


Computer-Based Attention Training in the Schools for Children With Attention Deficit/Hyperactivity Disorder: A Preliminary Trial

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Abstract

Objective. This study examined the efficacy of 2 computer-based training systems to teach children with attention deficit/hyperactivity disorder (ADHD) to attend more effectively. **Design/methods.** A total of 41 children with ADHD from 2 middle schools were randomly assigned to receive 2 sessions a week at school of either neurofeedback (NF) or attention training through a standard computer format (SCF), either immediately or after a 6-month wait (waitlist control group). Parents, children, and teachers completed questionnaires pre- and postintervention. **Results.** Primary parents in the NF condition reported significant ($P < .05$) change on Conners's Rating Scales–Revised (CRS-R) and Behavior Assessment Scales for Children (BASC) subscales; and in the SCF condition, they reported significant ($P < .05$) change on the CRS-R Inattention scale and ADHD index, the BASC Attention Problems Scale, and on the Behavioral Rating Inventory of Executive Functioning (BRIEF). **Conclusion.** This randomized control trial provides preliminary evidence of the effectiveness of computer-based interventions for ADHD and supports the feasibility of offering them in a school setting.

Keywords

ADHD, neurofeedback, biofeedback, computer attention training

Objective

Attention deficit/hyperactivity disorder (ADHD) is a neurologically based behavioral disorder whose core symptoms include hyperactivity, impulsivity, and distractibility/inattention. Prevalence estimates range from 4% to 10%. Comorbidities commonly include externalizing, internalizing, and/or specific learning disabilities,^{1–5} as well as trouble maintaining relationships with family and peers.^{6–8} Approximately 60% of children with ADHD continue to have symptoms in adolescence and into adulthood, leading to high risks of academic and vocational underachievement, interpersonal difficulties, substance abuse, and motor vehicle accidents.⁹

A great deal of research has demonstrated the efficacy of medication for treating the core symptoms of ADHD.¹⁰ However, about 30% of children experience adverse side effects,¹¹ such as appetite suppression,

insomnia, anxiety/irritability, rare but potentially serious cardiac problems,¹² and psychotic reactions,¹³ or they do not respond to medication. Long-term adherence to medication regimens is poor, with most estimates suggesting that fewer than 50% of children with ADHD maintain prescribed dosages over 6 months.¹³ Psychosocial interventions are time consuming, expensive, and have demonstrated limited effectiveness.¹⁴ Only about a third of primary care physicians believe that their community has adequate mental health resources to support these children and families.¹⁵

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Because of the limitations of medication, effective alternative therapies are needed.^{16,17} One form of treatment that has received increasing attention from researchers is computer-based attention-training exercises. Some systems rely on neurofeedback (NF; also called electroencephalography [EEG]-biofeedback) to detect and reinforce behaviors that are associated with increased attention as evidenced by specific brainwave patterns. Other systems use a standard computer format (SCF), a cognitive retraining approach to improve children's attention and concentration through a series of challenging exercises. We compared these 2 types of computer-based attention-training systems.

Attention Training With Neurofeedback

The rationale for commercially available computer training systems using NF is based on the finding that EEG patterns, as seen on quantitative electroencephalographic (QEEG) scans, differ between children with and without ADHD. Children with ADHD display increased frontal lobe low-frequency theta activity (associated with drowsiness),¹⁸⁻²¹ and a decrease in high-frequency beta wave activity (associated with a state of alert attention).^{20,22,23} The computer program provides them with immediate feedback about their level of attention, based on EEG wave activity. Through trial and error, children learn how to induce brain activity that yields the desired outcome.

Several studies suggest that attention training using NF may thereby result in a decrease in ADHD symptoms and improved academic performance and behavior.²⁴⁻²⁶ The American Academy of Pediatrics in its 2001 ADHD guidelines noted a "need for well-designed rigorous studies of currently promoted but less well-established therapies such as occupational therapy, biofeedback, herbs, vitamins, and food supplements."

