrast with previous studies and highlight the need for more rigorous scientific evaluation of marketed brain training products.

Introduction

Computerized brain training programs constitute a budding field in cognitive and behavioral therapy. Often marketed as a panacea for developmental impairments, such programs have captivated the interest of parents and clinicians as a means of enhancing various cognitive skills. Enveloped in hype, computerized brain training has engendered a society of fervent believers and advocates for their success, all contributing to a flourishing market. Developers of many commercially-available products, however, base their claims on testimonial evidence or company-led reports and often lack scientific vigor to support their alleged effectiveness.

Attention is an increasingly prominent target for commercially-available brain training products. A strong regulator of thought and action, attention refers to the preparedness for and selection of specific aspects of the environment, and plays a central role in mediating behavior (Raz & Buhle, 2006). Believed to continue developing throughout childhood, attention comprises a system of connected networks that mature and function independently of one another (Posner & Petersen, 1990; Rueda, et al., 2004). Within this system lies executive attention, which draws on dopaminergic neurotransmission and correlates with activation of the prefrontal cortex (PFC), anterior cingulate cortex (ACC), and basal ganglia (Posner & Rothbart, 2007b). The executive attention network is intimately related to behavior through its involvement in voluntary control and resolution of conflict between computations in competing neural areas (Raz & Buhle, 2006). Due to the functionality of this network, attention training (AT) focuses on exercising the neural networks that underlie attention through a series of conflict-related games or tasks. Studies have demonstrated links between executive attention and working memory, a system that mediates the temporary storage, modification, and protection of cognitively processed information (Bledowski, et al., 2010; Posner & Rothbart, 2007b; Rueda, Posner, et al., 2005). Activation of executive attention therefore mediates conflict-related activities such as planning, decision-making, error detection, executing new or ill-acquired responses, regulating thoughts and feelings, and overcoming habitual actions.

These abilities are particularly important for the development of self-monitoring and behavioral control during childhood, and may even influence scholastic achievement (Liew, 2011). Hence, an increasing number of programs aim to strengthen attention and thereby improve performance in social and academic settings.

Attention is an appealing target for training due to its role in impulse-control disorders such as Attention Deficit Hyperactivity Disorder (ADHD) (Rabipour & Raz, 2012). Characterized by an inability to maintain focus through inattention, hyperactivity-impulsivity, or a combination of the two (Barkley, 1997; Steinhausen, 2009; Wells, 2008), ADHD is the most common childhood-onset psychopathology (Barkley, 1997; Wallis, et al., 2008). Manifestations of ADHD center on executive function (Faraone & Biederman, 1998; Spencer, et al., 2002) and may stem from atypical development in neural areas associated with attention, including the PFC and ACC (Max et al., 2005; Rubia, 2007; Spencer, et al., 2002). The resulting symptomatology often triggers difficulties in the classroom environment (Kofler et al., 2008). In many cases, aggressive behavior and lack of inhibitory control in children with ADHD also lead to strained interpersonal relationships (Murray-Close, et al., 2010) and even social isolation (McBurnett & Pfiffner, 2008), which may negatively impact self-esteem. Current treatment options for ADHD largely surround stimulant medication, a highly controversial avenue due to reported side-effects and long-term health risks (Bejerot, et al., 2010; Daughton, et al., 2010; Elia, et al., 1999). In light of these caveats, many parents are hesitant to embrace drug-based therapy and often seek behavioral methods of treatment for their children. AT has therefore become a popular prospect for behavioral treatment of ADHD and similar childhood impulse-control disorders.

Previous studies have demonstrated the promise of AT and analogous programs in both typical and atypical development (Diamond & Lee, 2011; Rabipour & Raz, 2012). One study involving as few as five sessions of computerized AT demonstrated significant improvement in the performance of typically-developing children on measures of attention, emotional composure, and non-verbal intelligence, as well as a maturation of neural activation patterns in the ACC (Rueda, Rothbart, et al., 2005). More recently, a study involving 28 sessions of computerized AT reported improvements in the attentiveness of elementary school with varying levels of attentional impairments (Rabiner, et al., 2010). A number of studies in children, both healthy and diagnosed with ADHD, have demonstrated the effectiveness of a specific 5-6 week training program in improving performance on tests of working memory and non-verbal intelligence (Klingberg, 2007, 2008; Klingberg, et al., 2005; Klingberg, et al., 2002; Thorell, et al., 2009). Training with the same program also appears to increase neural activity in the PFC and parietal cortex, in healthy adults (Olesen, et al., 2004). These studies suggest that AT programs may enhance cognitive ability and attentional capacity in children and, in some cases, may decrease adverse symptomatology related to developmental impairments in attention.

In the present study, we investigate the effects of a computerized AT program in children with ADHD and highly comorbid disorders, including Oppositional Defiance Disorder (ODD) and Conduct Disorder (CD). Targeting executive attention in particular, our AT program implicates the same series of games used by Rueda et al. (2005) throughout 10 sessions. In light of the emotional toll placed on many children with these diagnoses, we coupled the sessions of computerized AT with a behavioral feedback system that we developed in order to uphold motivation, promote self-reinforcement strategies, and ultimately heighten emotional composure. Moreover, in line with studies showing the effectiveness of implementing role-playing in the context of training executive function (Diamond et al., 2007a), this behavioral paradigm encourages children to adopt specific roles that draw on self-regulation. Our examination of computerized AT coupled with a behavioral paradigm aims to evaluate the viability of such training as an adjunct or possible alternative to pharmaceutical treatments of developmental impulse-control impairments.

Methods

Participants

The study included 40 children 4-11 years of age (3 females; mean age: 86.6 months, SD: 26.5 months). The majority of participants (*n* = 27) were recruited from one of three clinical teams of the day program in the Child Psychiatry department of the Jewish General Hospital (JGH) in Montreal, Quebec. The remaining 13 participants were recruited externally, after expressing interest in the study via e-mail. Each child was given parental consent to participate. Children received stickers, certificates, and small prizes in compensation for their participation. Participants were selected based on the criteria outlined in Table 1.

Table 1. Inclusion and exclusion criteria.

INCLUSION CRITERIA	EXCLUSION CRITERIA
• 4 to 11 years of age. • Diagnosis of Attention Deficit Hyperactivity Disorder according to the DSM-IV-R criteria; and/or • Diagnosis of Oppositional Defiance Disorder according to the DSM-IV-R criteria; and/or • Diagnosis of Conduct Disorder according to the DSM-IV-R criteria.	• Diagnosis of Autism Spectrum Disorders; and/or • Epilepsy; and/or • Tourette's Syndrome; and/or • Mental retardation; and/or • Currently on psychotic or stimulant medication; and/or • Legally blind or deaf.

Experimental Design

The experiment comprised three distinct protocols: the treatment group (*n* = 19), designed to demonstrate the effects of participating in AT sessions coupled with behavioral feedback; the placebo-control group (*n* = 10), designed to evaluate the effects of behavioral feedback only; and the waitlist-control group (*n* = 11), designed to control for the effects of elapsed time and familiarity with the training environment. Each group received pre- and post-assessments within the same time intervals. A schematic of the protocols is provided in Table 2.

Table 2. Timeline showing experimental protocols by group.

	1-2 WEEKS BEFORE SESSIONS	3-4 WEEKS	1-2 WEEKS AFTER SESSIONS	2 MONTHS AFTER POST-ASSESSMENT	3-4 WEEKS
Treatment Group	Pre-assessment	AT sessions + Behavioral Paradigm	Post-assessment	Long-term assessment	No sessions
Placebo-control Group	Pre-assessment	Video sessions + Behavioral Paradigm	Post-assessment	Long-term assessment	AT sessions
Waitlist-control Group	Pre-assessment	No sessions	Post-assessment	Long-term assessment	AT sessions + Behavioral Paradigm

Sessions

Behavioral Paradigm: Each participant was assigned a personal trainer that supervised the one-on-one sessions to ensure compliance with the rules of the program and to provide appropriate feedback when necessary. In order to promote role-playing in a situation that would invoke heightened sense of self-regulation, children were told that they would be training to gain the skills of a “secret agent” and acquired an ID card. Every second session, children graduated to a new level and received a small prize with a certificate. In addition, the trainers conveyed specific messages that applied to each level: level-1 was *Police Officer,* with the message “always try your best”; level-2 was *Sergeant,* with the message “always have a good attitude”; level-3 was *Detective,* with the message “pay attention to every clue”; level-4 was *Inspector,* with the message “never lose heart”; level-5 was *Secret Agent,* with the message “help others and always make it to the end”. These phrases aimed to promote a positive attitude towards the program and also to facilitate self-reinforcement using constructive messages.

The trainers assigned to each participant offered behavioral feedback as outlined in a general script (*see Appendix A*); children were reminded to sit up straight, maintain their gaze on the screen, and concentrate on the objective of each game. Positive feedback was provided when children adhered to the expected behavioral conduct and when milestones were achieved during training (e.g., upon successful completion of difficult trials and different levels of the computer games). Children were reminded to remain on-task and given positive reinforcement if trials were not completed successfully (e.g., children were told that the training "was working" when they showed signs of frustration and that the levels were becoming "tricky" to better train their "Secret Agent skills"). The trainers ensured that each participant graduated to the subsequent level of the "Secret Agent Academy" at the appropriate time (i.e., after every second session), regardless of how many games had been completed.

Computer Games: Participants assigned to the treatment group underwent 10 sessions of 30 minutes during which they played computerized AT games, referred to as "missions". The sessions involved two timed 10-minute periods during which children played one of 12 computerized AT games previously reported to engage visual tracking, anticipation, stimulus discrimination, conflict resolution, and inhibitory control. The 10-minute playing times were separated by a brief break during which children received a sticker, for motivational purposes. *For a full description of the games, see Rueda et al. (2005).*

The protocol of the placebo-control group was virtually identical to that of the treatment group, except that participants in the placebo-control group watched automated videos of the AT games during the two 10-minute periods, instead of playing them. To uphold interest levels, participants watching the videos were automatically prompted with simple, general-knowledge multiple-choice questions at two-minute intervals. These questions were designed to be age-appropriate (e.g., younger participants were asked "What color is the sky?" whereas older ones were asked "What do you call rain that contains chemical waste and damages plants?").

