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A Randomized Trial of Two Promising Computer-Based Interventions for Students with Attention Difficulties

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Abstract Few studies have examined whether attention can be improved with training, even though attention difficulties adversely affect academic achievement. The present study was a randomized-controlled trial evaluating the impact of Computerized Attention Training (CAT) and Computer Assisted Instruction (CAI) on attention and academic performance in 77 inattentive first graders. Students receiving either intervention were more likely than controls to show a moderate decline in teacher rated attention problems in first grade. Students receiving CAI also showed gains in reading fluency and in teacher ratings of academic performance. Intervention effects for attention were absent by second grade largely because attention problems declined in all groups. However, post hoc analyses indicated potential longer-term benefits for children with 6 or more inattentive symptoms at baseline. Persistent attention problems were associated with poorer academic performance in multiple domains. Results provide initial evidence that CAT and CAI can improve children's attention in the classroom - and support additional studies to determine whether more clinically significant benefits are attainable.

Keywords Attention · ADHD · Academic achievement · Attention training · Computer-assisted instruction

Problems attending to classroom instruction are common in children (DuPaul et al. 2002) with as many as 16% of elementary school students displaying frequent inattention and/or poor concentration (Wolraich et al. 1998). Among students who meet criteria for Attention Deficit Hyperactivity Disorder (ADHD), up to 80% exhibit academic performance problems (Cantwell and Baker 1991) and these students are at increased risk for grade retention, placement in special education, and dropping out of school (Barkley et al. 2006; Murphy et al. 2002). Attention problems also compromise achievement in children not formally diagnosed with ADHD (Merrell and Tymms 2001, 2005; Rabiner et al. 2004), predict the onset of reading difficulties (Rabiner et al. 2000), and undermine traditional academic interventions such as tutoring (Rabiner et al. 2004). These findings indicate a strong need to develop more effective interventions for inattentive students.

Existing Evidence-based Interventions for Inattentive Students

Intervention research for child attention problems has largely focused on attention difficulties in the context of

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ADHD and includes limited work beyond studies of stimulant medication and behavioral interventions. Although medication reduces inattentive behavior while administered, results from the largest ADHD treatment study conducted to date indicate that long-term benefits beyond carefully monitored treatment implementation are lacking (MTA Cooperative Group 2009). In addition, "long-term effects on academic achievement as measured by standardized achievement tests have been either very small or nonexistent" (DuPaul 2007; p. 186), although recent findings suggest modest benefits on reading and math achievement (Scheffler et al. 2009). However, even if benefits were more enduring and the impact on academic achievement more robust, treatment adherence is often poor (Pappadopulos et al. 2009) and many parents will not use medication with their child. In addition, medication would not be appropriate for children lacking a formal diagnosis of ADHD.

Similarly, although behavioral interventions often enhance academic accuracy and productivity for students with ADHD (DuPaul et al. 2002), this has not translated into long-term achievement gains (DuPaul and Eckert 1998). Furthermore, behavioral interventions need to be sustained indefinitely to realize ongoing benefit which is costly and often impractical (Barkley 2007). These limitations of existing ADHD interventions highlight the need to develop alternative treatments to address child attention problems and the adverse impact attention difficulties often have on children's educational outcomes. One such alternative that has been the subject of preliminary research is attention training.

Can Attention be Trained?

Although it has been suggested that "...the development of specific brain networks during early childhood provides a strong rationale for sustained efforts to see if we can improve the attentional abilities of children" (Posner et al. 2006, p. 101), few studies have examined this question. Semrud-Clikeman et al. (1999) delivered an 18-week program to train visual and auditory attention in children diagnosed with ADHD. Training was associated with gains on non-trained measures of visual and auditory attention, but the impact on children's ability to attend in the classroom was not assessed. Kerns et al. (1999) randomized fourteen 7- to 14-year-old children with ADHD to attention training and control groups matched for age, sex, and medication status. Training was conducted in small groups using a program called *Pay Attention!* and consisted of two 30-minute sessions per week for 8 weeks. Treated children improved on several non-trained attention measures and on a measure of academic efficiency; effects on teacher attention ratings were marginally significant.

Several prior attention training studies have incorporated the use of computers, an approach referred to as computerized attention training (CAT). Although different CAT programs are available, the common element is using computers to present exercises where success depends on the ability to sustain attention and respond based on clearly defined rules, e.g., pressing a certain key whenever a particular stimulus is flashed on the screen. As the individual experiences success, the exercises typically become more challenging and the demands on attention increase. Thus, structured practice in learning to attend is provided. A potential benefit of CAT is that were it found to be effective, the computerized training format could facilitate its dissemination relative to approaches that require a trained therapist to implement.

CAT has been has been shown to improve attention in adults with schizophrenia (Bellucci et al. 2003), and adults who have suffered a stroke or traumatic brain injury (Rohling et al. 2009). Promising case study results of CAT for children with ADHD have also been reported (Kotwal et al. 1996; Slate et al. 1998). In the only randomized-controlled trial of CAT we are aware of, Shalev et al. (2007) tested a CAT program with thirty-six 6 to 13-year-olds diagnosed with ADHD. Although treated participants showed a reduction in parents' reports of attention problems and improvements in reading comprehension and passage copying, there was no long-term follow up and teacher behavior ratings were not collected. Finally, Rueda et al. (2005) reported that 4 and 6-year olds showed more mature performance on an executive attention task than untrained controls after five days of training (Rueda et al. 2005). This study used a normative sample, however, and the impact on classroom behavior was not examined.

Computer-assisted Instruction: Another Promising Intervention for Inattentive Students

Computer-assisted instruction (CAI) is a second promising intervention for students with attention difficulties (DuPaul and Eckert 1998; Xu et al. 2002). Unlike CAT, where successful performance requires sustaining attention to tasks that differ considerably from traditional academic activities, CAI involves presenting academic material via computer using instructional features that improve performance in children with short attention spans, e.g., providing immediate and frequent feedback and reinforcement and highlighting important information (Lillie et al. 1989). Because children must sustain attention to cognitive tasks of increasing difficulty, CAI may have attention training effects in addition to teaching basic academic knowledge and skills. In fact, CAI has been reported to reduce off-task behavior (Din 1996) and positive effects of CAI on students with ADHD have also been reported (Kleiman et al. 1981; Ota and DuPaul 2002; Mautone et al. 2005; Clarfield and Stoner 2005). These were all small sample studies, however, and there has been no randomized-controlled trial of CAI for young students with attention difficulties.