Attention Training With Standard Computer Format

Other commercially available attention-training systems use a standard computer, mouse, and keyboard. The child plays a series of interactive computer exercises, which aim to improve attention, problem solving, and working memory. As children progress through the sessions, they are able to complete the tasks with increased ease and rapidity, and decreased impulsivity, thus accumulating a higher score, and moving ahead to more challenging levels. Preliminary evidence suggests that programs of this type improve performance on working memory tasks^{22,23,27} and decrease parent-rated symptoms of ADHD.^{22,23,28} Improvements may also generalize to

Table 1. Sample Characteristics

Age in years; mean (SD)	12.4 (0.9)
Male gender (%)	52.2
Race (%)	
Caucasian	74
Asian American	24
African American	6
Hispanic ethnicity	12
Family income (%)	
<\$50 000	10
\$50 000-\$74 999	7
\$75 000-\$99 999	21
≥\$100 000	62
Proportion using ADHD medication (%)	60

nontrained tasks, such as conceptual reasoning, mathematical problem solving, reading comprehension, and passage copying.^{22,23}

Although previous studies have suggested intriguing effects of both NF and standard format of attention-training systems, the lack of random assignment of participants to appropriate control groups makes their results suspect. Furthermore, no studies have been published that assess their use in nonlaboratory settings, for example, in schools. Thus our objective was to conduct a pilot/feasibility study comparing 2 computer-based attention-training systems and a waitlist control (WLC) group within a middle school setting.

Methods

Sample

Parents of all children in grades 6, 7, or 8 from 2 middle schools, with a combined student population of 1269, in a mid-sized city near Boston were invited to have their child participate via an informational announcement sent from the schools' parent-teacher organization. Parents responded to the announcement if they were interested. Children were eligible if they had a diagnosis of ADHD confirmed by their physician and sufficient English ability to complete assessments and intervention protocols. Both boys and girls were eligible, regardless of their subtype of ADHD or medication use. Children were excluded if they had a coexisting diagnosis of conduct disorder, pervasive developmental disorder, or other serious mental illness (eg, psychosis). Sample characteristics are given in Table 1.

The study was approved by the Tufts Medical Center Institutional Review Board. Informed consent was obtained from all parents, and all participating students provided informed assent.