Children assigned to control groups (placebo or waitlist) received the same AT sessions provided to participants in the treatment group following completion of the long-term assessment. No data was collected from those sessions.

Pre- and Post-Assessments

Assessments were administered 1-2 weeks prior to the first session, and 1-2 weeks following completion of the sessions. For waitlist-controls, the assessments were administered 5-6 weeks apart. Participants completed the assessments on two consecutive days, at the same time each day. Due to scheduling conflicts, nine participants completed the assessments in a single day (four in the treatment group; three in the placebo-control group; two in the waitlist-control group). Each assessment included attention and intelligence tests, as well as a set of behavioral questionnaires administered to parents and teachers of the child.

Measures of Attention: The attention tests included computerized versions of the child Attention Networks Test (ANT) (Fan et al., 2002; Rueda, et al., 2004) and Simon task (Capilla Gonzalez, 2007). The participants were evaluated on efficiency of the attention networks, through the ANT conflict resolution task, and on inhibitory control, through the Simon task. *For a complete description of the child ANT and Simon task, see (Rueda, et al., 2004) and Appendix B, respectively*.

Measures of Intelligence: The intelligence measures included verbal and non-verbal subtests of the Reynolds Intellectual Screening Test (RIST) and the Reynolds Intellectual Assessment Test (RIAS). The validity of these tests is reported based on a test-retest interval of 9-39 days (Reynolds & Kamphaus, 2002; Reynolds & Kamphaus, 2003).

The RIST is a standardized screening instrument used to assess general intelligence in an efficient manner (Reynolds & Kamphaus, 2002; Reynolds & Kamphaus, 2003). This instrument consists of a verbal subtest (the *"Guess What"*), which provides a measure of crystallized intelligence, as well as a nonverbal subtest (the *"Odd Item Out"*), which provides a measure of fluid intelligence. In addition, we administered the *"What's Missing"* subtest from the RIAS, which provides another nonverbal measure of fluid intelligence.

Measures of Behavior: Parents and teachers completed respective versions of the Behavior Assessment System for Children (BASC-II) questionnaires (Reynolds & Kamphaus, 2004), as well as the Children's Behavior Questionnaire (CBQ) (Rothbart et al., 2001) for children 4-7 years of age or the Temperament in Middle Childhood Questionnaire (TMCQ) (Simonds, 2006; Simonds & Rothbart, 2006) for children 8-11 years of age. Whereas parents were asked to complete the full versions of these questionnaires, teachers were given the short-forms (Putnam & Rothbart, 2006).

The BASC-II comprises a comprehensive set of rating scales and provides an extensive view of adaptive and maladaptive behavior. The validity of these scales is reported based on a test-retest interval of 13-66 days (Reynolds & Kamphaus, 2004). We used teacher rating scales to measure behavior in the school setting and parent rating scales to measure behavior in the community and home setting. Teacher and parent forms are subdivided into three levels corresponding to age: preschool (2-5 years of age), child (6-11 years of age), and adolescent (12-21 years of age).

The CBQ and TMCQ provide highly differentiated assessments of temperament by measuring relatively enduring biological traits, reactivity (arousability of motor, affective, and sensory response systems), and self-regulation (Putnam & Rothbart, 2006; Rothbart, et al., 2001).

Long-term Assessments

In order to evaluate the sustainability of post-training effects, we mailed each participant the parent and teacher questionnaires at two months following completion of the post-assessment.

Statistical Analysis

We analyzed the data using Statistical Analysis Software (SAS) version 9.2 (SAS® Institute, Cary, NC). We examined descriptive statistics and used a mixed linear model to investigate potential differences between groups and across time. The mixed model includes corrections for multiple comparisons.

Results

Measures of Attention

ANT: For each cue type (center, double, spatial, none), we computed the conflict reaction times (RT) by subtracting mean RT on congruent trials from the mean RT on incongruent trials (see Table 3). For each condition, RT scores more than 2 SD above or below the mean were excluded. We measured accuracy by calculating the percentage of correct trials for each condition (see Table 4). Statistical analysis did not reveal any significant post-training changes in RT or accuracy scores.

Table 3. Mean RT (ms) on the ANT

Congruent	Center Cue		Double Cue		Spatial Cue		No Cue	
	PRE (SD)	POST (SD)	PRE (SD)	POST (SD)	PRE (SD)	POST (SD)	PRE (SD)	POST (SD)
Treatment	851.35 (213.17)	850.6 (129.41)	857.87 (172.73)	812.11 (130.07)	868.58 (189.16)	799.68 (130.04)	928.39 (226.26)	861.25 (146.92)
Placebo control	1121.8 (312.44)	954.58 (214.63)	1042.56 (275.33)	887.51 (241.34)	1105.57 (330.66)	935.32 (265.15)	1186.56 (349.1)	1015.68 (276.39)
Waitlist control	936.08 (270.79)	889.73 (352.24)	925.54 (268.53)	875.33 (337.9)	900.71 (237.19)	852.34 (292.65)	999.49 (250.52)	959.13 (344.53)

Incongruent	Center Cue		Double Cue		Spatial Cue		No Cue	
	PRE (SD)	POST (SD)	PRE (SD)	POST (SD)	PRE (SD)	POST (SD)	PRE (SD)	POST (SD)
Treatment	920.73 (177.88)	919.99 (133.84)	954.87 (254.17)	909.67 (144.66)	918.16 (208.49)	893.83 (172.75)	1029.83 (248.05)	954.05 (126.51)
Placebo control	1224.73 (327.83)	985.07 (227.16)	1203.88 (304.63)	1024 (268.24)	1236.57 (398.65)	1068.06 (321.12)	1235.31 (330.42)	1031.93 (235.74)
Waitlist control	1075.46 (291.35)	948.36 (316.42)	1043.18 (305.78)	938.41 (334.62)	1019.31 (295.88)	946.52 (370.08)	1060.93 (246.73)	1005.41 (333.17)

Table 4. Mean accuracy scores (%) on the ANT.

Congruent	Center Cue		Double Cue		Spatial Cue		No Cue	
	PRE (SD)	POST (SD)	PRE (SD)	POST (SD)	PRE (SD)	POST (SD)	PRE (SD)	POST (SD)
Treatment	92.5 (12.77)	93.75 (11.33)	93.75 (10.02)	95.83 (11.25)	92.08 (11.2)	95 (11.38)	93.75 (16.19)	92.08 (14.46)
Placebo control	90.97 (14.01)	85.42 (14.68)	94.44 (8.52)	89.58 (12.5)	90.28 (17.98)	94.44 (5.8)	93.06 (7.93)	88.19 (11.88)
Waitlist control	91.88 (21.46)	90 (14.79)	95 (11.71)	95.63 (8.36)	95 (13.76)	95.63 (7.82)	95.63 (9.79)	95 (8.23)

Incongruent	Center Cue		Double Cue		Spatial Cue		No Cue	
	PRE (SD)	POST (SD)	PRE (SD)	POST (SD)	PRE (SD)	POST (SD)	PRE (SD)	POST (SD)
Treatment	91.25 (13.73)	90.83 (14.34)	91.25 (14.33)	92.08 (14.46)	88.33 (14.34)	92.08 (18.97)	88.75 (16.9)	91.67 (20.55)
Placebo control	83.33 (28.64)	86.11 (23.55)	76.39 (30.26)	83.33 (29.81)	79.86 (29.77)	80.56 (23.06)	77.08 (31.41)	79.17 (30.3)
Waitlist control	90.63 (21.09)	93.13 (10.4)	91.25 (15.65)	93.13 (13.32)	85 (26.05)	92.5 (16.08)	88.75 (23.34)	94.38 (8.04)

Simon Task: We computed the conflict RT by subtracting mean RT on congruent trials from the mean RT on incongruent trials (see Table 5a). For each condition, RT scores more than 2 SD above or below the mean were excluded. We measured accuracy by calculating the percentage of correct trials for each condition (see Table 5b). There were no statistically significant changes in RT and accuracy scores following training.

Table 5. Mean RT (ms) and accuracy scores (%) on the Simon task.

a)	**RT**			
	Congruent		Incongruent	
	PRE (SD)	POST (SD)	PRE (SD)	POST (SD)
Treatment	974.73 (443.8)	1005.36 (794.28)	986.82 (322.89)	1247.09 (1486.29)
Placebo-control	988.89 (347.21)	840.89 (218.09)	1079 (522.67)	987.56 (261.09)
Waitlist-control	906.75 (276.64)	824.75 (260.11)	1049.25 (334.78)	920.58 (224.59)

b)	**Accuracy**			
	Congruent		Incongruent	
	PRE (SD)	POST (SD)	PRE (SD)	POST (SD)
Treatment	87.45 (13.4)	95 (3.75)	71.82 (15.4)	74.94 (21.59)
Placebo-control	93.17 (7.11)	95 (5.28)	68.28 (31.73)	83.92 (17.53)
Waitlist-control	94.67 (5.31)	95.29 (5.18)	78.92 (15.89)	79.68 (18.68)

Measures of Intelligence

RIST and RIAS: Raw scores on the RIST and RIAS tests were converted to standardized T scores. Analysis of the *"What's Missing"* test revealed a significant interaction between group and time [$F(2,34) = 7.06$, $p < 0.0027$]. Closer inspection showed that children in both the treatment and placebo-control groups significantly improved their scores ($p < 0.0001$ and $p < 0.02$, respectively; see Figure 1). While the main effect of group and time was not significant on the *"Odd Item Out"* test [$F(2,35) = 2.19$, $p < 0.13$], children in the treatment group significantly improved their performance compared to controls ($p < 0.0001$; see Figure 2). Similarly, while the main effect of group and time was not significant on the *"Guess What"* test, [$F(2,35) = 1.19$, $p < 0.32$], participant scores in all three groups improved significantly ($p < 0.0002$ treatment; $p < 0.05$ placebo-control; $p < 0.0001$ waitlist-control; see Figure 3). However, data collected for all three tests showed significant group differences at baseline. These differences were unrelated to age, as mean age did not vary significantly between the three groups.