Project CLASS - Children Learning Academic Success Skills

Project CLASS is a randomized-controlled trial examining the impact of CAT and CAI on children's attention in the classroom, their daily academic performance, and their academic achievement. The questions of primary interest are whether CAT or CAI promotes gains in children's ability to attend in the classroom as well as their academic performance. To build on earlier work documenting an association between attention and academic achievement in normative samples (Rabiner et al. 2000), the relationship between attention and achievement in children selected for attention problems was also examined.

Method

Participants

Participants were 77 first grade students attending five public schools in the southeastern United States, all of whom had been identified by their teacher as having attention difficulties (see below). Sixty-nine percent were male. The racial/ethnic composition was 58% African American, 24% Hispanic, 11% Caucasian, 7% other (either Asian or multiracial) and consistent with the schools participants attended. Sixty-seven percent received free or reduced lunch. Fifty-two percent resided in two-parent families, 38% lived with their biological mother, and the remainder lived with their biological father and/or grandparents. Twenty-one percent (n=16) had repeated a grade, 16% (n=12) were reported by their parent/guardian to have ADHD, and 7% (n=5) were receiving ADHD medication.

Measures

Attention Children's attention was assessed using the DSM-IV Inattentive Scale from the Conners' Teacher Ratings Scale-Revised: Long Version (CTRS-R:L; Conners 1997) which includes the nine DSM-IV inattentive symptoms of ADHD rated from 0 to 3 indicating how problematic each behavior has been in the past month. This scale is internally consistent (alpha=0.95) and has a stability coefficient of 0.70 over a 6–8 week period (Conners 1997).

Classroom behavior and social-emotional functioning Other CTRS-R:L subscales examined were the DSM-IV Hyperactive-Impulsive, Oppositional, Social Problems, and Anxious/Shy subscales. These areas were assessed to determine whether any intervention effects obtained were limited to attention, or extended to other aspects of children's functioning. Internal reliability estimates are satisfactory (0.77–0.96 across subscales) and test-retest reliabilities range from 0.47–0.88 across subscales (Conners 1997).

Academic achievement Academic achievement was assessed with the Woodcock Johnson III, Tests of Achievement (Woodcock et al. 2001). The WJ-III has strong psychometric properties and is widely used to assess achievement in public school systems. Subtests administered at baseline included Letter-word identification, Word Attack, Calculation, and Math Fluency. At subsequent administrations the Reading Fluency, Passage Comprehension, and Applied Problems subtests were added. These subtests were not administered at baseline due to expected floor effects at the beginning of first grade.

The Basic Reading Skills cluster, our primary reading outcome, is a combination of Letter Word Identification and Word Attack and provides a measure of sight vocabulary, phonics, and structural analysis. This cluster has a test-retest reliability of 0.92 at one year for children in the same age range as our subjects. Math Calculation Skills is an aggregate measure of computational skills and automaticity with basic math facts. It is comprised of the Calculation and Math Fluency subtests and has a test-retest reliability of 0.89 at one year for children similarly aged to our sample (Woodcock et al. 2001).

Children were also administered the Dynamic Indicators of Basic Early Literacy Skills (DIBELS; Good et al. 2002), a curriculum-based measure used to assess the change in reading fluency over time in young children. The DIBELS requires that children read three short passages and the number of words read correctly in one minute is computed for each passage. The middle number of these three serves as each child's score. Concurrent validity has been demonstrated with teacher ratings of achievement and standardized measures of phonological awareness and reading (Hintze et al. 2003).

Daily academic performance Teachers completed the Academic Performance Rating Scale (APRS; DuPaul et al. 1991), a standardized measure with subscales that assess Academic Productivity, i.e., the percentage and accuracy of assigned work that students complete, Academic Success, i.e., teachers' perception of students' skill level in reading, math, and written language, and Academic Impulse Control, i.e., students' tendency to approach work in a deliberate and careful manner. Internal consistency is excellent, i.e., alphas>0.90 and stability coefficients exceed 0.90 over a 2 week period.

Intellectual ability IQ was estimated at baseline using the Kaufman Brief Intelligence Test, Second Edition (KBIT-2; Kaufman and Kaufman 2004), an individually administered test that measures verbal and nonverbal abilities. The KBIT-2 yields a full scale IQ estimate that is highly correlated with scores on the WISC-IV (r=0.77; Kaufman and Kaufman 2004).

Procedure

First grade teachers rated each of their students (n=630) on the DSM-IV Inattentive Scale of the CTRS-R:L approximately 5 weeks into the school year. (Hispanic children were not rated if their teacher felt that the child's English language skills were not sufficient to understand the computer programs, which were available only in English.) Children scoring at least 1.0 standard deviations above the sample mean (n=136) were potentially eligible for the study. Parent consent and student assent was obtained from 103 (76%) of these students. To restrict the sample to children with stable attention difficulties, a second rating was obtained 4 to 5 weeks later via the full CTRS-R:L. Twenty students were excluded from further participation because their T-score on the DSM-IV Inattentive Scale was below 60 based on published norms. Six additional students with full scale IQ scores below 70 were excluded because pilot testing indicated these children were likely to become frustrated by the training tasks. Students for whom English was a second language were included if their non-verbal IQ score exceeded 70 as this was deemed to be a better indicator of their ability level.

The 77 remaining students were randomly assigned to the CAT (n=25), CAI (n=27), or wait-list control (n=25) condition. Randomization was done within school to insure a balanced representation of students within condition at all schools. Parents of students randomized to the control condition were offered the opportunity to have their child receive the intervention of their choice the following year after all assessment data had been collected.

