J Learn Disabil OnlineFirst, published on March 5, 2009 as doi:10.1177/0022219408331042

Journal of Learning Disabilities
Volume XX Number X
Month XXXX xx-xx

10.1177/0022219408331042
http://journaloflearningdisabilities.sagepub.com
hosted at
http://online.sagepub.com

The Role of Multidimensional Attentional Abilities in Academic Skills of Children With ADHD

Andrew S. Preston
Brown University

Shelley C. Heaton
Sarah J. McCann
William D.Watson
University of Florida

Gregg Selke
Rhode Island Hospital

Despite reports of academic difficulties in children with attention-deficit/hyperactivity disorder (ADHD), little is known about the relationship between performance on tests of academic achievement and measures of attention. The current study assessed intellectual ability, parent-reported inattention, academic achievement, and attention in 45 children (ages 7–15) diagnosed with ADHD. Hierarchical regressions were performed with selective, sustained, and attentional control/switching domains of the *Test of Everyday Attention for Children* as predictor variables and with performance on the *Wechsler Individual Achievement Test–Second Edition* as dependent variables. It was hypothesized that sustained attention and attentional control/switching would predict performance on achievement tests. Results demonstrate that attentional control/switching accounted for a significant amount of variance in all academic areas (reading, math, and spelling), even after accounting for verbal IQ and parent-reported inattention. Sustained attention predicted variance only in math, whereas selective attention did not account for variance in any achievement domain. Therefore, attentional control/switching, which involves components of executive functions, plays an important role in academic performance.

Keywords: *ADHD; academic; achievement; attention; executive functioning; assessment; children*

Academic difficulties comprise some of the most consistently reported and impairing sequelae of attention-deficit/hyperactivity disorder (ADHD). Numerous studies have demonstrated that children with ADHD have poorer grades, higher rates of school failure and repeated grades, and greater rates of academic underachievement compared to same-aged and even IQ-matched peers (Deshazo, Lyman, & Klinger, 2002; Holborow & Berry, 1986; Kamphaus & Frick, 1996; Lambert & Sandoval, 1980; Wilson & Marcotte, 1996). In fact, many children with ADHD meet criteria for a learning disability (Cantwell & Satterfield, 1978; Lambert & Sandoval, 1980), with comorbidity rates as high as 30% between the two disorders (Faraone, Biederman, Monuteaux, Doyle, & Seidman, 2001).

There is considerable evidence that academic difficulties can have a significant impact on the educational attainment and social functioning of ADHD children. Several studies have indicated that children with ADHD have higher rates of school dropout and suspensions during adolescence (Hinshaw, 1992; Moffitt & Silva, 1988; Satterfield, Hoppe, & Schnell, 1982; Wilson & Marcotte, 1996; Zagar, Arbit, Hughes, Busell, & Busch, 1989). These problems continue to manifest in college, with these youth earning lower grades and experiencing more academic probations (Heiligstein, Guenther, Levy, Savino, & Fulwiler, 1999). Poor academic achievement also appears to contribute to delinquency among children diagnosed with ADHD. A study by Pisecco, Wristers, and Swank (2001) found that poor academic self-concept predicted antisocial behavior in early adolescents with ADHD. These findings suggest that academic difficulties, or at least the perception of these difficulties, directly contribute to poor academic outcomes and related antisocial behavior. Studies have further demonstrated that delinquency is more prevalent in children with ADHD (Hinshaw, 1992; Moffit & Silva, 1988; Satterfield et al., 1982; Wilson & Marcotte, 1996; Zagar et al., 1989).