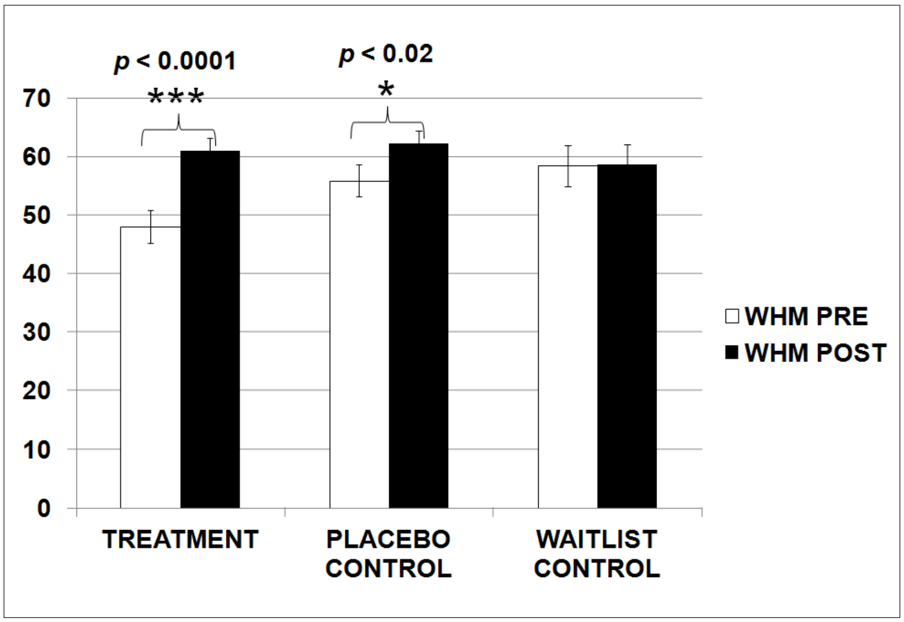

Figure 1. Participant scores on the “What’s Missing” (WHM) test of the RIAS at the pre- and post-assessments.

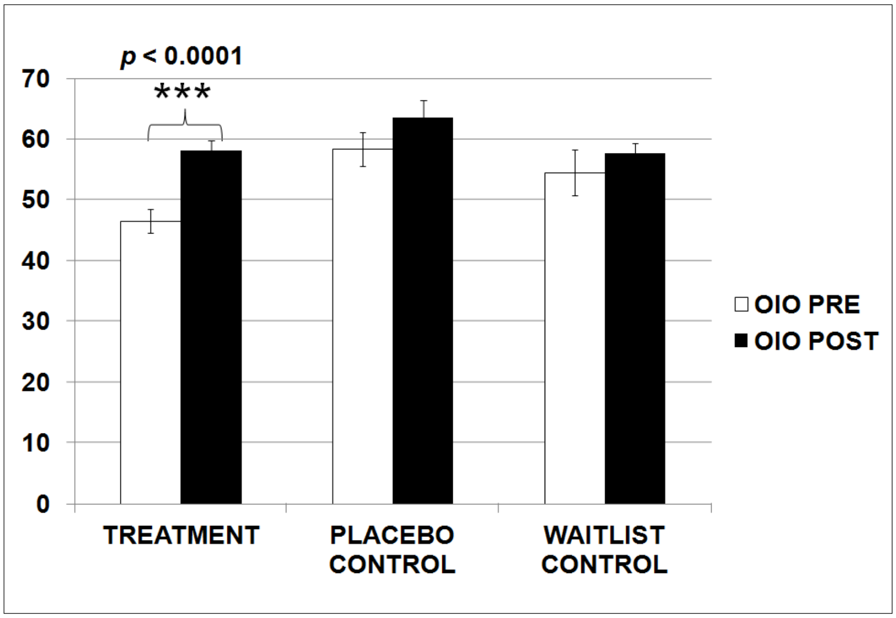

Figure 2. Participant scores on the "Odd-Item Out" (OIO) test of the RIST at the pre- and post-assessments.

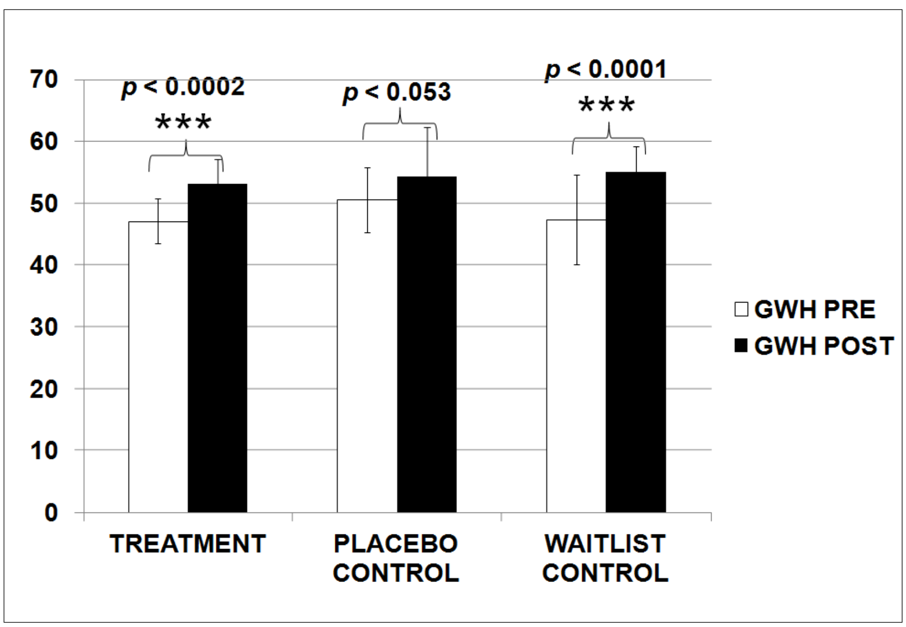

Figure 3. Participant scores on the "Guess What" (GWH) test of the RIST at the pre- and post-assessments.

Measures of Behavior

Due to insufficient responses, all teacher questionnaires and questionnaires sent for the long-term assessment were excluded from data analysis.

BASC-II: Raw scores on the BASC-II questionnaires were converted to standardized T scores. These scores were then compared to general norms based on a large sample representative of the general population of children in the US, with regard to race, ethnicity, parent education, geographic region, and clinical or special-education classification (Reynolds & Kamphaus, 2004). The subscales analyzed include Depression (maladaptive child cognitions about the self, the world, and the future); Hyperactivity (hyperactive and impulsive behavior, including interrupting, being over-active, and having poor self-control); and Attention Problems (inability to maintain attention and easily distracted from tasks requiring attention).

The main effect of group and time was not significant for either the Depression subscale [$F(2,24) = 1.59$, $p < 0.22$] or the Hyperactivity subscale [$F(2,23) = 1.32$, $p < 0.29$)]. However, compared to the control groups, children in the treatment group showed a trend towards lower scores related to depression ($p < 0.059$) and hyperactivity ($p < 0.086$). These results are depicted in Figures 4 and 5. Data collected from these parent reports did not indicate any significant changes on the Attention Problems subscale.

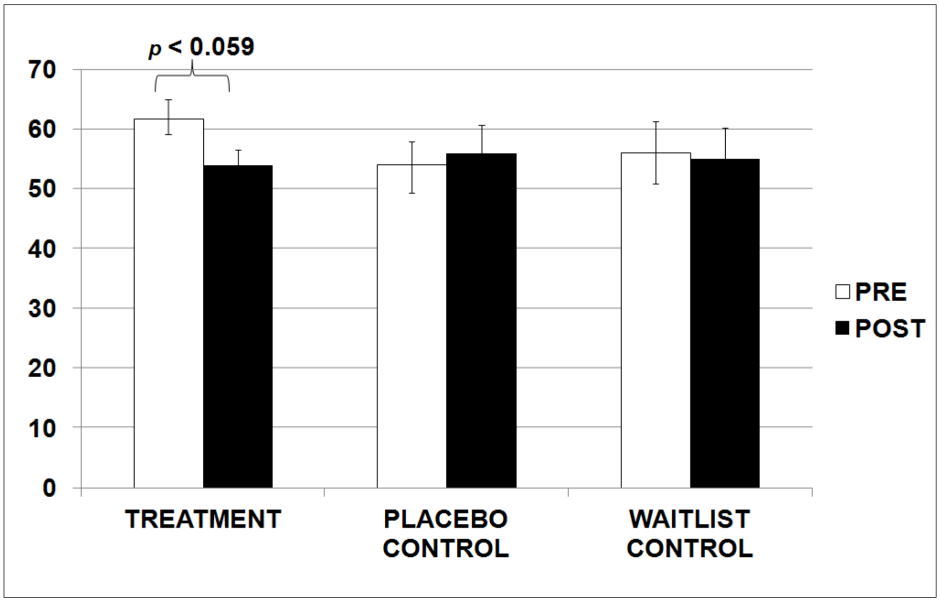

Figure 4. Participant scores on the Depression subscale of the BASC-II questionnaire, as rated on the parent report at the pre- and post-assessments.