Measurement timeline Data was collected before the intervention began (T1), immediately following the intervention (T2), and during fall of the following year (T3); approximately 6 months separated each assessment point. The KBIT-2 (T1 only) and the WJ-III were administered by trained examiners blind to experimental condition; alternate forms of the WJ-III were administered at adjacent assessments.

Interventions

Computerized Attention Training (CAT) Captain's Log (Braintrain®) is a commercially available program that provides structured opportunities for exercising attention. It includes 36 exercises designed to train a variety of cognitive skills. Ten exercises that focus on training auditory and visual sustained attention and that were easily understood by pilot participants were selected for the study. As examples of the exercises used, one required children to press the space bar each time a symbol appeared that matched one already shown on the screen, and to refrain from responding to all other stimuli. In another exercise, children listened to a sequence of tones and had to decide whether a second sequence was the same or different. Other tasks required children to remember the location of objects that were briefly presented and then hidden. All exercises required children to respond based on directions provided, and gave immediate feedback on the correctness of every response.

Each exercise began at the easiest stage and lasted 3 minutes. Stages were passed by meeting criteria that included the percent of trials answered correctly, average response time, and the number of inappropriate responses, i.e., responding when no response was called for. When a stage was passed, the program advanced to the next stage and the exercise duration increased by one minute. Thus, in advancing through the program, children had to sustain their attention for increasing time to tasks that became more difficult. When a stage was failed, a research assistant reviewed the child's performance and discussed how to improve; the exercise was then repeated.

Computer Assisted Instruction (CAI) Destination Reading and Math published by Riverdeep were used in the CAI condition. This program was selected based on its consistency with guidelines from the Committee on the Prevention of Reading Difficulties (Snow et al. 1998) and the National Reading Panel (NICHD 2000), evidence of effectiveness available at the time (De Long-Cotty and Levenson 2004), and its widespread use in schools. At the 1st grade level, Destination Reading targets five key skills: phonemic awareness, phonics, fluency, vocabulary, and comprehension. Destination Math covers number sense, counting, addition and subtraction, comparing and ordering, measurement, geometry, and patterns. Students worked on reading and math activities on alternate days.

Instructional features of Destination Reading and Math are consistent with guidelines from the literature for effectively teaching academic skills to inattentive students (DuPaul 2007), e.g., students work at their own pace and information is presented in small pieces with repetition provided until mastery is achieved. The program incorporates engaging, age-appropriate animation and graphics and provides students with frequent and immediate feedback on their performance. Reading and math programs are divided into units that present material designed to teach specific concepts, e.g., blending sounds, counting skills, etc. After students completed activities in each unit, mastery was assessed by a brief test generated by the program. Students who passed progressed to the next unit. If the test was not passed, exercises were reassigned.

Intervention implementation Project CLASS was held two afternoons per week for 14 weeks; each session lasted about 75 min with 50–60 min spent on computer exercises. Groups included 4–6 students who were monitored by two or three trained research assistants and school staff paid by the study. Over the course of the intervention, participants attended an average of 82% of scheduled sessions and only 5 attended less than two-thirds of the sessions.

To promote cooperation and motivation, group rewards, e.g., a pizza party, were provided for following Project CLASS rules. Each session began with a brief review of the rules and a reminder of the rewards students could earn. Students were given tangible evidence of their progress towards earning group rewards by placing marbles in a jar when rules were followed; when the marbles reached a certain level (calibrated to occur every 2–3 weeks), the group earned a reward. Students also received “stars” for passing each CAT exercise or CAI unit quiz and used these stars to purchase individual rewards from a prize box. The ratio of stars to rewards was set so students earned an average of one prize each week. Although this program introduces an element of contingency management into the intervention, pilot testing indicated that it was essential to promote students’ effort on the computer tasks. To promote generalization to the classroom, students were prompted to evaluate their focus each session and praised for attending to the computer tasks. Staff was observed bi-weekly by the investigators and project director to insure that procedures were carefully adhered to. Weekly meetings to review procedures and address issues that emerged during implementation were also held.

Although the controlled nature of this trial makes it more of an efficacy than effectiveness study, procedures were employed to make school-based implementation feasible were the interventions found effective. Thus, to the extent possible, principles outlined in the deployment focused model of treatment development suggested by Weisz and Gray (2008) were incorporated. This included identifying participants using screening procedures that could be readily implemented by schools, not excluding children who had behavior difficulties in addition to attention problems, delivering the intervention at school rather than in a research setting, conducting training in small groups, and including school staff in intervention implementation.

The intervention was piloted with 46 students in four schools and resulted in significant changes to the intervention delivery. This included reducing group size from as many as 9 to no more than 6, decreasing the student to staff ratio from 4:1 to 2:1 or 3:1, revising the behavior management and incentive system, changing several exercises used in the CAT intervention, modifying the use of unit quizzes in the CAI intervention, and changing how each intervention was introduced to participants. Session frequency was also changed from four 45 minute sessions to two 75 minute sessions each week in order to improve student attendance. No intervention participants from the pilot year are included in the analyses below. However, because recruitment and data collection procedures remained identical across years, control subjects from the pilot year are included in analyses that are restricted to the control sample.

Results

Preliminary Analyses

Although baseline scores were included as covariates in the analyses reported below, we tested whether the groups differed at baseline on any of these measures. None of these differences approached significance, i.e., all p’s>0.25. There were also no group differences at baseline on a range of demographic factors, including the percentage of students on free or reduced lunch, who had repeated a grade, who were diagnosed with ADHD, or who were receiving medication for ADHD, i.e., all p’s >0.30.

Table 1 presents variable means and standard deviations across the entire sample at each time point. The average IQ of 86 is nearly one standard deviation below the normative mean. Average inattention scores were two standard deviations above the normative mean at baseline and all APRS subscale scores were at least a standard deviation below the normative mean. Reading achievement was in the average range and above what would be expected based on the IQ results; achievement scores in math were consistent with IQ findings. By the final assessment, attention problems had declined by nearly a full standard deviation and reading achievement by roughly one-third of a standard deviation. Although APRS scores had improved they remained below average.