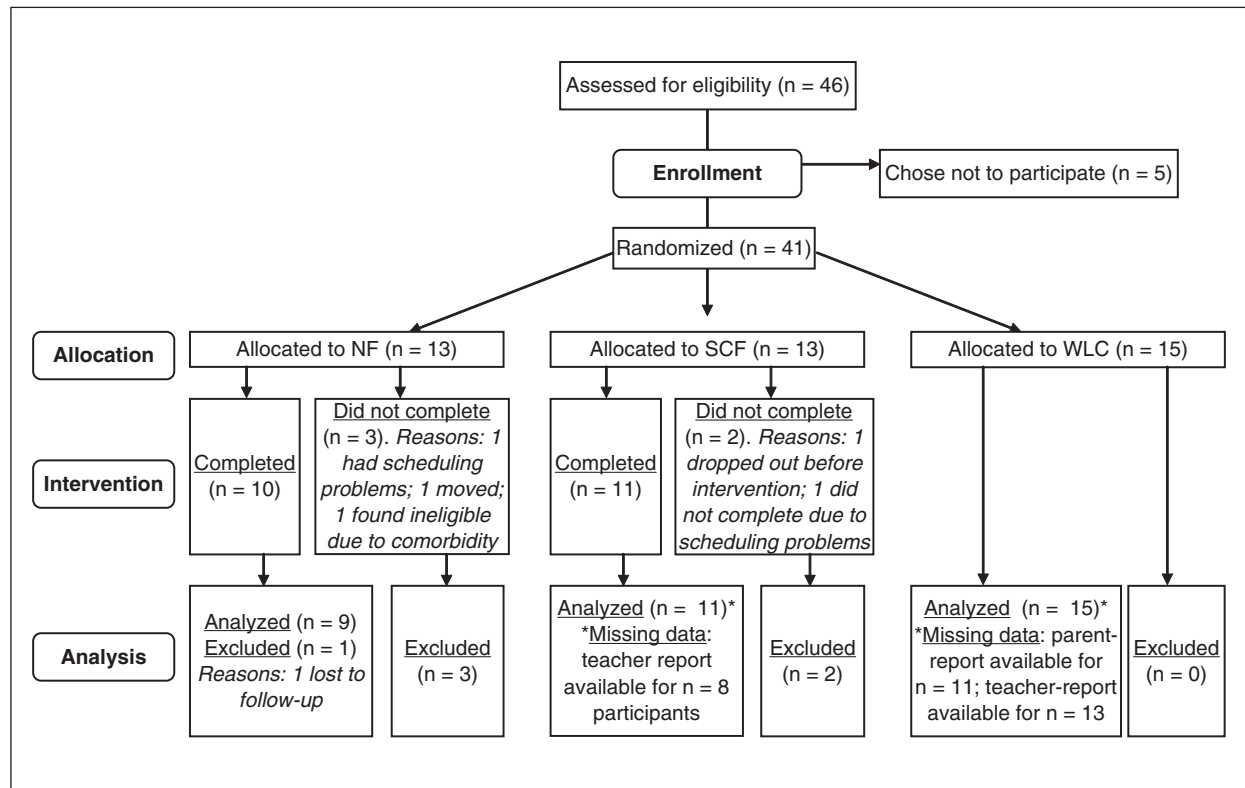


Figure 1. Consort diagram

Procedures

Families of 46 children initially requested participation and met eligibility criteria. Five ultimately chose not to participate. Using a computer-generated random digit generator, the remaining 41 were randomly assigned to one of the two commercially available computer-based interventions or to a WLC condition (Figure 1). All families were encouraged to continue with regular appointments with their physicians for treatment and evaluation during and after the interventions.

Interventions

Neurofeedback. This system detects 2 frequency ranges, one in the low-frequency theta range that has been associated with drowsiness (4 to 8 Hz), and another in the high-frequency beta range that has been associated with alert attention (12 to 16 Hz). Three EEG sensors are embedded in a bike helmet, 1 located at the top of the head, and 2 behind the ears on the straps. During NF training sessions, children play a simple computer game that involves flying an airplane. Children are told that if they concentrate, the airplane will go up, and if not, the plane will go down. An individual baseline is set at the

beginning of each session, and as the children progress they reach higher (more challenging) levels. The computer interface provides children with immediate auditory and visual feedback about the degree to which they are successful in paying attention.²⁹

Standard computer format. The SCF treatment includes an array of visual and auditory exercises designed to reduce impulsivity and increase attentiveness to the task being presented. The participants in this study used the attention training and working memory modules.³⁰

The authors had no financial interests in either of these commercial programs.

Waitlist control. Children in the WLC condition were provided no intervention until after the final postintervention assessment, after which they were invited to complete a course of SCF or NF.

During the 4-month intervention, children participated in 45-minute sessions twice a week, supervised by research assistants. One research assistant was assigned to 2 children at the same time, both practicing either NF or SCF. The same protocol was used for both the NF and the SCF groups. The 45-minute sessions included transition time from classroom to intervention room, review of previous session, 30 minutes of computer-based

Table 2. Outcome Measures

Instrument	Abbreviation	Scales Used for Analyses	Respondents
Conners's Rating Scales–Revised	CRS-R	Cognitive Problems / Inattention Scale Hyperactivity Scale ADHD Index	Parents, teachers, students
Behavioral Rating Inventory of Executive Functioning	BRIEF	Global Executive Composite Score	Parents, teachers
Behavior Assessment Scales for Children–2	BASC-2	Hyperactivity Scale Attention Problems Scale	Parents, students
Satisfaction with intervention			Parents, students
Integrated Visual and Auditory Continuous Performance Test	IVA-CPT	Full-Scale Response Control Quotient (FS RCQ) Full-Scale Attention Quotient (FS AQ)	Students

intervention, setting goals for the session, and return to class. Students received the intervention during the school's "team time" so that classroom instruction was not affected.