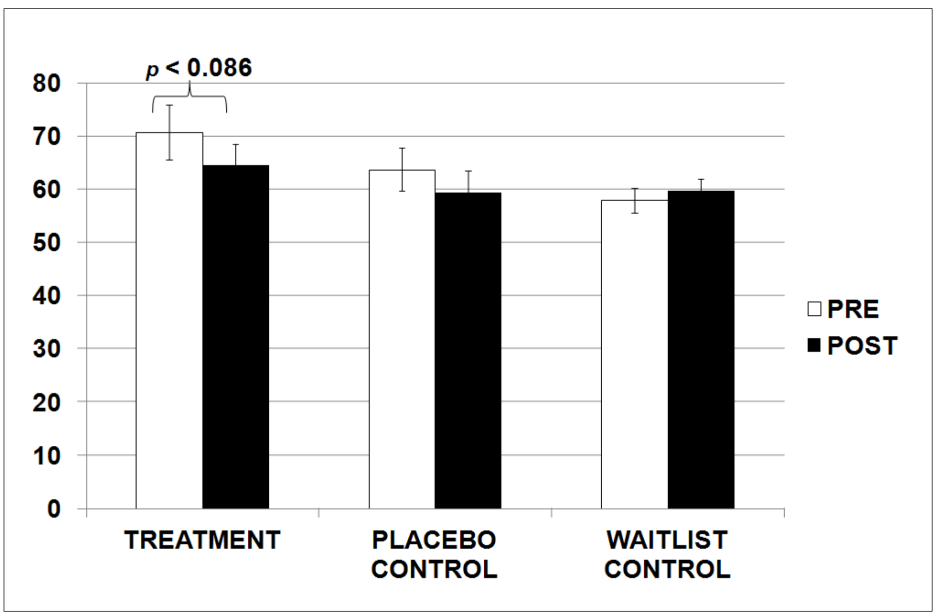

Figure 5. Participant scores on the Hyperactivity subscale of the BASC-II questionnaire, as rated on the parent report at the pre- and post-assessments.

In light of the clinical nature of our study, we analyzed the data from each individual participant using a clinical profile provided by the BASC-Assist

(Reynolds & Kamphaus, 2004). Two examples are presented in Figures 6 and 7. For some participants, symptoms related to hyperactivity, depression, and attention decreased from the clinical range (score of 70 or higher) to the average range (score of 41-59). In other cases, however, decreases in scores on these scales were not clinically-significant. *See Appendix C for a more complete illustration of individual participant trends.*

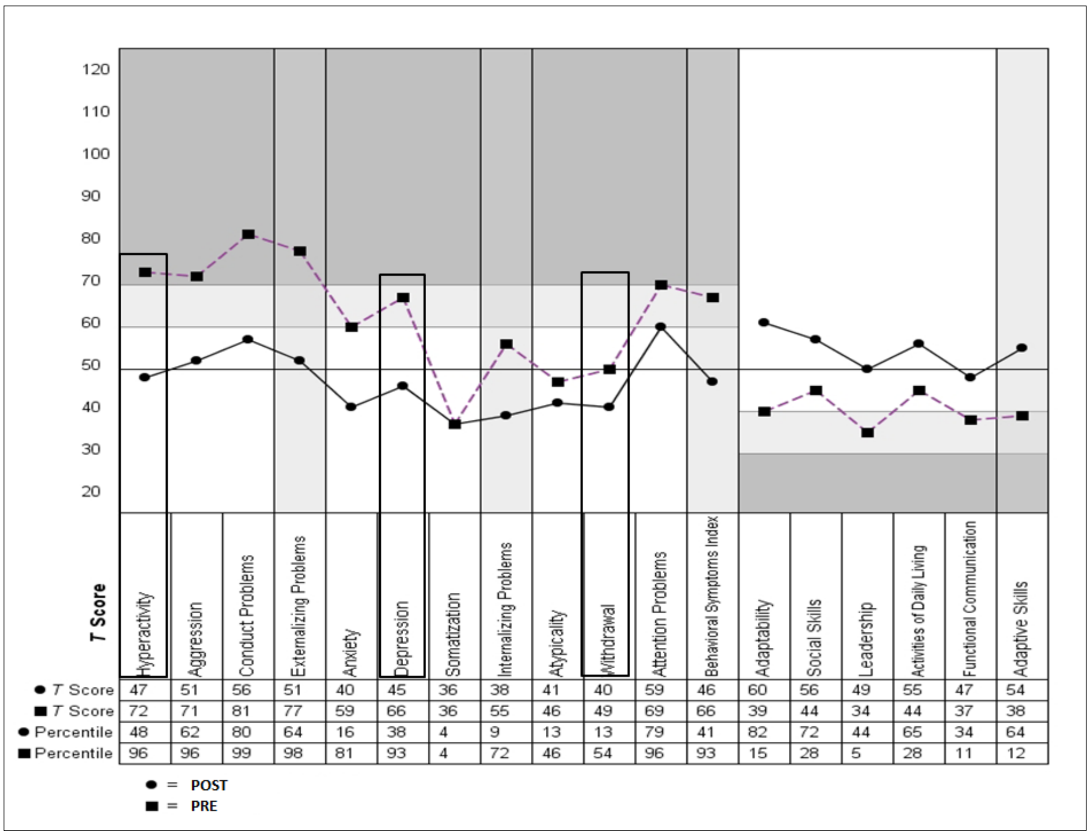

Figure 6. Parent-rated scores of a participant in the treatment group on the BASC-II questionnaire. Dark shades of grey indicate scores in the clinical range, light shades of grey indicate scores “at-risk” for clinical range, and white indicates scores within the normal range. Results show clinically-significant post-training differences on the Depression, Hyperactivity, and Attention Problems subscales.

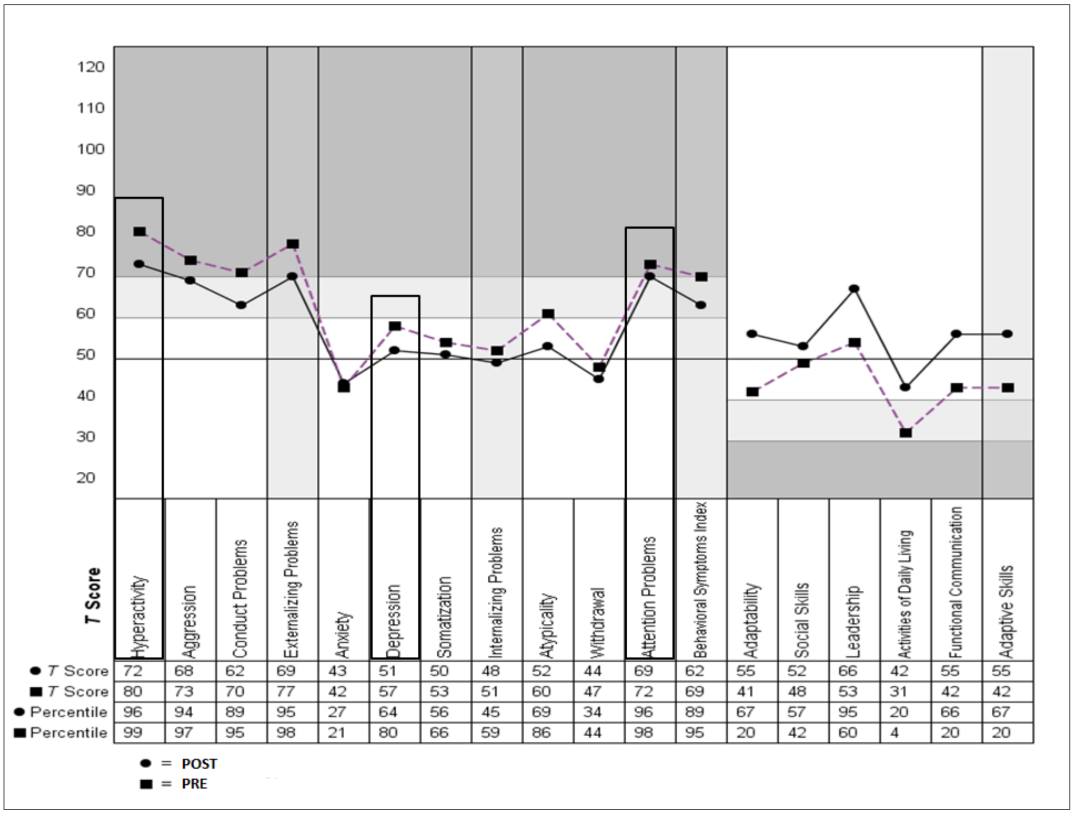

Figure 7. Parent-rated scores of a participant in the treatment group on the BASC-II questionnaire. Dark shades of grey indicate scores in the clinical range, light shades of grey indicate scores "at-risk" for clinical range, and white indicates scores within the normal range. Results show no clinically-significant post-training differences on the Depression, Hyperactivity, and Attention Problems subscales.

CBQ and TMCQ: To compare data from the CBQ and TMCQ, we normalized all scores to a 5-point scale. Our analysis considered only the subscales that were most relevant to behavior associated with attention and emotional composure in our population. The included subscales were: impulsivity (speed of response rate); inhibitory control (capacity to plan and suppress inappropriate approach responses under instructions or in novel/uncertain situations); activity level (rate and extent of locomotion); shyness (slow or inhibited approach in situations involving novelty or uncertainty); anger/frustration (negative affect related to interruption of ongoing tasks or goal blocking); and fear (negative affect, including unease, related to anticipated pain, distress, or potentially threatening situations).

We did not find a significant main effect of group and time for the subscales evaluated. Parent reports, however, indicated a significant decrease in impulsivity ($p < 0.046$) and inhibitory control ($p < 0.011$) in the treatment group, compared to controls. These results are shown in Figures 8 and 9. No significant changes were found in the other subscales analyzed.

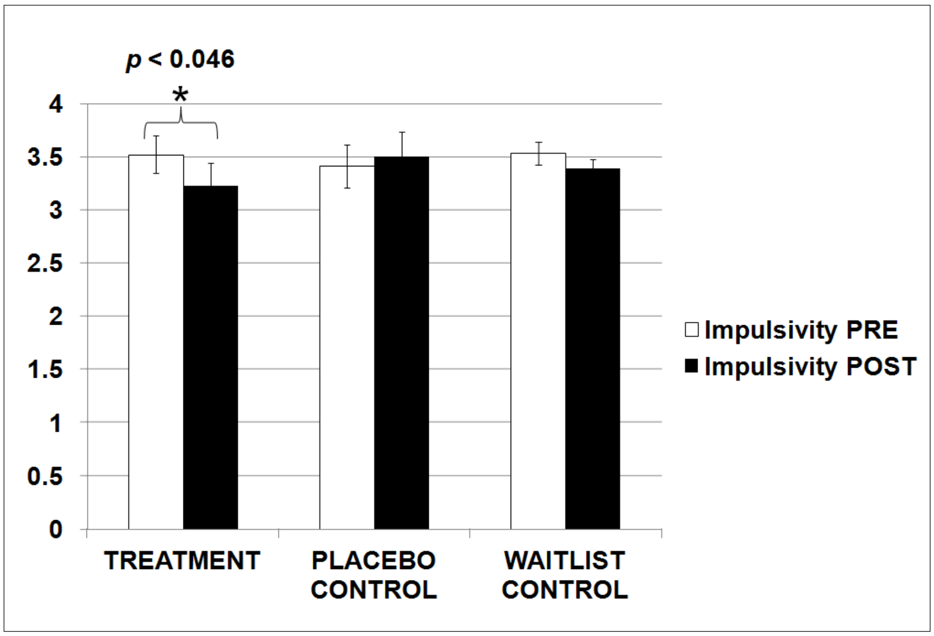

Figure 8. Participant scores on the Impulsivity subscale of the CBQ and TMCQ questionnaires, as rated on the parent report at the pre- and post-assessments.