Table 1 Sample Characteristics at Each Time Point

Variable	T1 (n=77)	T2 (n=71)	T3 (n=66)
IQ	86.7/12.3	NA	NA
DSM-IV Inattention	71.7/6.2	67.7/8.97	61.9/10.4
WJ-III Reading	96.6/16.1	94.52/18.9	91.5/18.9
WJ-III Math	86.8/18.4	87.35/18.6	90.2/18.3
DIBELS	12.63/18.4	31.1/29.4	43.0/32.3
Academic Productivity	33.9/6.7	37.8/8.9	40.9/9.4
Academic Success	32.7/9.2	36.0/8.9	37.9/10.4
Academic Impulse Control	39.3/8.6	40.5/9.2	44.2/8.4

IQ was only assessed at Time 1. DSM-IV = Diagnostic and Statistical Manual, 4th edition; WJ-III = Woodcock-Johnson, Third Edition; DIBELS = Dynamic Indicators of Basic Early Literacy Skills.

Baseline correlations between study variables are presented in Table 2. IQ was positively correlated with reading and math achievement and with teachers' ratings of academic success. Academic Success ratings were positively correlated with WJ-III reading achievement and the DIBELS; the correlation with WJ-III math was in the expected direction but not significant. The absence of significant correlations between attention problems and most academic measures is expected given the restricted range of attention problems in the sample.

Missing data Primary analyses were conducted using likelihood-based methods for accounting for missing data. The multilevel models that used PROC GLIMMIX in SAS v.9.2 (SAS Institute 2007) are appropriate for observations in the longitudinal data missing at random (MAR); likewise, the path models estimated with M*plus* v5.2 (L. K. Muthén and B. O. Muthén 2009) use full information maximum likelihood estimation to account for data missing in endogenous variables (all but the covariates, race, gender, and IQ), assuming Missing at Random (MAR). The MAR assumption is that, roughly, the probability of a data-point being missing is uncorrelated with its true value, conditioned on other variables in the model (Little and Rubin 1987). Because the inclusion of covariates and observations of outcomes at different times bolsters the MAR assumption, these methods were selected over listwise deletion which yields reduced power and biased results even under the case of MAR.

Intervention effects To evaluate the impact of CAT and CAI on students' attention and academic performance, we examined differences in the percent of intervention and control children who showed positive change of at least 0.5 standard deviations, a moderate sized effect, on study outcomes rather than testing for average differences between groups. This categorical approach provides a direct indication of how many children benefited from either CAT or CAI, which is especially relevant to educators who might consider employing these interventions in their school. For attention problems, the primary study outcome, this equated to a reduction of at least five T-score points on the DSM-IV Inattentive Scale. To better understand the clinical significance of any intervention effect for attention that emerged, the percent of children in each group with DSM-IV Inattentive Scale scores that declined to the normal range at T2 and T3, i.e., T<60, was also computed. The remaining outcomes were evaluated in the same fashion, i.e., testing for differences in the percent of children within each group that showed an improvement of at least 0.5 standard deviations between baseline and post-test scores.

Table 2 Correlation between Study Variables at Baseline

	IQ	INATT	DIBELS	WJIIIR	WJIIIM	AP	AS	AIC
IQ		−0.13	**0.40**	**0.41**	**0.39**	0.17	**0.37**	−0.06
INATT			0.03	0.09	0.23	**−0.42**	−0.15	0.06
DIBELS				**0.61**	**0.29**	**0.25**	**0.41**	**−0.25**
WJ-III Reading					**0.65**	0.03	**0.27**	−0.12
WJ-III Math						0.01	0.14	0.00
AP							**0.75**	−0.13
AS								−0.04

N=77; entries in bold are significant at p<0.05. INATT = CTRS-R:L DSM-IV Inattentive scale; DIBELS = Dynamic Indicators of Basic Early Literacy Skills; WJ-III = Woodcock-Johnson, Third Edition; AP = Academic Productivity subscale of the Academic Performance Rating Scale (APRS); AS = Academic Success subscale of the APRS; AIC = Academic Impulse Control subscale of the APRS

Differences in the percent of intervention and control participants meeting this change criteria for each outcome were tested by multilevel logistic regression accounting for the nesting of children within teachers and teachers within schools, using PROC GLIMMIX in SAS (GLIMMIX is a relatively new SAS procedure that performs the functions of PROC MIXED for multilevel models but allows non-linear link functions, such as logistic multilevel regression). All models contrasted CAT and CAI conditions separately against the control condition, covarying student race, sex, and full-scale IQ. Each outcome variable was tested in a separate model. Given the multi-level nature of the study, and our relatively small sample size, our power to detect an intervention effect of 0.5 standard deviations was only 0.47. Because the likelihood of Type II errors was already substantial, and adjusting alpha to account for increases in experiment-wise error rate would have compounded this, all comparisons were tested with alpha set at 0.05. (Note - The pattern of results obtained using an ANOVA-based approach to analyze change scores was essentially identical to those reported below.)

Odds ratios were calculated for each significant effect to provide an estimate of magnitude of change. The percentage of students meeting the change criterion between T1 and T2 for each outcome is presented in Table 3, as are odds ratios and 95% confidence intervals for the effects of each treatment condition relative to the control condition. Results are summarized below.

Attention Analyses of improvement in the CTRS-R:L DSM-IV Inattention scale showed significant beneficial effects, i.e., $p<0.05$, for both CAT and CAI, as only 16% of control subjects showed a decline of 0.5 *SD* on the DSM-IV Inattentive Scale compared to 44% of CAT students and 56% of CAI students. The percent of children whose score declined to the normal range was 24%, 22%, and 4% ($n=1$) for CAI, CAT, and control conditions respectively.

Academic functioning For the Academic Success Scale, 33% of children receiving CAI improved by at least 0.5 standard deviations compared to only 16% of controls; corresponding figures for Academic Impulse Control were 41% vs. 8%. Both differences were significant at $p<0.05$. For CAT, the effect on Impulse Control approached significance, i.e., $p<0.10$, with 28% of participants meeting the improvement threshold vs. 8% of controls. Intervention effects on Broad Reading and Math scores on the WJIII were not significant for either intervention. However, a significant effect of CAI was found for the DIBELS fluency test, with 67% of participants improving by at least 0.5 standard deviations compared to only 40% of controls.