Fidelity to the protocol was ensured in several ways. Research assistants received standardized training following a written protocol on how to administer each intervention. Extensive care was given during training to inform the research assistants that both interventions were considered to be clinically equal to minimize bias. The research assistant prompted children if they became distracted, helped them set goals, and evaluated their progress. If the student was progressing successfully, the research assistant did not intervene. The research assistants completed checklists during each session that documented fidelity to intervention, progress, and any off-task behaviors observed. The first author observed each research assistant's sessions and reviewed their reports weekly to ensure persistent adherence to the protocol.

Outcome Measures. Outcome measures are described in Table 2.

Questionnaires. Parents, children, and teachers completed a systematic assessment pre- and postintervention. Parent questionnaires were completed by the primary caregiver, usually the mother, and whenever possible by a secondary caregiver, usually the father. The preintervention questionnaires were filled out at the time of enrollment at the end of the previous school year, and the postintervention questionnaires were filled out within 1 month after the intervention. An English or social studies teacher and a math or science teacher were asked to complete the checklists about each child before and after the intervention, and these scores were averaged to form a single teacher score. Because the child was in a different grade at each time point, teacher questionnaires were filled out by different teachers.

The Conners Rating Scales–Revised (CRS-R), was used to assess specific ADHD symptomatology. All

subscales display acceptable internal consistency, retest reliability, and factor structure.^{31–35} The Cognitive Problems/Inattention Scale, the Hyperactivity Scale, and the ADHD Index were used for the analyses. The Behavioral Rating Inventory of Executive Functioning (BRIEF) was used to assess executive functioning. The BRIEF has been found to display good reliability and convergent validity when compared with measures of inattention and impulsivity.³⁶ The Global Executive Composite Score was used for all analyses.

Behavioral symptoms were evaluated using the Behavior Assessment Scale for Children (BASC). The BASC has been shown to have adequate reliability and validity based on concurrence with similar scales.³⁷ The Attention Problems and Hyperactivity subscales were used for the analyses. After intervention was complete, parents and children also completed questionnaires developed for the study to assess their satisfaction with the intervention.

Continuous Performance Test. The children in both intervention groups completed the Integrated Visual and Auditory Continuous Performance Test (IVA CPT) pre- and postintervention. Although these measures are not recommended for individual clinical purposes, their use provides an objective assessment of group effects in a research context.

Medication usage. The research team was in the schools only to provide the intervention and had no clinical role nor any direct contact with parents. Medication usage was not monitored continuously, and was not a primary outcome measure; however, parents were asked about medication usage and dosage as part of the pre- and postintervention questionnaires.

Statistical Analyses

Descriptive statistics were calculated for demographic variables and for baseline data, and independent samples *t* tests were used to analyze differences between children who completed the research protocol and those

who did not. Repeated measures analyses of variance (ANOVAs) were conducted to determine whether each experimental condition was superior to WLC at the postintervention assessment, while controlling for preintervention scores, as well as to analyze changes over time within each condition in off-task behaviors during sessions and scores on each outcome measure. Cohen's effect sizes were also calculated for changes in scores. To capture changes in medication status, McNemar tests were used to determine whether the proportion of children using medication for ADHD changed over time, and then *t* tests were used to determine whether the dose of medication among those who persisted evidenced change.

Results

Of the 41 enrolled children, 13 were assigned to the NF intervention, 13 to the SCF intervention, and 15 to the wait list control group. There were no statistically significant preintervention differences in demographic characteristics among children in the three conditions. Six children dropped out or were lost to follow-up, leaving 35 children (84%) with complete data for analysis (9 who completed NF, 11 who completed SCF, and 15 in the WLC condition (see Figure 1). All children assigned to intervention were able to understand the procedures and completed at least 19 sessions (average 23.4) of the NF or SCF intervention. Review of the research assistants' fidelity checklists revealed that the NF and SCF interventions were implemented successfully with fidelity to the protocol. Changes in outcome measures from pre- to postintervention for each of the 3 experimental conditions are presented in Table 3.

