Clinical Pediatrics
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*CLIN PEDIATR* 2011 50: 615 originally published online 10 May 2011
DOI: 10.1177/0009922810397887

Clinical Pediatrics
50(7) 615–622

DOI: 10.1177/0009922810397887
http://cpj.sagepub.com
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# Computer-Based Attention Training in the Schools for Children With Attention Deficit/Hyperactivity Disorder: A Preliminary Trial

**Naomi J. Steiner, MD[1], Radley Christopher Sheldrick, PhD[1], David Gotthelf, PhD[2], and Ellen C. Perrin, PhD[1]**

**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.

**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 |

### *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 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.

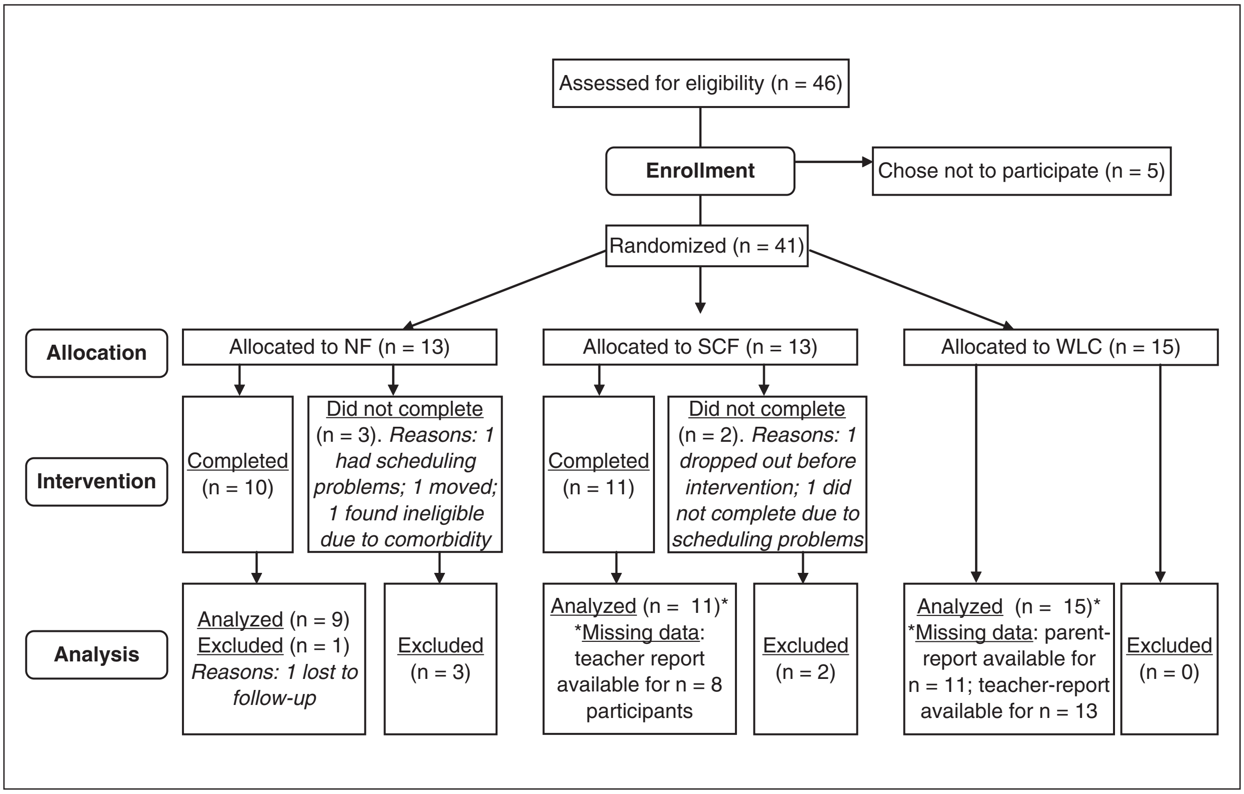


**Figure 1.** Consort diagram

## 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<br>Hyperactivity Scale<br>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<br>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)<br>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 | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Pre-Tx | Post-Tx | | | Pre-Tx | Post-Tx | | | Pre-Tx | Post-Tx | | | | |
| | Mean (SD) | Mean (SD) | ES | n | Mean (SD) | Mean (SD) | ES | n | Mean (SD) | Mean (SD) | ES | n | NF vs WLC | SCF vs WLC |
| *CRS-R Cognitive Problems/Inattention Scale* | | | | | | | | | | | | | | |
| 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 | — | — |
| *CRS-R Hyperactivity Scale* | | | | | | | | | | | | | | |
| 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 | — | — |
| *CRS-R ADHD Index* | | | | | | | | | | | | | | |
| 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 | — | — |
| *BRIEF Global Executive Composite Score* | | | | | | | | | | | | | | |
| 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 | — | — |
| *BASC Hyperactivity Scale* | | | | | | | | | | | | | | |
| 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 | — | — |
| *BASC Attention Problems Scale* | | | | | | | | | | | | | | |
| 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] |
| *IVA CPT Response Control Quotient* | | | | | | | | | | | | | | |
| Student | 93.7 (18.8) | 101.8 (16) | 0.5 | 6 | 86.9 (21.2) | 87 (15.6) | 0.0 | 10 | | | | | | |
| *IVA CPT Attention Quotient* | | | | | | | | | | | | | | |
| 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, preinterventioan; 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.
[a] $P < .05$.