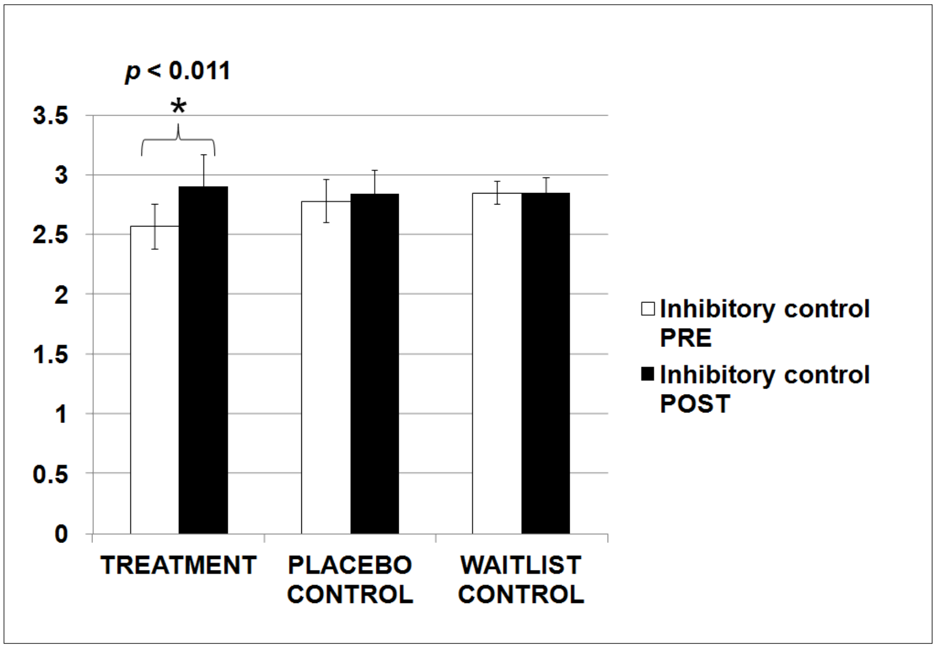

Figure 9. Participant scores on the Inhibitory Control subscale of the CBQ and TMCQ questionnaires, as rated on the parent report at the pre- and post-assessments.

Discussion

The present study investigated the effects of short-term AT coupled with behavioral feedback. Our protocol provided children with 200 minutes of game-playing overall, using a series of computer games previously studied in typically-developing children (Rueda, Rothbart, et al., 2005). Our program targeted atypically-developing children diagnosed with common impulse-control impairments, including ADHD, ODD, and CD. We sought to test the viability of computerized AT as an alternative to current drug-based therapies.

Despite previously reported post-training improvements on the child versions of the ANT (Rueda, Rothbart, et al., 2005) and Simon task (Capilla Gonzalez, 2007), our results do not reveal significant improvement on these indices of attention. This finding may reflect that our training period was too short to produce measurable changes on objective tests of attention. Indeed, our modified protocol involved less training than the previous five-hour AT program (Rueda, Rothbart, et al., 2005) as well as other computerized AT studies that showed post-training improvements on tasks related to executive attention (Klingberg, et al., 2005; Klingberg, et al., 2002). Hence, longer periods of training may result in more robust effects. A lack of observed changes in performance on the measures of attention administered may also suggest that participants – particularly the older ones – performed at maximal capacity during the baseline assessment, and therefore reflect a ceiling effect. In this case, there may be a need to increase the levels of difficulty on the administered tests of attention.

Participant scores improved throughout all groups on the verbal standardized index of intelligence. This finding likely reflects the natural effects of development over time, particularly in our sample of children receiving specialized attention in the rehabilitation program at the JGH or with an external therapist. Test-retest effects may also account for this observed improvement, although this explanation is less likely given the test-retest validity of the RIST and RIAS. Participants in the treatment and placebo-control groups, but not in the waitlist-control group, significantly increased their scores on non-verbal indices of intelligence administered. This finding suggests that the behavior-training component of our AT program through use of the "Secret Agent Academy" protocol may also influence performance. By receiving behavioral feedback throughout each session and learning to uphold morale when faced with challenging situations, participants in both the treatment and placebo-control groups may have adopted self-reinforcement strategies that manifest outside the context of training. This would enable children to strengthen their perception of personal potential and increase their motivation to perform better. Finally, familiarity with the testing environment may partially account for these findings. While research assistants never trained the same person that they evaluated on pre- and post-assessments, the rooms used for both training sessions and assessments were consistent for each participant. This explanation is less likely, however, due to the lack of observed improvement in participants assigned to the waitlist-control group, who also completed pre- and post-assessments in the same room.

Possible interpretations of increased scores on intelligence scales are nevertheless limited due to the observed differences between the three groups at the pre-assessment. One possible explanation for this finding may stem from potential disparities in the diagnoses of the participants. The intention of this study was to evaluate the effectiveness of an AT paradigm in children diagnosed with impairments in impulse-control. For this reason, we did not perform a standardized diagnostic assessment but, instead, required participants to have a diagnosis of ADHD, ODD, or CD prior to inclusion. Having recruited participants from one of three clinical teams at the JGH as well as from external sources, there may have been some disparity in the diagnoses based on each clinician's personal tendencies. As a result, participants may have had slightly varying degrees of severity in their symptomatology upon inclusion in the study. Similarly, underlying differences in the neurological functioning of children who exhibit symptoms more strongly related to either ADHD, ODD, or CD may also account for these findings (Rubia, 2011). The range of age within each group is unlikely to account for these baseline differences since there were no significant differences in age between the three groups.

Data from the parent reports of behavior suggest that the current AT protocol can enhance subjective perception of behavior related to impulsivity and inhibitory control, as indexed by a significant improvement on those respective scales of the CBQ and TMCQ questionnaires. Parents further noted a non-significant decrease in symptomatology related to atypical childhood behavior, including depression and hyperactivity, on the BASC-II questionnaires. These findings indicate that the combination of computerized AT and behavioral feedback facilitated subjective improvements in adverse childhood behavior, and that these improvements may not manifest with behavioral training alone – even when administered in the context of a rehabilitation program.

In addition, our analysis of clinical reports revealed that, for a number of participants, AT produced clinically-significant improvements in symptomatology related to attention, depression, and hyperactivity. Interestingly, the individual reports also reveal clinically-significant improvements in subscales that were beyond the scope of our evaluation. Notable examples include Aggression, Adaptability, and Leadership. This finding demonstrates that average data may mask individual benefits of AT, which are an important consideration given the clinical potential for such programs. Currently, primary treatment options for children with common impulse-control largely consist of psychostimulant medication, despite reports of adverse side-effects including insomnia, diminished appetite, cardiovascular problems, and substance abuse (Bejerot, et al., 2010; Daughton, et al., 2010; Elia, et al., 1999). Although psychostimulants are effective in reducing symptoms in the majority of cases (Daughton, et al., 2010), some children do not respond to these medications. Given the long-term health concerns associated with current pharmaceutical therapy and the clinical effectiveness of AT for certain individuals, AT programs may serve as a better primary treatment option for these children, particularly within the context of a more extensive rehabilitation program.

Limitations

Our modest sample size did not allow for meaningful age comparisons between subjects, which may have revealed age-related training effects due to the rapid development of the attention networks between 4-7 years of age (Posner & Rothbart, 2007b). This period of attentional development may enable younger children to experience greater benefits of AT compared to older children. In addition, low response rates prevented analysis of teacher responses as well as responses at the two-month follow-up. Inability to evaluate teacher responses constitutes a major caveat because many of the behavioral manifestations of impulse-control impairments such as ADHD become most prominent in the classroom, where children face both academic and social pressures. Thus, collecting teacher-ratings of behavior would enable a more meaningful evaluation of AT as a potential treatment avenue. Likewise, data from the long-term assessments would offer an index of the sustainability of post-training benefits, which represents another important consideration regarding the clinical merit of AT.

Conclusions

In the present study, we evaluated the effects of a 10-session computerized AT program in children with common impulse-control impairments. We coupled the computerized training with a motivational paradigm whereby children were told that they were training to become a “Secret Agent” and received behavioral feedback throughout each session. While we did not observe significant changes in measures of attention, our findings suggest that computerized AT may facilitate improvements in measures of behavior and intelligence in clinical populations, particularly when combined with a motivational paradigm. Furthermore, in certain cases, such training can improve clinical symptomatology of behavioral disorders including ADHD, ODD, and CD, and may therefore represent a viable adjunct or alternative to pharmaceutical treatment. The benefits of such short-term programs, however, are generally subtle and may become more pronounced with longer periods of training and with more refined techniques such as neuroimaging. Future studies will need to ascertain optimal training periods and compare the effectiveness of computerized AT with drug-based therapy as well as other rehabilitative programs.