Parent Reports

In the NF condition, primary parents reported significant ($P < .05$) change on all 3 CRS-R and the 2 BASC subscales, and coparents reported change on the CRS-R Inattention scale and ADHD Index. In the SCF condition, primary parents reported significant ($P < .05$) change on the CRS-R Inattention Scale and ADHD Index, the BASC Attention Problems Scale, and on the BRIEF.

In the WLC condition, only changes in parent reports on the BASC Attention Problems Scale were statistically significant. NF proved superior to WLC on 3 parent scales. No other significant differences were found.

Teacher Reports

No teacher reports for either condition reached statistical significance, either for pre-post effects or when compared

with the WLC condition. Teachers reported statistically significant change on the BRIEF in the WLC condition. Although the effect size was the same in the NF condition ($ES = -0.5$), this effect was nonsignificant because of smaller sample size.

Student Assessments

Students reported statistically significant change (≤ -0.5) on the CRS-R ADHD Index in the WLC condition and on the BASC Attention Problems Scale in the SCF condition, which differed from the effect in the WLC condition. No other significant effects were found. No effects were found for CPT in either condition.

Observed Behavior During the Intervention

Behavioral checklists were completed by research assistants at each session. Most participants in both intervention groups initially demonstrated fidgetiness or increased activity that affected their ability to concentrate, had difficulty keeping their eyes on the screen, became easily distracted by people or noises around them, and/or talked during the tasks. The most frequent behavioral goals recorded by research assistants were reducing fidgetiness and moving around, increasing focus, and ignoring distractions. One participant remarked "I won't get distracted so much if I don't fidget." In all, 25% of children realized that moving less and being calm helped decrease frustration and increase their focus on the tasks. Between their first and last sessions, participants in the NF group displayed a trend toward lower levels of observed off-task behaviors ($P = .06$). Although a similar trend was not observed in the SCF group, all children progressed to higher and more complex tasks and displayed no significant trend in observed off-task behavior ($P = .62$).

Satisfaction With Intervention

In general, parents were pleased with their child's participation in the program. They commented on the children's improved ability to focus ("for the first time in her life she realized that she had the ability to focus"), improved organizational and study skills, including ability to start a project and finish it ("much better at organizing homework and completing assignments"). Gains in self-esteem and motivation were also noted ("a very big change in her attitude towards her school/homework. She's received the Honor Roll for the first time").

All the students reported that the interventions were easy to understand and follow. Two thirds of the students thought that the research assistants were helpful