Other behavioral outcomes Group differences in the percent of students who declined by at least 0.5 standard deviations on several other CTRS-R:L scales, i.e., DSM-IV Hyperactive-Impulsive Scale, Oppositional Scale, Social Problems, and Anxious/Shy were all non-significant, i.e., p's>0.10. The specificity of the effect to the DSM-IV Inattention Scale argues against rater bias as an explanation for the reduction in attention difficulties that was observed.

Were teachers' post-intervention ratings of attention problems related to their knowledge of students' condition? Teachers were initially blind to students' condition but some undoubtedly became aware of who received intervention. To test whether intervention effects on attention were explained by this, teachers were asked whether their student(s) received intervention and responses were examined in relation to whether students met change criteria on the DSM-IV Inattentive Scale. Although intervention vs. control status was identified for 34 of 52 intervention subjects ($X^2=5.67$, $p<0.05$), and for 21 of 25 control participants ($X^2=10.71$, $p<0.01$), this was not related to the likelihood of a 0.5 standard deviation decline in attention ratings ($X^2=1.70$, $p=0.19$). Furthermore, the average inattentive score at T2 for

Table 3 Intervention Effects

Outcome	Percent Control	Percent CAT	Odds Ratio for CAT	Percent CAI	Odds Ratio for CAI
CTRS-R Inattention	16	44	1.33 (1.02–1.73)	56	1.46 (1.14–1.88)
APRS Academic Success	16	28	1.14 (0.90–1.43)	33	1.24 (1.00–1.55)
APRS Academic Productivity	32	28	0.95 (0.74–1.21)	48	1.25 (0.99–1.57)
APRS Impulse Control	08	28	1.23 (0.97–1.57)	41	1.37 (1.08–1.74)
DIBELS Fluency	40	44	1.07 (0.81–1.42)	67	1.32 (1.01–1.73)
WJ-III Math	24	16	0.91 (0.72–1.15)	41	1.19 (0.95–1.51)
WJ-III Reading	08	12	1.04 (0.87–1.24)	11	1.05 (0.88–1.24)

Percent Control, Percent CAT, and Percent CAI represent the percent of students in each group who improved by at least 0.5 standard deviations on the designated measure; OR = Odds Ratio; WJ-III = Woodcock-Johnson, Third Edition.

students' whose intervention status was known vs. unknown was nearly identical (67.5 vs. 66.4).

Change in attention problems between baseline and long-term follow-up The long-term impact of CAT and CAI on children's attention was examined by computing the percentage of students in each group who declined by at least 0.5 standard deviations on the DSM-IV Inattentive Scale between T1 and T3. The percent of participants in the CAT, CAI, and control conditions who showed this level of decline was 59%, 65%, and 76% respectively, a non-significant difference. The percent of children whose T score now fell in the normal range was 42%, 35%, and 52% respectively, also a non-significant difference. Other intervention effects that had been evident at T2 were also non-significant at T3.

The strong normative decline in attention difficulties within the control group was unexpected and raised the question of whether this would also be evident among children with the most extreme attention difficulties. To examine this, children with six or more inattentive symptoms at baseline – the symptom requirement to possibly warrant an ADHD diagnosis – were identified. This included 8 children in the CAT group, 14 in the CAI group, and 9 controls. Following published guidelines (Conners 1997) symptoms required a rating of '3' to be counted. Next, we examined how many intervention and control participants were essentially symptom free at T3, defined as having zero or one symptom, and how many continued to show six or more symptoms based on ratings made by their new teacher.

Among the 8 CAT participants, 5 (63%) were reported to show zero or one symptom in second grade and only 1 (13%) was rated with six or more symptoms. In the CAI group, 9 of 14 children (64%) had no more than one symptom and only 1 (7%) was rated with six or more. In contrast, only 2 of 9 control participants (22%) had one for fewer symptoms and 2 were rated with six or more. The percent of highly symptomatic children who became largely asymptomatic at follow-up was significantly different between control and intervention participants (CAT and CAI combined), $\chi^2(2, n=31)=4.39$, $p<0.05$.

The contribution of attention difficulties to the acquisition of early reading and math skills The association between attention difficulties and academic achievement was examined within the control group only as the hypothesis did not involve intervention effects. Further, preliminary analyses constraining the links between Time 1 and Time 2 variables to be equal across condition fit poorly (χ^2 and associated statistics could not be computed, but the standardized root mean squared residual was an unacceptably high 0.168), suggesting that treatment condition may have moderated the inattention-achievement relations. Given this finding, it would be problematic to include intervention subjects in these analyses as the interventions appear to have had some effect on the relations, rendering them unsuitable for a normative analysis. Due to the small number of control participants ($n=25$), 12 students from the control condition in the previous year's pilot study were included. As previously noted, these students had been identified and assessed using identical procedures. In addition, control participants from the pilot and study year did not differ significantly at baseline on any rating scale or academic achievement measure.

Effects were assessed in a pair of path analysis models using M*plus* v.5.2 (L. K. Muthén & B. O. Muthén 2009). The key variables in each analysis were CTRS-R:L DSM Inattention scores at each time and WJ-III broad achievement scores at each time (math and reading were analyzed in separate models). Student race, gender, and IQ were used as covariates, predicting all variables; the model accounted for nesting in classroom (or teacher), but the current version of M*plus* does not support a second level of nesting (i.e., school). Each pre-test variable was modeled as predicting every post-test variable, and all pre-test and post-test variables were allowed to predict every one-year follow-up variable; thus, the model was saturated and fit perfectly, which facilitates the evaluation of the model coefficients as there is no lack of fit which could bias the estimates.