General Discussion and Conclusions

Brain training has grown into a household term. With individual programs advertised to improve a wide range of cognitive skills and behavioral shortcomings, such training has garnered the interest of both clinicians and lay consumers. Brain training programs are enticing as a potential therapeutic avenue for individuals with cognitive or behavioral impairments, particularly in cases where treatments primarily revolve around medication. Because many programs require considerable time commitment and monetary resources, however, we sought to determine the scientific validity regarding claims of effectiveness and sustainability. Findings from our review suggest that, while brain training can facilitate changes within neural functioning and may offer tangible benefits to specific populations, there is a notable disparity between what scientific experimentation has shown and what product developers advertise. These disparities may stem, at least in part, from the fact that companies often lead their own investigations or base their claims on testimonial evidence. We highlight the potential biases and pitfalls introduced when relying on such non-scientific evidence in our commentary, provided in Appendix D.

The purpose of our study was to elucidate the potential of AT – one increasingly popular and easily-accessible form of brain training – for treating children with common behavioral disorders that involve impairments in impulse-control. We supplemented the computerized training with a motivational paradigm in order to promote self-regulation through role-playing and personalized behavioral feedback. Our findings demonstrate that such programs may lead to improvements in subjective ratings of behavior related to impulsivity and inhibitory control. This finding is promising, as these behaviors closely associate with executive function (Enticott et al., 2006) and may therefore indicate maturation in this system as a result of training. Moreover, individual clinical reports strengthen these findings by showing clinically-significant post-training improvements in symptoms related to depression, hyperactivity, and attention in a number of participants. Our findings further support previous reports that show improvements in specific indices of intelligence, particularly non-verbal intelligence, following training (Klingberg, et al., 2005; Rueda, Rothbart, et al., 2005). Contrary to previous reports, however, we found no significant improvement in performance on objective measures of attention. While unexpected given the nature of the training program, disparity between ages and baseline severity of clinical symptomatology may have facilitated a ceiling effect for older or less-impaired participants on the attentional measures used and thereby account for this finding.

Due to the constraints of the Master's program, our study focuses on behavioral outcome measures that provide standardized indices of attention, intelligence, and childhood temperament. The experiments described are therefore a preamble to more thorough investigations, including neuroimaging studies that would offer a glimpse of subtle effects of such programs at the more fundamental neural level. In addition, studies investigating AT over a longer training period and using a larger sample would likely uncover more meaningful findings. We are currently in the process of carrying out one such study in a cohort of children at Akiva Elementary, a private school in Westmount, Quebec. This sample includes both typically and atypically developing children, 8-10 years of age, training with slightly more challenging games that we have developed based on the model used in the current experiments.

Extended periods of brain training – including AT – would likely produce more potent effects. Studies show that exercising attention, through computerized or alternative means, can alter neural morphology and patterns of activation (Fox, et al., 2005; Rueda, Rothbart, et al., 2005; Tang, et al., 2010). Such changes in neural structure and function would likely manifest behaviorally following prolonged periods of training. In addition, supplementing training programs with a motivational paradigm analogous to the one we developed would likely increase compliance as well as provide participants with an opportunity to take on roles that require behavior that is desirable outside the experimental context. Thus, whereas the "quick and easy" solutions currently advertised by commercialized products hardly produce meaningful cognitive and behavioral changes, long-term programs – especially when integrated into daily lifestyle – would likely facilitate lasting improvements. Establishing the effectiveness and sustainability of these programs, however, should be on the forefront of brain training research.

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Appendix A – Sample of Scripts for Behavioral Feedback

General words of encouragement:

"You're so good at this Mission!"

"Wow, you were SO close! Let's try that one again!"

"You're making agent Cat really happy!"

"It's okay, that one was just a little tricky, but I think you can do it this time! Let's try it again!"

"We're almost done with this Mission! You're doing such a good job. Let's try just a couple more before the "beep" sound."

"Wow, that police officer/sergeant/detective/inspector/secret agent is paying a lot of attention to the clues!"

"Great job!"

"You are doing great at this secret agent training!"

"Wow, you caught the bad guy/clue/right trail!"

If the child is trying to look at the timer:

"Remember try your best, we are close to hearing the timer go off and you will soon have your sticker!"

"Just a few minutes more and you will have your sticker/secret prize".

"Just a few more tries and you will get to choose your sticker to put on your ID card",

"Don't forget after four stickers, you get a secret prize and you will become a ________(e.g., detective)!".

If the child says: "I can't do it, this is too hard"

"Don't let the bad guy make you feel angry!"

"You are feeling tired because the training is working. Don't get discouraged, you are doing very well! Just a few minutes more and you will have a sticker/secret prize/break.

If the child says: "This is boring" or "I am bored" or becomes distracted

"If you get tired, it's a good sign – training your attention is tricky and getting tired means that you're really working out your Secret Agent skills! Even feeling a little bit

bored is normal – that means you're training patience. Secret Agents are really good at being patient. But, we can make it fun as long as we have a good attitude!"

"Come on! Try your best, only a few minutes before the sticker time."

If the child is getting frustrated with the speed:

"You are training your patience as well. The bad guy wants to make you feel mad so that you lose control and you don't pass the level; keep a positive attitude!"

"Great job, no bad guy/trap/clue can get away from you!"

Example of script used for assistance and reinforcement on one of the AT games:

Mission Name: Uncover the right clues

"As part of your training as Secret Agent you need to have a great visual memory so the clues cannot be misplaced. First, you click inside this top clue box. Then the number with the clues will appear.

Let me show you what to do.

You click inside this box, then clues, will appear.

Can you count how many clues are here?

Now I'll click inside the box again.

Which one is the same as before? I'm going to click on that one.

Hey, everyone's clapping for you!

OK, now you can try it."

(Trainers assist the children through the process until they can do it on their own)

If the child says the wrong number during the trials:

"Can you count them again?"

If the child continues to say the wrong number:

"Let's count them together." (Let the child count out loud as you point to the clues). *You are training to be an Inspector so, you have to be tough and you never lose heart!*

Appendix B – The Simon Task

The Child Simon Task; translated description taken, in part, from (Capilla Gonzalez, 2007)

The child version of the Simon Task involves *congruent* stimuli, which appear in the same visual hemi-field as the hand that makes the response, and *incongruent* stimuli, appear in the contralateral hemi-field (see Figure 10). Children sit facing a computer screen with a computer-mouse on each side (i.e., one on the left and one on the right). The task comprises two consecutive blocks of trials, where children must click the button on the mouse that corresponds to where the pencil stimulus is pointing during each trial (see Figure 11). Stimuli remain on-screen until participants respond, in order to minimize working memory demands of the task and thereby isolate inhibitory processes as much as possible. The first block of trials presents 96 congruent stimuli, of which 48 are on the right side and 48 are on the left side. In the second block of trials, both congruent and incongruent stimuli are presented on both sides, in an interleaved manner. There are 64 congruent stimuli (32 on each side) and 32 incongruent stimuli (16 on each side). Each block of trials contains two sequences of 24 stimuli presented in an original sequence (A) or its homologue (B), generating a design of A-B-B-A; this enables a counterbalance of sequence presentation.

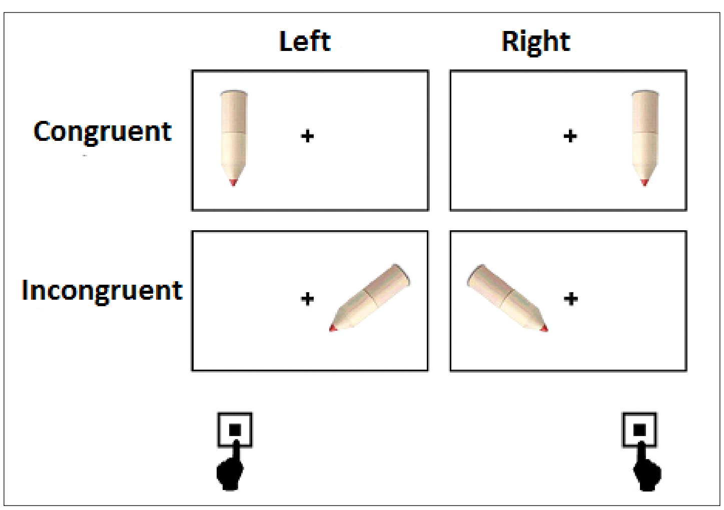


Figure 10. Stimuli of the Child Simon Task (Capilla Gonzalez, 2007).