Table 3. Changes in Child Symptoms From Pre- to Postintervention

	NF				SCF				WLC				NF vs WLC	SCF vs WLC	
	Pre-Tx		ES	n	Pre-Tx		ES	n	Pre-Tx		ES	n			
	Mean (SD)	Post-Tx Mean (SD)			Mean (SD)	Post-Tx Mean (SD)			Mean (SD)	Post-Tx Mean (SD)					
<i>CRS-R Cognitive Problems/Inattention Scale</i>															
Parent #1	76.1 (11.3)	67.5 (10.2)	−0.8 ^a	9	67.2 (12.0)	60.1 (5.3)	−0.8 ^a	11	73.3 (11.4)	71.0 (14.0)	−0.2	11	—	—	
Parent #2	70.3 (8.6)	62.1 (9.0)	−0.9 ^a	5	64.2 (7.5)	58.3 (7.2)	−0.8	5	70.6 (14.3)	74.2 (12.7)	0.3	9	^a	—	
Teacher	55.5 (11.6)	55.4 (11.6)	−0.0	9	56.2 (9.8)	55.7 (10.2)	0.0	8	58.7 (7.0)	59.8 (10.0)	0.1	13	—	—	
Student	57.1 (6.5)	53.4 (4.6)	−0.7	9	52.9 (10.3)	53.1 (11.3)	0.0	11	63.1 (9.5)	60.1 (11.3)	−0.3	15	—	—	
<i>CRS-R Hyperactivity Scale</i>															
Parent #1	90.5 (29.7)	71.3 (26.5)	−0.7 ^a	9	59.3 (16.3)	58.7 (18.2)	0.0	11	68.4 (18.3)	64.5 (17.8)	−0.2	11	^a	—	
Parent #2	68.2 (10.7)	64.0 (13.0)	−0.4	5	56.2 (16.9)	60.7 (22.3)	0.2	5	77.0 (27.4)	70.3 (21.7)	−0.3	9	—	—	
Teacher	55.5 (9.7)	56.1 (14.3)	0.0	9	59.8 (9.6)	64.6 (18.4)	0.3	8	57.6 (13.6)	52.8 (7.2)	−0.4	13	—	—	
Student	53.0 (10.4)	51.6 (12.5)	−0.1	9	49.2 (6.9)	49.8 (9.7)	0.1	11	55.7 (9.0)	52.6 (10.4)	−0.3	15	—	—	
<i>CRS-R ADHD Index</i>															
Parent #1	82.1 (11.3)	68.8 (10.0)	−1.2 ^a	9	70.3 (11.3)	62.9 (10.4)	−0.7 ^a	11	74.2 (9.3)	73.6 (12.4)	−0.1	11	^a	—	
Parent #2	69.9 (4.3)	64.9 (6.3)	−0.9 ^a	5	63.5 (6.5)	61.3 (7.4)	−0.3	5	70.9 (13.6)	72.4 (14.0)	0.1	9	—	—	
Teacher	59.3 (7.9)	58 (7.9)	−0.2	9	65.7 (9.4)	66.5 (15.0)	0.1	8	64.5 (8.7)	61.0 (8.4)	−0.4	13	—	—	
Student	50.8 (9.0)	48.7 (6.7)	−0.3	9	51.0 (9.8)	50.3 (10.9)	−0.1	11	56.5 (9.0)	52.7 (10.0)	−0.4 ^a	15	—	—	
<i>BRIEF Global Executive Composite Score</i>															
Parent #1	73.1 (19.9)	68.2 (12.8)	−0.3	9	65.7 (15.3)	57.7 (13.6)	−0.6 ^a	11	66.7 (11.8)	64.9 (13.5)	−0.1	11	—	—	
Parent #2	67.0 (18.6)	61 (17.8)	−0.3	5	62.3 (21.5)	53.8 (15.5)	−0.5	5	67.0 (20.3)	65.9 (21.3)	−0.1	8	—	—	
Teacher	68.4 (13.0)	61.3 (12.9)	−0.5	9	72.4 (13.3)	71.2 (21.3)	−0.1	8	73.6 (12.7)	66.8 (13.7)	−0.5 ^a	13	—	—	
<i>BASC Hyperactivity Scale</i>															
Parent #1	72.3 (18.1)	62.0 (13.3)	−0.6 ^a	9	56.2 (8.3)	52 (7.5)	−0.5	10	64.6 (10.5)	59.9 (10.0)	−0.5	11	—	—	
Parent #2	63.4 (7.8)	55.8 (9.8)	−0.9	5	56.4 (13.1)	52.1 (14.1)	−0.3	5	63.0 (13.9)	64.4 (13.1)	0.1	9	—	—	
Student	52.7 (11.1)	55.4 (12.6)	0.2	8	52.1 (14.4)	49.0 (12.2)	−0.2	10	51.8 (10.6)	51.0 (11.4)	−0.1	14	—	—	
<i>BASC Attention Problems Scale</i>															
Parent #1	66.9 (4.7)	62.9 (6.2)	−0.7 ^a	9	62.1 (5.8)	57.4 (6.6)	−0.8 ^a	11	67.2 (5.7)	63.1 (8.2)	−0.6 ^a	11	—	—	
Parent #2	62.1 (3.0)	60.1 (6.7)	−0.4	5	57.6 (12.1)	56.4 (8.4)	−0.1	5	63.5 (10.5)	66.1 (9.6)	0.3	8	—	—	
Student	61.0 (5.7)	59.5 (6.7)	−0.2	9	60.8 (10.6)	54.2 (13.1)	−0.6 ^a	10	58.9 (8.3)	60.3 (9.9)	0.2	14	—	^a	
<i>IVA CPT Response Control Quotient</i>															
Student	93.7 (18.8)	101.8 (16)	0.5	6	86.9 (21.2)	87 (15.6)	0.0	10							
<i>IVA CPT Attention Quotient</i>															
Student	97.3 (22)	104.2 (25.4)	0.3	6	84.8 (27.2)	79.6 (12.9)	−0.2	10							