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 parents[38] 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.

## Funding

The author(s) disclosed receipt of the following financial support for the research and/or authorship of this article:

This study was supported by grants from the Deborah Munroe Noonan Memorial Research Fund and the Newton Schools Foundation.

## References

1. Kadesjo B, Gillberg C. The comorbidity of ADHD in the general population of Swedish school-age children. *J Child Psychol Psychiatry*. 2001;42:487-492.
2. Newcorn JH, Halperin JM, Jensen PS, et al. Symptom profiles in children with ADHD: effects of comorbidity and gender. *J Am Acad Child Adolesc Psychiatry*. 2001;40:137-146.
3. Pliska S. Comorbidity of attention-deficit/hyperactivity disorder with psychiatric disorder: an overview. *J Clin Psychiatry*. 1998;59:50-58.
4. Rabiner D, Coie JD. Early attention problems and children's reading achievement: a longitudinal investigation. The Conduct Problems Prevention Research Group. *J Am Acad Child Adolesc Psychiatry*. 2000;39: 859-867.
5. Wolraich M, Hannah J, Baumgaertel A, Feurer I. Examination of DSM-IV criteria for attention deficit/hyperactivity disorder in a county-wide sample. *J Dev Behav Pediatr*. 1998;19:162-168.
6. Hoza B, Mrug S, Gerdes AC, et al. What aspects of peer relationships are impaired in children with attention-deficit/hyperactivity disorder? *J Consult Clin Psychol*. 2005;73:411-423.
7. Mrug S, Hoza B, Gerdes AC. Children with attention-deficit/hyperactivity disorder: Peer relationships and peer-oriented interventions. In: Nangle DW, Erdley CA, eds. *New Directions for Child and Adolescent Development: No. 91. The Role of Friendship in Psychological Adjustment*. San Francisco, CA: Jossey-Bass; 2001: 51-77.
8. Whalen CK, Henker B. The social profile of attention-deficit/hyperactivity disorder: five fundamental facets. *Child Adolesc Psychiatr Clin N Am*. 1992;1: 395-410.
9. Farone S, Biederman J, Mick E. The age-dependent decline of attention deficit hyperactivity disorder: a meta-analysis of follow-up studies. *Psychol Med*. 2006;36: 159-165.
10. MTA Cooperative Group. A 14-month randomized clinical trial of treatment strategies for attention-deficit/hyperactivity disorder. The MTA Cooperative Group. Multimodal Treatment Study of Children with ADHD. *Arch Gen Psychiatry*. 1999;56:1073-1086.
11. American Academy of Pediatrics: Subcommittee on Attention-Deficit/Hyperactivity Disorder and Committee on Quality Improvement. Clinical practice guideline:

treatment of the school-aged child with attention-deficit/hyperactivity disorder. *Pediatrics*. 2001;108:1033-1044.
12. Gould MS, Walsh BT, Munfakh JL, et al. Sudden death and use of stimulant medications in youths. *Am J Psychiatry*. 2009;166:992-1001.
13. Hoagwood K, Jensen P, Feil M, Vitiello B, Bhatara V. Medication management of stimulants in pediatric practice settings: a national perspective. *J Dev Behav Pediatr*. 2000;21:322-331.
14. Jensen PS, Garcia JA, Glied S, et al. Cost-effectiveness of ADHD treatments: findings from the multimodal treatment study of children with ADHD. *Am J Psychiatry*. 2005;162:1628-1636.
15. Rushton J, Fant K, Clark S. Use of practice guidelines in the primary care of children with attention-deficit/hyperactivity disorder. *Pediatrics*. 2004;114:e23-e28.
16. MTA Cooperative Group. MTA at 8 years: Prospective follow-up of children treated for combined-type ADHD in a multisite study. *J Am Acad Child Adolesc Psychiatry*. 2009;48:5.
17. Rojas NL, Chan E. Old and new controversies in the alternative treatment of attention-deficit hyperactivity disorder. *Mental Retard Dev Disabil Res Rev*. 2005;11: 116-130.
18. Chabot RJ, Serfontein G. Quantitative electroencephalographic profiles of children with attention deficit disorder. *Biol Psychiatry*. 1996;40:951-963.
19. El-Sayed E, Larsson JO, Persson HE, Rydelius PA. Altered cortical activity in children with attention-deficit/hyperactivity disorder during attentional load task. *J Am Acad Child Adolesc Psychiatry*. 2002;41:811-819.
20. Mann CA, Lubar JF, Zimmerman AW, Miller CA, Muenchen RA. Quantitative analysis of EEG in boys with attention-deficit-hyperactivity disorder: controlled study with clinical implications. *Pediatr Neurol*. 1992;8:30-36.
21. Monastra VJ, Lubar JF, Linden M, et al. Assessing attention deficit hyperactivity disorder via quantitative electroencephalography: an initial validation study. *Neuropsychology*. 1999;13:424-433.
22. Klingberg T, Forssberg H, Westerberg H. Training of working memory in children with ADHD. *J Clin Exp Neuropsychol*. 2002;24:781-791.
23. Klingberg T, Fernell E, Olesen PJ, et al. Computerized training of working memory in children with ADHD: a randomized, controlled trial. *J Am Acad Child Adolesc Psychiatry*. 2005;44:177-186.
24. Levesque J, Beauregard M, Mensour B. Effect of neurofeedback training on the neural substrates of selective attention in children with attention-deficit/hyperactivity disorder: a functional magnetic resonance imaging study. *Neurosci Lett*. 2006;394:216-221.
25. Linden M, Habib T, Radojevic V. A controlled study of the effects of EEG biofeedback on cognition and behavior of children with attention deficit disorder and learning disabilities. *Biofeedback Self Regul*. 1996;21:35-49.
26. Monastra VJ, Monastra DM, George S. The effects of stimulant therapy, EEG biofeedback, and parenting style on the primary symptoms of attention-deficit/hyperactivity disorder. *Appl Psychophysiol Biofeedback*. 2002;27:231-249.
27. Kotwal DB, Burns WJ, Montgomery DD. Computer-assisted cognitive training for ADHD: a case study. *Behav Modif*. 1996;20:85-96.
28. Shalev L, Tsal Y, Mevorach C. Computerized progressive attentional training (CPAT) program: effective direct intervention for children with ADHD. *Child Neuropsychol*. 2007;13:382-388.
29. Play Attention Web site. http://www.playattention.com.
30. BrainTrain Web site. http://www.braintrain.com.
31. Conners C. *Conners' Rating Scales–Revised Technical Manual*. North Tonawanda, NY: Multi-Health Systems; 1997.
32. Conners C, Wells KC, Parker JD, Sitarenios G, Diamond JM, Powell JW. A new self-report scale for assessment of adolescent psychopathology: factor structure, reliability, validity, and diagnostic sensitivity. *J Abnorm Child Psychol*. 1997;25:487-497.
33. Conners C, Sitarenios G, Parker JD, Epstein JN. The revised Conners' Parent Rating Scale (CPRS-R): factor structure, reliability, and criterion validity. *J Abnorm Child Psychol*. 1998;26:257-268.
34. Collett BR, Ohan JL, Myers KM. Ten-year review of rating scales. V: Scales assessing attention-deficit/hyperactivity disorder. *J Am Acad Child Adolesc Psychiatry*. 2003;42:1015-1037.
35. Kumar G, Steer RA. Factorial validity of the Conners' Parent Rating Scale–Revised: short form with psychiatric outpatients. *J Pers Assess*. 2003:80:252-259.
36. Gioia GA, Isquith PK, Guy SC, Kenworthy L. *Behavior Rating Inventory of Executive Function (BRIEF) Manual*. Odessa, FL: Psychological Assessment Resources; 2000.
37. Reynolds C, Kamphaus R. *Behavior Assessment Scale for Children Manual*. Circle Pines, MN: American Guidance Service; 1992.
38. Achenbach T, McConaughy S, Howell C. Child/adolescent behavioral and emotional problems: implications of cross-informant correlations for situational specificity, *Psychol Bull*. 1987;101:213-232.
39. Riley AW. Evidence that school-age children can self-report on their health. *Ambul Pediatr*. 2004;4(4 Suppl): 371-376.