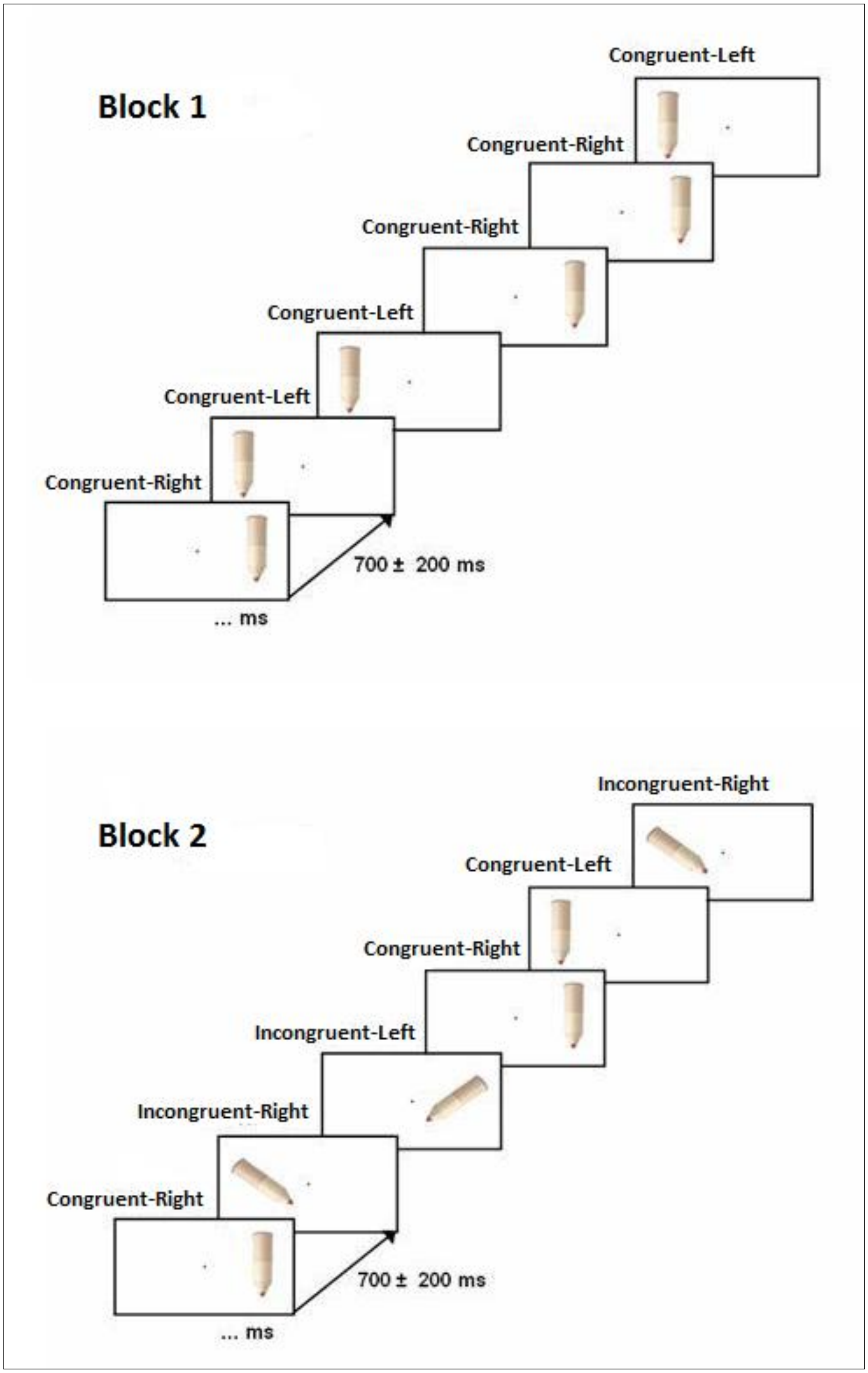
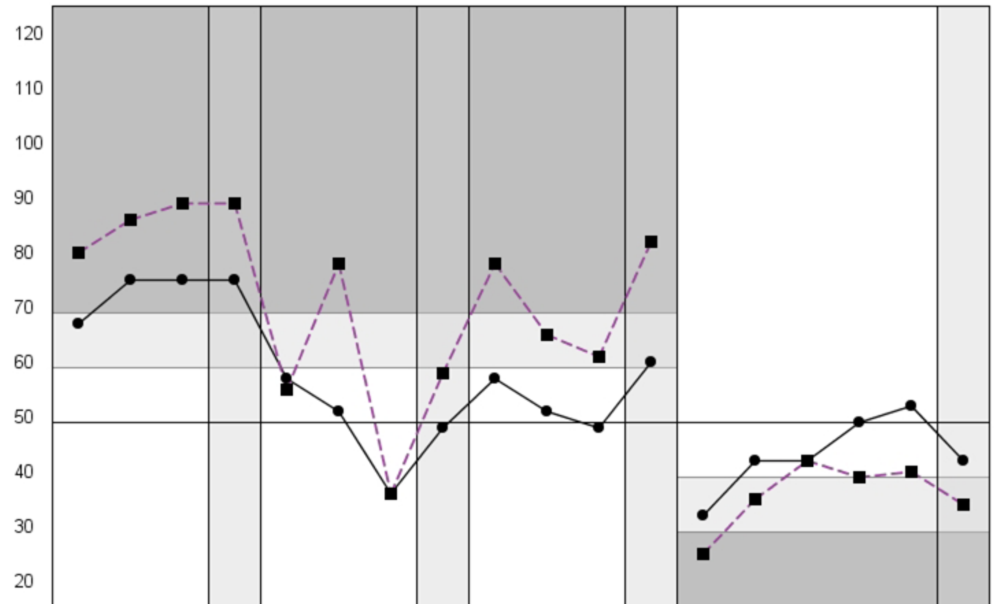


Figure 11. Schematic of trial sequences on the child version of the Simon Task.

Appendix C – Individual Participant Reports on the BASC-II Questionnaire

The figures below represent individual reports from four male participants in the treatment group. The scores indicated in the graphs represent standardized T scores, based on parent ratings. We provide these reports to demonstrate the profiles of participants who experienced clinically-significant improvements in at least one out of the Depression, Hyperactivity, and Attention Problems subscales of the BASC-II.



T Score	Hyperactivity	Aggression	Conduct Problems	Externalizing Problems	Anxiety	Depression	Somatization	Internalizing Problems	Atypicality	Withdrawal	Attention Problems	Behavioral Symptoms Index	Adaptability	Social Skills	Leadership	Activities of Daily Living	Functional Communication	Adaptive Skills
● *T* Score	67	75	75	75	57	51	36	48	57	51	48	60	32	42	42	49	52	42
■ *T* Score	80	86	89	89	55	78	36	58	78	65	61	82	25	35	42	39	40	34
● Percentile	94	97	97	98	77	64	4	45	82	63	47	86	5	21	23	45	53	21
■ Percentile	99	99	99	99	72	98	4	81	98	91	84	99	1	8	23	15	17	6

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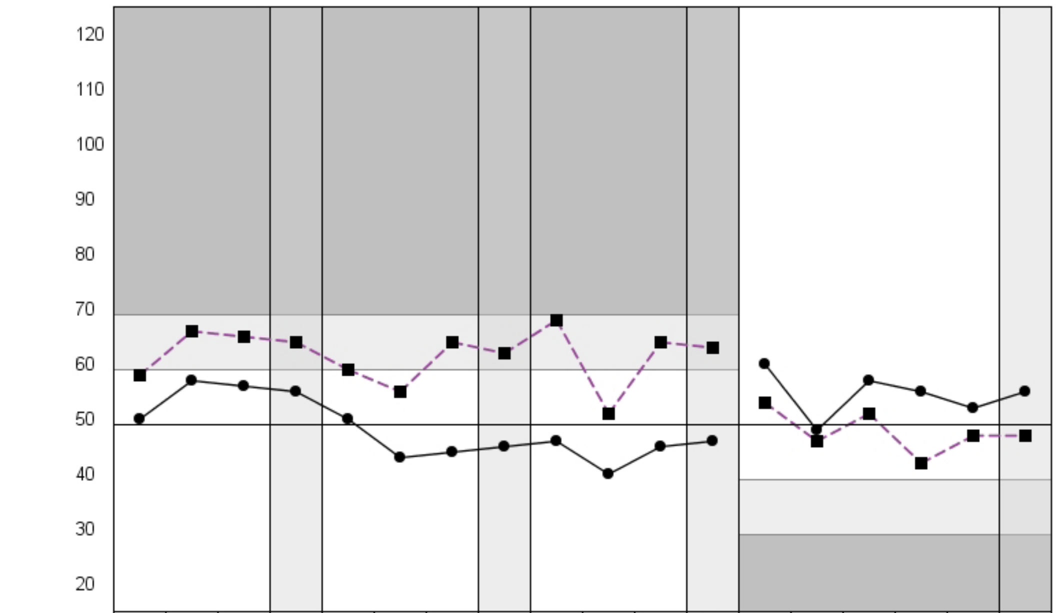

	Hyperactivity	Aggression	Conduct Problems	Externalizing Problems	Anxiety	Depression	Somatization	Internalizing Problems	Atypicality	Withdrawal	Attention Problems	Behavioral Symptoms Index	Adaptability	Social Skills	Leadership	Activities of Daily Living	Functional Communication	Adaptive Skills
● *T* Score	50	57	56	55	50	43	44	45	46	40	45	46	60	48	57	55	52	55
■ *T* Score	58	66	65	64	59	55	64	62	68	51	64	63	53	46	51	42	47	47
● Percentile	57	81	80	75	54	27	33	32	46	13	37	39	82	42	75	65	53	68
■ Percentile	82	93	92	92	81	76	90	88	94	63	89	90	58	34	52	20	34	38

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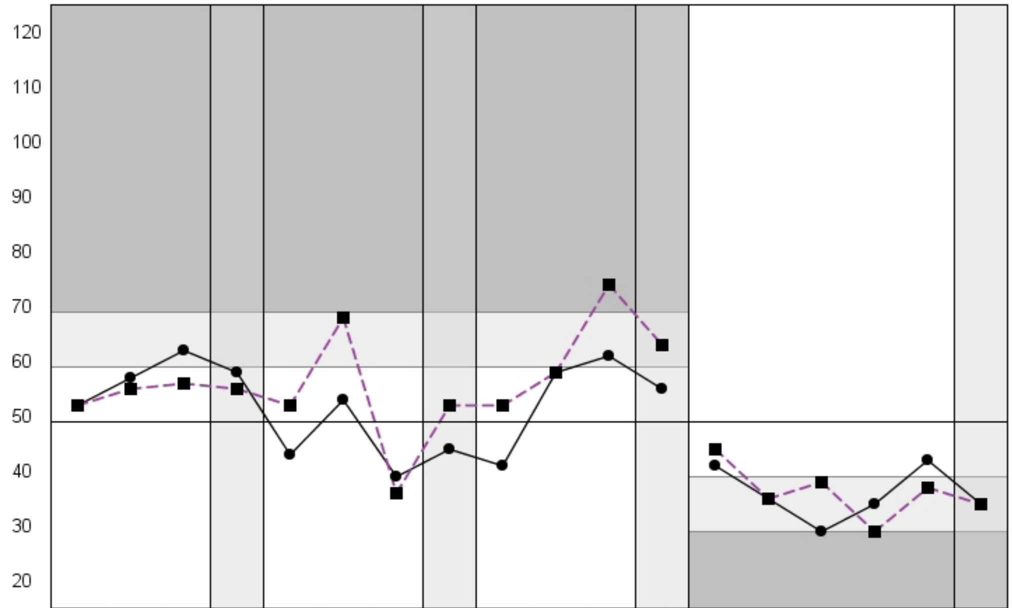