Abbreviations: NF, neurofeedback; SCF, standard computer format; WLC, waitlist control; SD, standard deviation; ES, Cohen's effect size (calculated for dependent samples); Pre-Tx, preintervention; Post-Tx, postintervention; CRS-R, Conners' Rating Scales-Revised; ADHD, attention deficit/hyperactivity disorder; BRIEF, Behavioral Rating Inventory of Executive Functioning; BASC, Behavior Assessment Scales for Children; IVA CPT, Integrated Visual and Auditory Continuous Performance Test.

^aP < .05.

and that the sessions helped them concentrate. On the other hand, nearly all the participants reported that they found the sessions "boring." One student who reported this also wrote that the computer system made him aware of how he was concentrating and how to focus better.

Medication Use

Medication changes were noted over the project period in the number of children using stimulant medications and their dosage. Of the 20 children receiving intervention, 18 were taking stimulant medication at the beginning of the project. By the end of the project, 4 had stopped taking medication, and 2 were using decreased

dosages. No decrease in dosage or discontinuation of medication was observed in the WLC.

Discussion

The outcomes of this pilot study are mixed. Parents reported fewer ADHD symptoms among children in both intervention conditions. These positive effects occurred despite a relatively small "dose" of the intervention and despite a drop in medication use among children in the intervention. Each of the commercially available systems recommends 40 sessions actual work time, whereas the average "dose" in our study was only 23 sessions.

Teachers and students did not consistently report significant change in ADHD symptoms. Our failure to find changes in teacher reports may result from the fact that assessments were completed in different school years by different teachers, thus lowering reliability, or from a lack of improvement in classroom behavior and performance.

The failure to find student effects was not surprising as the validity of child self-report is an area of controversy. Some studies suggest that children tend to rate their behavior in a more positive light than do their parents³⁸ and others relate that parents might be better at reporting symptoms of external behavior and social competence.³⁹

A notable success of this study was its implementation. Several types of computer-based interventions are available commercially and advertised to improve children's attentiveness and academic performance. This is the first study to evaluate their efficacy during the school day and teaching children to follow intervention protocols. We were successful in training research assistants to administer the computer-based interventions to 2 children at a time, scheduling children for intervention sessions under regular school conditions. These results demonstrate that it is feasible to implement computer-based interventions in a school setting, though implementing them requires intense coordination with the school team. The interventions were well-accepted by teachers, parents, and children. Scheduling conflicts were the leading cause for drop-outs.

As a pilot project, this study has important limitations. The small number of participants reduces the power necessary to explore the results in detail. Furthermore, the sample represents primarily suburban families of medium-to-high socioeconomic status.

This study provides preliminary evidence of the feasibility and effectiveness of computer-based interventions as adjunctive therapies for children with ADHD and supports the feasibility of offering them in a school setting. These results support the need for a large randomized trial of computer-based interventions in schools. Such a study is ongoing, including a larger, more diverse sample and careful assessments of the effects of the treatments on classroom behavior and academic performance. Long-term follow-up is essential to assess whether gains attributable to treatment are maintained over time.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interests with respect to the authorship and/or publication of this article.

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