For WJ-III reading, the covariance with inattention was significant at post-test, controlling for pre-test, $Est.=-0.119$, $SE=0.032$, $Est./SE=3.77$, $p<0.001$, corresponding to a partial correlation (adjusting for pre-test inattention and reading, as well race, gender, and IQ) of −0.414. The covariance at one-year follow-up was not significant, $Est./SE<1$. The two covariance estimates differed significantly, χ^2 $(1, n=37)=4.61$, $p=0.031$, indicating that the association between attention and reading achievement diminished between post-test and follow-up.

For WJ-III math, the residual covariance between post-test inattention and post-test math, controlling for pre-test values of both, was not significant, $Est./SE<1$; but at the grade 2 follow-up, the covariance approached significance, $Est.=-0.200$, $SE=0.109$, $Est./SE=1.86$, $p=0.065$, corresponding to a partial correlation (adjusting for pre-test and post-test inattention and math, as well race, gender, and IQ) of −0.424. The difference between the covariance estimates approached significance, χ^2 $(1, n=37)=2.75$, $p=0.097$, suggesting that the association may be stronger in grade two than at the end of grade one.

To further examine the longitudinal association between attention difficulties and academic achievement, control participants were classified according to whether their DSM-IV Inattentive Scale score fell in the normal range

Table 4 Academic Functioning of Students with Normal vs. Elevated Attention Difficulties at T3

Variable	T1		T3	
	Normal	Elevated	Normal	Elevated
WJ-III Reading Skills	98.3	94.9	97.6^{**}	90.9
WJ-III Calculation	89.5	83.9	95.5	93.0
DIBELS	15.7	9.5	47.2^{*}	29.2
Academic Productivity	34.3	33.6	49.0^{***}	36.9
Academic Success	32.3	33.0	46.2^{***}	32.9
Academic Impulse Control	38.7	39.9	48.1	44.3

DIBELS = Dynamic Indicators of Basic Early Literacy Skills; WJ-III = Woodcock-Johnson, Third Edition. Entries at T1 indicate group means adjusted for IQ. T3 group means are adjusted for the T1 score and IQ. N=28 for normal' group and 38 for 'elevated' group.

* $p<0.10$; ** $p<0.05$; *** $p<0.01$

at T3, i.e., T<60. Academic functioning for these groups at T1 and T3 was then compared. Scores at T1 were adjusted for IQ and T3 scores were adjusted for IQ and children's T1 score on the same variable. These data are presented in Table 4. Although no significant differences were evident at baseline, students whose attention difficulties declined to the normal range had higher second grade WJII reading achievement scores, performed marginally better on the DIBELS, and received significantly higher second grade ratings on two of the three APRS subscales.

Discussion

Our primary objective was to test whether CAT or CAI helps inattentive first graders attend better in the classroom and perform better academically. Both interventions reduced inattentive behavior during first grade as roughly 50% of intervention participants showed declines in attention difficulties of at least 0.5 standard deviations compared to only 16% of controls. In addition, nearly 25% of intervention participants had inattentive scores in the normal range immediately following the intervention (T2) compared to only 4% of controls. Because this benefit was unrelated to teachers' knowledge of condition, and was limited to ratings of attention difficulties and not to ratings of other problems, it likely reflects actual improvement in children's attention rather than teacher bias. Children receiving CAI also made gains in reading fluency and in ratings of academic functioning.

Although these are encouraging results, fewer than 25% of participants received normalized ratings of attention difficulties at the end of first grade. Furthermore, improvements in WJ-III academic achievement were not seen for either intervention and initial intervention effects for attention were not sustained into the next school year (T3) as compared to controls. Thus, one explanation for the overall pattern of results is that the interventions accelerated what appears to be a strong normative decline in inattentive behavior over time.

Although there was no evidence of long-term benefit in the main analyses, post-hoc comparisons conducted with the most inattentive children, i.e., participants who began the study with a sufficient number of inattentive symptoms to potentially warrant an ADHD diagnosis, suggested a different conclusion. Among this subsample, intervention participants were more likely to have one or fewer symptoms in 2nd grade than were controls, 64% vs. 22%. This is an intriguing finding, but should be viewed cautiously given that this was a post-hoc analysis and the small sample size precluded the multi-level approach used for the primary analyses.

Overall, the results provide initial evidence that CAT and CAI can improve children's ability to attend in the classroom and suggest that benefits may be greater among children with particularly high numbers of inattentive symptoms. To our knowledge, this is the first time that such an effect has been demonstrated. Given the modest magnitude of the effects on attention that were obtained, however, it is reasonable to ask whether these interventions can make meaningful contributions to the clinical care of young children with attention difficulties. Based on results from this study alone, the answer to this question may be no. However, rather than abandoning these approaches because the benefits were modest, we suggest that the findings support the value of evaluating more intensive and/ or different training paradigms to learn whether greater benefits are attainable. Following the deployment-focused model of treatment development advocated by Weisz and Gray (2008), a reasonable next step might be several smaller studies that test the impact of modifying the duration and intensity of training. For example, delivering 20 minutes of training each day over the school year might yield greater benefits than those obtained in the current study. Given the results obtained in post-hoc analyses restricted to children with six or more inattentive symptoms, single-case pilot studies with children diagnosed with ADHD should also be considered.

One might also question the value of attention training efforts in general given that many inattentive children receiving no intervention showed substantial improvement by 2nd grade. Thus, why not wait and see whether difficulties resolve naturally before initiating treatment? Results pertaining to the association between attention difficulties and reading achievement argue against this, however, as first grade attention difficulties predicted how well children learned to read, even when prior reading achievement was controlled for. This finding extends existing research on the association between inattention and reading achievement in normative samples (Dittman 2008; Rabiner et al. 2000) and suggests that waiting to intervene is likely to be associated with adverse affects on the acquisition of early reading skills. Thus, effective early intervention for children's attention difficulties is a goal that should be pursued.

Results from exploratory analyses comparing academic outcomes for children with and without attention difficulties in 2nd grade offer another reason for continuing efforts to develop interventions to enhance attention. Although no significant group differences were evident at baseline, children with persistent attention difficulties had significantly lower second grade scores on WJ-III reading achievement, the DIBELS, and teacher ratings of academic productivity and success. This indicates that when attention problems persist beyond first grade – as was true for more than 50% of children – academic functioning is likely to be compromised in multiple domains.

