Working Memory Training for Children with Attention Problems or Hyperactivity: A School-Based Pilot Study

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Abstract We piloted a computer program to train working memory for children with attention problems or hyperactivity who attended an urban public school serving economically disadvantaged neighborhoods. Training was conducted daily for 5 weeks during school hours. Teachers rated children’s behaviors before and after the intervention, and standardized assessments of verbal and visuo-spatial working memory were also conducted. No attrition occurred due to an inability or unwillingness on the part of children to complete the training. Overall, children’s behavior and working memory improved following training, compared to baseline. Our findings suggest that school-based working memory training may be a viable means for treating children with attention problems or hyperactivity that warrants further investigation. This approach may also overcome barriers to care delivery for economically disadvantaged children who are known to be at higher risk for poor school outcomes.

Keywords ADHD · Attention problems · Computer-assisted learning · Hyperactivity · School-based interventions · Working memory training

Introduction

Problems of inattention, hyperactivity, and impulsivity of the sort typically seen in children who suffer from attention-deficit hyperactivity disorder (ADHD), when left unattended, have been associated with school failure, social isolation, depression, substance abuse, delinquency, and suicide (Biederman et al., 2004, 2006; Drabick, Gadow, & Sprafkin, 2006). As a result, investigators have assiduously sought to identify core deficits underlying the observable symptoms of ADHD in an effort to devise effective treatments. Impairments in executive function have shown promise in this regard.

For example, Barkley (1997) proposed a conceptual model that involves the interplay of different components of executive function in order to explain the symptoms seen in ADHD. In this model, behavioral inhibition is purported to be necessary for other processes such as working memory to inform the subsequent planning and regulation of goal-directed behaviors. In fact, working memory, the focus of this study, is the ability to keep information accessible for as long as it is necessary to guide and carry out goal-directed behaviors. For everyday purposes, one needs working memory to remember what to focus on, what to do next, and how to do it.

Conceptually and heuristically, working memory is often separated into verbal and visuo-spatial domains. Each domain is further subdivided into recall and manipulation. Recall involves an exact reproduction of information; for example, repeating a sequence of objects or numbers in the same order they were given. Manipulation involves recall of information in some alternative manner, for example, repeating a sequence of numbers backward, or grouping objects by supra-ordinate rules (e.g., animals, fruits, etc.), and reflects the capacity to recall and utilize information in

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more flexible ways. Like other executive functions, the proficiency of working memory matures considerably with development from preschool through adolescence (Conklin, Luciana, Hooper, & Yarger, 2007; Luciana, Conklin, Hooper, & Yarger, 2005). This maturation in proficiency corresponds to changes in frontal-parietal gray matter structures and their white matter inter-connections (Klingberg, 2006).

Empirical research by other investigators, while never actually testing the model originally proposed by Barkley (1997), has nonetheless supported the potential explanatory value of working memory deficits among the underlying problems encountered in ADHD. A meta-analysis of working memory performance indicated that verbal and visuo-spatial working memory are both compromised in children with ADHD, with greater impairments noted for the manipulation of visuo-spatial information (Martinussen, Hayden, Hogg-Johnson, & Tannock, 2005). Neuro-imaging studies of normal development of working memory capacity on the one hand, and the neural correlates of ADHD on the other, suggest commonalities in the brain substrates underlying the two. Maturation of frontal-parietal gray matter structures and their white matter inter-connections was associated with increases in working memory capacity between early childhood and mid-adolescence (Klingberg, 2006), as well as with symptoms of ADHD when these structures appeared to be less functionally active (Dickstein, Bannon, Castellanos, & Milham, 2006).

Barkley’s views (1997) concerning possible mechanisms underlying the symptoms of ADHD are actually embedded within a broader theoretical model addressing the regulation of goal-directed behavior. This model is consistent with the perspectives of others, in that the observable inattention and hyperactivity–impulsivity encountered in children with ADHD can be conceptualized as relative failures of behavioral regulation, often referred to as self-regulation, that have equally important implications for interference with adaptive functioning as they do for the production of symptoms (Blair & Diamond, 2008; Buckner, Mezzacappa, & Beardslee, 2009; Posner & Rothbart, 2000). This conceptualization permits psychopathology and any related impairments to be studied from the perspective of the components and skills that support self-regulation and to design interventions targeting symptoms and adaptive functioning through these fundamental self-regulatory skills.

There is mounting evidence for the plasticity of self-regulatory skills, as well as emerging data suggesting that both typically developing children and children with impairments may benefit from interventions designed to improve these skills. For example, a universal, preventive, classroom-based preschool curriculum designed to enhance a range of executive functions, including working memory, led to greater improvements in school-readiness skills compared to a standard preschool preparatory curriculum that focused solely on content-based skills (Diamond, Barnett, Thomas, & Munro, 2007). In a similar vein, typically developing preschool children showed improvements in working memory following cognitive training, along with improvements in non-trained attentional skills, suggesting that training of one skill may transfer to related skills (Thorell, Lindqvist, Nutley, Gunilla, & Klingberg, 2009).

Interventions designed to strengthen self-regulatory skills may be particularly relevant for children whose skills are lagging or impaired, since these abilities are crucial to successful adaptation both in and out of school. For example, Holmes et al. (2009) reported that cognitive training for children with working memory deficits led to sustained enhancement of this skill and was associated with improvement in mathematical skills assessed 6 months following the intervention, indicative of enduring transfer of trained skills to meaningful school function.

A handful of studies to date have adopted cognitive training interventions for children who suffer from ADHD. Klingberg et al. (2005) tested a computer program designed to improve working memory in children struggling with ADHD. After 5 weeks of training, they observed positive effects on visuo-spatial working memory, verbal working memory, complex reasoning, and parent-reported symptoms of inattention and hyperactivity–impulsivity. Once again, there was evidence for transfer of training effects to non-trained skills and to observable behavior, which was still present when children were re-assessed 3 months following the intervention.

Using the program developed by Klingberg et al. (2005), Holmes et al. (2010) compared the effects of cognitive training to stimulant medication on working memory deficits in children with ADHD. With Badessey’s (2000) model of working memory as the underpinning for the assessments used in this study, they found that cognitive training improved verbal, visuo-spatial, and executive aspects of working memory alike. Furthermore, the beneficial effects on executive working memory were apparent 6 months after the intervention was completed, while stimulant medication was associated with non-enduring improvements in visuo-spatial working memory. Finally, Shalev et al. (2007) studied computerized training for sustained, selective, orienting, and executive attention in children struggling with ADHD. They focused on the transfer of training effects to behavioral and school performance indices and found significant improvements in reading comprehension and passage copying, and in parent reports of inattentiveness.

Compounding the problems encountered with attention problems, hyperactivity and impulsivity per se, children living in poverty are at heightened risk for developing