Despite numerous studies demonstrating a link between ADHD and poor academic achievement, the specific nature of this relationship is unclear. Only a handful of studies have attempted to examine specific ADHD-related behaviors that contribute to poor academic performance. A study by Zentall, Smith, Lee, and Wieczoreck (1994) reported that children with ADHD performed more poorly on math computations because they were slower and less accurate than controls, in addition to being more off task; children with ADHD were out of their seat, looking away and talking more than controls, which could clearly impact speed and accuracy of performance. Merrell and Tymms (2001) reported that a teacher rating of *Diagnostic and Statistical Manual of Mental Disorders–Fourth Edition* (*DSM-IV*; American Psychiatric Association, 1994) inattentive behaviors was significantly higher in children who performed poorly on achievement tests of reading and math.

In addition to observed ADHD-related behaviors, two studies have demonstrated specific cognitive deficits in ADHD that may contribute to academic performance with neuropsychological testing. Aylward, Gordon, and Verhulst (1997) found a small but significant relationship between performance on a *Continuous Performance Test* and scores on standardized achievement tests on a large sample of children with ADHD, suggesting a relationship between sustained attention and academic performance. DeShazo et al. (2002) found that performance on tests of executive function predicted performance on academic achievement tests in the areas of basic skills and math but not reading and writing. This study also measured parent-reported behaviors of ADHD, which predicted performance on all areas of academic achievement even after controlling for performance on tests of executive function. These studies support a relationship between specific ADHD-related deficits and academic performance; however, the studies are limited by their lack of a multidimensional conceptualization of cognitive functioning. For example, Aylward et al. (1997) examined only one domain of attention, sustained attention; DeShazo et al. (2002) examined the broad construct of executive functions. However, it is difficult to make firm conclusions about performance on other aspects of attention because few studies have used a measure that allows for assessment across multiple domains of attention. Therefore, to accurately treat attentional deficits and their accompanying problems in academic achievement, it is vital to understand how specific attentional deficits may impact academic performance. This requires objective measures that evaluate attentional performance across multiple domains of attention, as well as ecologically valid reports of ADHD-related behaviors from parents and/or teachers.

The current study examined the relationship between ADHD and academic performance through a combination of neuropsychological tests of different aspects of attention and parent-report measures of ADHD symptoms. The *Test of Everyday Attention for Children* (TEA-Ch; Manly, Robertson, Anderson, & Nimmo-Smith, 1999) was used to assess a multidimensional model of attention, consisting of sustained attention, selective attention, and attentional control/switching. Sustained attention involves maintaining attention over an extended period. Selective attention involves attending to relevant stimuli while ignoring irrelevant stimuli. Attentional control/switching is often referred to as involving executive functioning skills and involves changing attentional focus flexibly and adaptively (Cooley & Morris, 1990; Mirsky, Anthony, Duncan, Dhearn, & Kellam, 1991; Sergeant & van de Meere, 1990) as well as the ability to inhibit automatic, irrelevant responses and initiate more relevant alternative responses (Anderson, 2002; Baddeley, 1986). By comparing performance on these tests to performance on tests of academic achievement, we hope to begin to develop a thorough and accurate understanding of the specific relationship between attentional deficits, behavioral symptoms, and academic performance. This in turn may lead to better treatment of academic problems in children with ADHD and thereby assist in reducing rates of school failure, dropout, delinquency, and other behavior problems. Based on past research that children with ADHD perform poorly on tests of sustained attention and attentional control, we hypothesized that academic performance would be predicted by performance on the TEA-Ch composite scores of sustained attention and attentional control above and beyond verbal intellectual performance and parent ratings of inattention.

Method

Participants

Participants were recruited from a psychology clinic located in a large teaching hospital, where they were being seen for a psychological evaluation. To reduce possible confounds related to significant general cognitive limitations, such as mental retardation, participants were excluded from the study if they obtained a Verbal, Performance, or Full Scale IQ score of less than 70, as determined by the *Wechsler Intelligence Scale for Children–Fourth Edition* (WISC-IV; Wechsler, 2003), *Wechsler Intelligence Scale for Children–Third Edition* (WISC-III; Wechsler, 1991), or the *Wechsler Abbreviated Scale of Intelligence* (WASI; Wechsler, 1999). Participants were also excluded if they had a diagnosis of Mental Retardation or other comorbid neurological disorder (i.e., epilepsy). Furthermore, participants were excluded from the analyses if they were missing data for any of the variables of interest.