Our results may also elucidate why demonstrating academic achievement gains in ADHD treatment studies has proven difficult. Specifically, the data suggest that although better academic outcomes result when inattentive symptoms decline into the normal range, treatment vs. control differences are muted because this fails to occur for many participants. For example, in the MTA Study (MTA Cooperative Group 1999), 40% of students in the medication group and nearly one-third in the combination treatment group had elevated ratings of ADHD symptoms after 14 months (Swanson et al. 2001). It is thus not surprising that robust effects on academic achievement were not found.

Apart from the modest intervention effects, several other study limitations should be noted. First, only one exemplar of CAT and CAI was implemented which precludes general conclusions about these approaches from being made. Second, although delivering a more intensive intervention was not possible given the need to implement after school, nearly all students received less than 20 hours of training, which is a relatively small amount over an entire grade. Third, we cannot rule out the possibility that the behavior management plan designed to encourage engagement on the computer tasks directly contributed to gains in classroom attention. It would be unexpected, however, for attention benefits derived from a contingency management plan to transfer to the classroom where similar contingencies were not in place. And, if this were the case, improvements in other aspects of children's classroom behavior would be expected and no evidence of this was found. Thus, it seems more likely that the focused practice in attention provided by both interventions was the more important contributor to classroom gains in attention. Finally, because participants were primarily minority students from lower SES families with below average cognitive abilities, caution is necessary in generalizing these results to other populations. However, obtaining even modest effects in a sample with these additional risk characteristics beyond attention difficulties is notable.

In summary, these results provide initial evidence that CAT and CAI can enhance children's attention in the classroom, and suggest that computer-based interventions offer promise for cost-effective early intervention for inattentive, at-risk children. Although treatment effects were modest, they support the value of further studies of more intensive training and/or different training interventions. Especially intriguing was exploratory data suggesting these interventions may yield longer-term benefit for children with more extreme attention problems. Because variation in first grade attention problems predicted the acquisition of early reading skills, and persistent attention difficulties were associated with compromised academic achievement in multiple domains, failure to obtain more robust effects should not derail further investigations to develop effective methods for addressing children's attention difficulties.

References

Barkley, R. (2007). School interventions for attention deficit hyperactivity disorder: where to from here? *School Psychology Review, 36*, 279–286.

Barkley, R., Fischer, M., Smallish, L., & Fletcher, K. (2006). Young adult outcome of hyperactive children: Adaptive functioning in major life activities. *Journal of the American Academy of Child & Adolescent Psychiatry, 45*, 192–202.

Bellucci, D. M., Glaberman, K., & Haslam, N. (2003). The effectiveness of computer-assisted cognitive rehabilitation for patients with chronic mental illness. *Schizophrenia Research, 59*, 225–232.

Cantwell, D. P., & Baker, L. (1991). Association between attention-deficit/hyperactivity disorder and learning disorders. *Journal of Learning Disabilities, 24*, 88–95.

Clarfield, J., & Stoner, G. (2005). Research brief: The effects of computerized reading instruction on the academic performance of students identified with ADHD. *School Psychology Review, 34*, 246–254.

Conners, C. K. (1997). *Conners' rating scales-revised*. North Tonawanda, NY: Multi-health systems.

De Long-Cotty & Levenson, T. (2004). The impact of destination reading: summary of research findings. Retrieved September 3, 2005, from the WestEd web site: http://hmlt.hmco.com/downloads/Research/

Din, F. (1996). Computer-assisted instruction, students' off-task behavior and their achievement. *Education and Treatment of Children, 19*(2), 170–183.

Dittman, C. (2008). An investigation of the concurrent and predictive contribution of ADHD- like behaviours and phonological processing to early word reading development. Unpublished doctoral dissertation. Queensland, Australia: The University of Queensland.

DuPaul, G. J. (2007). School-based interventions for students with attention deficit hyperactivity disorder: current status and future directions. *School Psychology Review, 36*, 183–194.

DuPaul, G. J., & Eckert, T. L. (1998). Academic interventions for students with attention- deficit/hyperactivity disorder: a review of the literature. *Reading & Writing Quarterly, 14*, 59–73.

DuPaul, G. J., Rapport, M. D., & Perriello, L. M. (1991). Teacher ratings of academic skills: the development of the Academic Performance Rating Scale. *School Psychology Review, 20*, 284–300.

DuPaul, G. J., Stoner, G., & O'Reilly, M. J. (2002). Best practices in classroom interventions for attention problems. In A. Thomas & J. Grimes (Eds.), *Best practices in school psychology, vol. 2* (pp. 1115–1127). Washington, DC: National Association of School Psychologists.

Good, R., Gruba, J., & Kaminski, R. (2002). *Best practices in using dynamic indicators of basic early literacy skills (DIBELS) in an outcomes-driven model. Best practices in school psychology IV (Vol. 1, Vol. 2)* (pp. 699–720). Washington, DC: National Association of School Psychologists.

Hintze, J. M., Ryan, A. L., & Stoner, G. (2003). Concurrent validity and diagnostic accuracy of the dynamic indicators of basic early literacy skills and the comprehensive test of phonological processing. *School Psychology Review, 32*, 541–556.

Kaufman, A. S., & Kaufman, N. L. (2004). *Kaufman brief intelligence test, 2nd edn (KBIT-2)*. Circle Pines, MN: American Guidance Service Publishing.

Kerns, K. A., Eso, K., & Thomson, J. (1999). Investigation of a direct intervention for improving attention in young children with ADHD. *Developmental Neuropsychology, 16*, 273–295.

Kleiman, G., Humphrey, M., & Lindsay, P. H. (1981). Microcomputers and hyperactive children. *Creative Computing, 7*, 93–94.

Kotwal, D. B., Burns, W. J., & Montgomery, D. D. (1996). Computer-assisted cognitive training for ADHD. *Behavior Modification, 20*, 85–96.