	Hyperactivity	Aggression	Conduct Problems	Externalizing Problems	Anxiety	Depression	Somatization	Internalizing Problems	Atypicality	Withdrawal	Attention Problems	Behavioral Symptoms Index	Adaptability	Social Skills	Leadership	Activities of Daily Living	Functional Communication	Adaptive Skills
● *T* Score	52	57	62	58	43	53	39	44	41	58	61	55	41	35	29	34	42	34
■ *T* Score	52	55	56	55	52	68	36	52	52	58	74	63	44	35	38	29	37	34
● Percentile	65	81	89	82	27	70	11	29	13	81	84	74	20	8	2	7	20	6
■ Percentile	65	76	80	75	61	94	4	65	69	81	99	89	26	8	12	3	11	7

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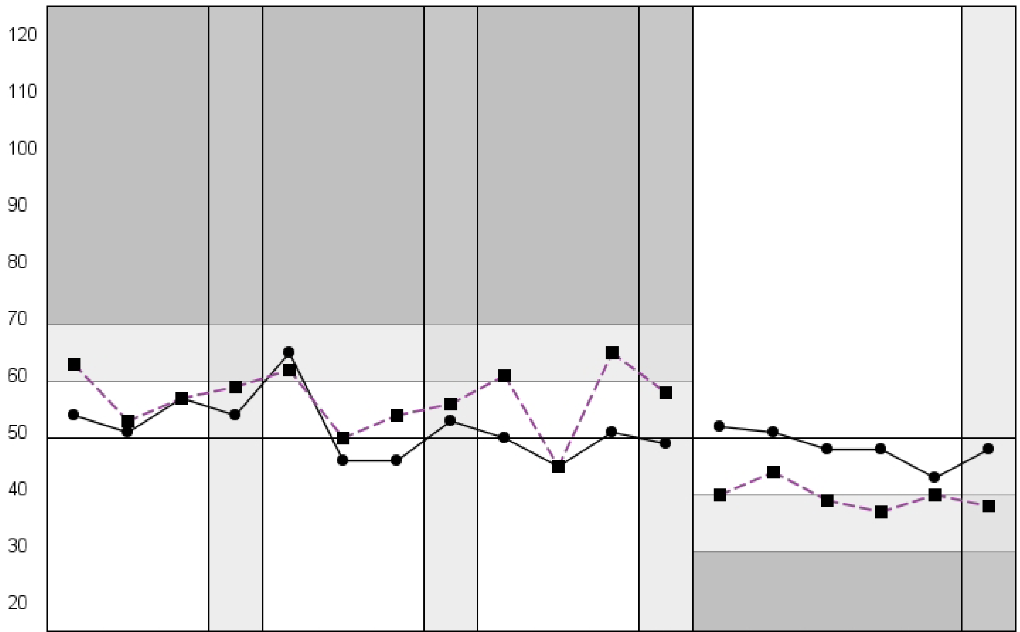

	Hyperactivity	Aggression	Conduct Problems	Externalizing Problems	Anxiety	Depression	Somatization	Internalizing Problems	Atypicality	Withdrawal	Attention Problems	Behavioral Symptoms Index	Adaptability	Social Skills	Leadership	Activities of Daily Living	Functional Communication	Adaptive Skills
● *T* Score	53	50	56	53	64	45	45	52	49	44	50	48	51	50	47	47	42	47
■ *T* Score	62	52	56	58	61	49	53	55	60	44	64	57	39	43	38	36	39	37
● Percentile	69	58	76	70	91	36	34	63	61	30	54	49	51	48	39	35	20	35
■ Percentile	89	66	76	81	85	55	69	75	86	30	90	79	16	25	13	10	13	10

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Appendix D – Commentary

(Manuscript 3)

In response to "Brain Branding: When Neuroscience and Commerce Collide", by Bree Chancellor and Anjan Chatterjee

AJOB *Neuroscience*, 2(4): 18-27, 2011

Quandaries and Perspectives on Potential Bias

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In their thought-provoking article, Chancellor & Chatterjee address the current trend in academia to sustain financial relations with industry. Here we acknowledge the perils of introducing such conflicts of interest (COI) in research and clinical practice, and argue that these conflicts pose an equal threat to academic integrity in situations unaffiliated with industry. We further contend that current guidelines stipulating disclosure of financial conflicts are hardly adequate preventative measures. Broadening the context of COI and acknowledging the deficits of disclosure, we propose a more rigorous defense against potential industry-inflicted bias.

COI can arise in a number of situations outside of industry. Defined broadly, such conflicts comprise “a set of conditions in which professional judgment concerning a primary interest, such as a patient’s welfare or validity of research, may be unduly influenced by a secondary interest such as financial gain” (Stossel, 2007). Recent, high-profile cases of research misconduct involving a prominent Harvard psychologist and a South Korean investigator at Seoul National University (Normile, 2009) epitomize cases where the stress of excelling in a competitive academic scene skews scientific work. Even students may succumb to partiality as a result of pressures to stand out in their fields of study. For example, lack of practice allegedly motivated surgical residents in Greek universities to falsely diagnose immigrants with appendicitis in order to glean additional experience (Tatsioni et al., 2001). In such instances, the secondary interests creating conflict arise from pressures to outshine colleagues rather than industry involvement (Lilienfeld, 2010).

Despite firm beliefs by researchers and clinicians that their work cannot be influenced by a third party, bias resulting from COI is often subtle and unintentional (Kassirer, 2009a). Defenders of COI assert that segregation between clinical goals and promotional motivation is impossible: even researchers usually strive to showcase their work, and clinicians often attract clientele through advertising (Stossel, 2007). Such ambition-related COI, however, likely stem from human tendencies and remain inherent to individual scientific pursuits.

Industry-related COI, on the other hand, result from conscious decision and are therefore preventable (Kassirer, 2009b). The intrinsic nature of certain COI demands avoidance, whenever possible, of conflicts under voluntary control, such as those mediated by ties to industry.

In the cases where industry involvement necessarily ties to research, such as during the development of commercial products, the scientific community often considers the peer review process and disclosure as panaceas for COI. History has nonetheless demonstrated the limitations of peer-review in upholding scientific rigor, perhaps most notably through the infamous reports linking autism to the measles, mumps, and rubella vaccine (Eggertson, 2010). While Chancellor & Chatterjee emphasize that the issue surrounding COI lies within the potential for bias, they further suggest that such conflicts are only problematic if “colleagues remain unaware of these ties”. Undoubtedly, discovering undisclosed links between companies and the researchers testing their products engenders suspicion regarding the objectivity of experimental findings. In some cases, uncovering such relations has even led to the removal of prominent academic figures from their esteemed positions in order to maintain academic integrity ("Credibility crisis in pediatric psychiatry," 2008). For this reason, a number of institutions require detailed elaboration on any ties between researchers and industries that stand to profit from their work (Stossel, 2007).

Does disclosure protect against potential bias? Scientists who shelter themselves behind the veil of disclosure simply attest to the existence of a COI without confirming or denying partiality in their work (Kassirer, 2009a). The burden of identifying bias therefore passes to the impacted public, allowing researchers and clinicians to continue receiving royalties from the companies involved. By continuing to consider disclosure as an adequate solution to COI, we may perpetuate reports and clinical practices laced with subtle influences that counteract the very purpose of research and medicine: to advance knowledge and improve standards of daily living. The threat of skewed research is of particular concern for clinical populations, who may end up disregarding a better treatment alternative or relying on medication carrying substantial side-effects. The chronicles of pharmaceutical research contain a number of cases involving the distribution of harmful products as a result of corrupt studies (Brody, 2008). Prominent psychiatrists from Harvard and Stanford, for example, were instrumental in fostering a drug-friendly climate, which had been allegedly fuelled by undisclosed contributions from pharmaceutical companies ("Credibility crisis in pediatric psychiatry," 2008). The scientific community therefore faces a pressing need to re-evaluate the implications of COI in research and reconsider the practical effectiveness of disclosure.

Given the shortcomings of disclosure, we propose to establish new clinical research standards modeled after clinical practice guidelines. To create viable products, Chancellor & Chatterjee encourage closer alignment with clinical standards of care, yet barely mention that these standards also draw on research with potential COI. For example, clinicians sometimes administer therapies they are still investigating (e.g., psychotherapy, cognitive training) as part of lucrative private practices. The observed benefits of these therapies, however, may arise due to psychological phenomena such as the placebo effect, which continue to bewilder the scientific community. In order to prevent secondary influences from tarnishing scientific rigor yet still benefit from industry-mediated coffers, certain scholars advocate for an indirect relationship between industry and its scientists (Sniderman & Furberg, 2009). With this principle in mind, we believe that the scientific community may better preserve the objectivity of research by introducing a neutral organization through which all clinical trials must proceed.

Acting independently from specific companies and research groups, a Federal Regulating Body (FRB) could mediate between industry and academia. This hypothetical organization would be particularly useful for the evaluation of psychological tools and remediation techniques (e.g., brain training software). Largely unregulated and poorly understood, such psychological applications tend to beguile the public with scientific jargon, and may influence behavior and cognitive function as much as pharmacological agents and medical devices.

Hence, not unlike the Food and Drug Administration (FDA), the FRB could evaluate efficacy, effectiveness, and safety of psychological products that companies wish to promote. Whereas the FDA reviews submitted reports using its in-house staff, however, the FRB could blindly assign researchers to independently assess these products – in a similar fashion to sitting on a grant panel or reviewing for a scientific journal. The FRB could provide research groups with an opportunity to weigh in on these issues with their academic and experimental expertise. Validating commercial products through this system could develop into a binding standard for companies intending to advertise the safety and efficacy of their products. Both successful and unsuccessful applications would appear in an open-access FRB website for the benefit of the public. In this way, the FRB would confer credibility to previously unregulated consumer products. Adopting this method, the scientific community may better evade research bias and uphold the integrity of the consumer-industry relationship.

From industry relations to personal ambition, COI threaten the reliability of research and clinical practice. While the scientific community invokes disclosure as protection against potential bias, the continuing impact of such conflicts on academic integrity calls for more rigorous preventive methods. When avoidance is unfeasible, as in the development of commercial products, we advocate for the establishment of a neutral third party to mediate between researchers and the source of conflict. Adopting more scrupulous COI protocols would bolster the credibility of scientific discovery and enhance acceptability by consumers.

We thank members of the Raz Lab for helpful comments on earlier drafts of this manuscript.