Lillie, D. L., Hannun, W. H., & Stuck, G. B. (1989). *Computers and effective instruction*. New York: Longman.

Little, R. J. A., & Rubin, D. B. (1987). *Statistical analysis with missing data*. New York: Wiley.

Mautone, J. A., DuPaul, G. J., & Jitendra, A. K. (2005). The effects of computer-assisted instruction on the mathematics performance and classroom behavior of children with ADHD. *Journal of Attention Disorders, 9*, 301–312.

Merrell, C., & Tymms, P. B. (2001). Inattention, hyperactivity, and impulsiveness: Their impact on academic achievement and progress. *British Journal of Educational Psychology, 71*, 43–56.

Merrell, C., & Tymms, P. B. (2005). Rasch analysis of inattentive, hyperactive, and impulsive behavior in young children and the link with academic achievement. *Journal of Applied Measurement, 6*, 1–18.

MTA Cooperative Group. (1999). A 14-month randomized clinical trial of treatment strategies for ADHD. *Archives of General Psychiatry, 56*, 1073–1086.

MTA Cooperative Group. (2009). The MTA at 8 years: prospective follow-up of children treated for combined-type ADHD in a multisite study. *Journal of the American Academy of Child and Adolescent Psychiatry, 48*, 484–500.

Murphy, K., Barkley, R. A., & Bush, T. (2002). Young adults with ADHD: subtype differences in comorbidity, educational, and clinical history. *Journal of Nervous and Mental Disease, 190*, 147–157.

Muthén, L. K., & Muthén, B. O. (2009). *Mplus user's guide (v5.2)*. Los Angeles: Muthén & Muthén.

National Institute of Child Health and Human Development. (2000). *Report of the national reading panel: teaching children to read*. Washington, DC: National Institute for Literacy.

Ota, K., & DuPaul, G. (2002). Task engagement and mathematics performance in children with attention-deficit hyperactivity disorder: effects of supplemental computer instruction. *School Psychology Quarterly, 17*, 242–257.

Pappadopulos, E., Jensen, P., Chait, A., Arnold, L., Swanson, J., Greenhill, L., et al. (2009). Medication adherence in the MTA: saliva methylphenidate samples versus parent report and mediating effect of concomitant behavioral treatment. *Journal of the American Academy of Child & Adolescent Psychiatry, 48*, 501–510.

Posner, M. I., Sheese, B. E., Odludas, Y., & Tang, Y. (2006). Analyzing and shaping human attentional networks. *Neural Networks, 19*, 1422–1429.

Rabiner, D. L., Coie, J. D., & CPPRG. (2000). Early attention problems and children's reading achievement: a longitudinal investigation. *Journal of the American Academy of Child and Adolescent Psychiatry, 39*, 859–867.

Rabiner, D. L., Murray, D. W., Schmid, L., & Malone, P. (2004). An exploration of the relationship between ethnicity, attention problems, and academic achievement. *School Psychology Review, 33*, 498–509.

Rabiner, D. L., Malone, P. S., & CPPRG. (2004). The impact of tutoring on early reading achievement for children with and without attention problems. *Journal of Abnormal Child Psychology, 32*, 273–284.

Rohling, M. L., Faust, M. E., Beverly, B., & Demakis, G. (2009). Effectiveness of cognitive rehabilitation following acquired brain injury: A meta-analytic re-examination of Cicerone et al.'s (2000, 2005) systematic reviews. *Neuropsychology, 23*, 20–39.

Rueda, M. R., Rothbart, M. K., McCandliss, B. D., Saccomanno, L., & Posner, M. I. (2005). Training, maturation, and genetic influences on the development of executive attention. *Proceedings of the National Academy of Sciences of the United States of America, 102*, 14931–14936.

SAS Insitute. (2007). *SAS (v9.2) [software]*. Cary, NC: SAS Institute.

Scheffler, R. M., Brown, T. T., Fulton, B. D., Hinshaw, S. P., Levine, P., & Stone, S. (2009). Positive association between attention-deficit/hyperactivity disorder medication use and academic achievement during elementary school. *Pediatrics, 123*(5), 1273–9.

Semrud-Clikeman, M., Nielsen, K. H., Clinton, A., Sylvester, L., Parle, N., & Connor, R. T. (1999). An intervention approach for children with teacher- and parent-identified attentional difficulties. *Journal of Learning Disabilities, 32*, 581–590.

Shalev, L., Tsal, Y., & Mevorach, C. (2007). Computerized progressive attentional training (CPAT) program: effective direct intervention for children with ADHD. *Child Neuropsychology, 13*(4), 382–388.

Slate, E., Meyer, T. L., Burns, W. J., & Montgomery, D. D. (1998). Computerized cognitive training for severely disturbed children with ADHD. *Behavior Modification, 22*(3), 415–437.

Snow, C. E., Burns, M. S., & Griffin, P. (1998). *Preventing reading difficulties in young children*. Washington, DC: National Academy Press.

Swanson, J. M., Kraemer, H. C., Hinshaw, S. P., Arnold, L. E., Conners, C. K., Abikoff, H. B., et al. (2001). Clinical relevance of the primary findings of the MTA: Success rates based on severity of ADHD and ODD symptoms at the end of treatment. *Journal of the American Academy of Child & Adolescent Psychiatry, 40*, 168–179.

Xu, C., Reid, R., & Steckelberg, A. (2002). Technology applications for children with ADHD: assessing the empirical support. *Education and Treatment of Children, 25*, 224–248.

Weisz, J. R., & Gray, J. S. (2008). Evidence-based psychotherapy for children and adolescents: data from the present and a model for the future. *Child and Adolescent Mental Health, 13*, 54–65.

Wolraich, M. L., Hannah, J. N., Baumgaertel, A., & Feurer, I. D. (1998). Examination of DSM-IV criteria for attention-deficit/hyperactivity disorder in a county-wide sample. *Journal of Developmental and Behavioral Pediatrics, 19*, 192–168.

Woodcock, R. W., McGrew, K. S., & Mather, N. (2001). *Woodcock-Johnson III tests of achievement*. Itasca, IL: Riverside Publishing.