A total of 45 participants were included in this study. All participants were diagnosed with ADHD by a clinical psychologist specializing in childhood disorders in the psychology clinic. The diagnosis was based on clinical history, interview of the parents, and results of parent and teacher ratings on behavioral questionnaires. All participants met the American Psychiatric Association's (2000) *Diagnostic and Statistical Manual of Mental Disorders–Fourth Edition, Text Revision* (*DSM-IV-TR*) diagnostic criteria for ADHD. The group subtypes consisted of 17 children with Inattentive Subtype, 26 with Combined Subtype, and 2 children with Not Otherwise Specified Subtype. A total of 22 participants (49%) met the American Psychiatric Association's (2000) *DSM-IV-TR* criteria for comorbid psychological conditions including Reading Disability ($n = 5$), Oppositional Defiant Disorder ($n = 6$), Conduct Disorder ($n = 3$), Adjustment Disorder ($n = 3$), and Mood or Anxiety Disorder ($n = 4$). Four of these participants had more than one comorbid psychiatric condition. Numerous other factors, including age, grade, gender, ethnicity, and medication usage were also considered. Participants had a mean age of 10 years 4 months (range = 7–15 years). Participants had a mean grade level of mid–Grade 4 (range = 1–9). Consistent with literature indicating that significantly more boys are diagnosed with ADHD than girls in clinical settings, 73% ($n = 33$) of participants were boys. Participants in this study were of multiple ethnicities. Specifically, 80.0% ($n = 36$) were Caucasian, 17.8% ($n = 8$) were African American, and the remaining 2.2% ($n = 1$) was self-described as "other." Parent socioeconomic status (SES) was available for approximately half of the participants. Among 20 participants, mother's education ranged from 6 to 16 years, with an average that was slightly above the 12th grade ($M = 12.9$, $SD = 2.25$). Among 16 participants, father's education ranged from 8 to 19 years with an average slightly above 12th grade ($M = 12.4$, $SD = 2.4$). Annual incomes among 19 participants ranged from less than $5,000 to more than $65,000. Parents reported a range of occupations, including disability or unemployment, skilled and semiskilled labor, business managers, administrators, and other professional and semiprofessional occupations. In terms of medication, 22 participants (49%) were being treated with a psychostimulant (Methylphenidate or Dextroamphetamine) at the time of testing. As noted above, children were only included if they had a Full Scale IQ at or above 70. Table 1 depicts group characteristics.

Table 1
Demographic Variables of All Participants

Demographic Variable	Value
Total sample size	45
Age (years.months)	10.4 (2.4)
School grade level	4.4 (2.4)
Gender (M:F)	33:12
Ethnicity[a]	
Caucasian	36 (80%)
African American	8 (18%)
Hispanic or "other"	1 (2%)
Psychiatric comorbidity[a]	
Reading Disability	5 (11%)
Oppositional Defiant Disorder	6 (13%)
Conduct Disorder	3 (7%)
Adjustment Disorder	3 (7%)
Mood/Anxiety Disorder	4 (9%)
Intellectual abilities[b]	
Full Scale IQ	96.2 (11.6)
Verbal IQ	97.4 (12.5)
Performance IQ	95.9 (12.1)

Note: Values reflect group mean (standard deviation), unless otherwise noted.
a. Values reported as *n* (% of sample).
b. IQ estimates derived from the *Wechsler Abbreviated Scale of Intelligence* or the *Wechsler Intelligence Scale for Children–Third Edition*.

Procedures

Parents of study participants gave informed consent prior to testing, and youth provided verbal or written assent to participate in the study. All assessment measures were administered by an experienced clinician or research assistant trained in test administration and scoring. Parents of participants were asked to fill out the *Conners Parents Rating Scales–Revised* (Long Version) (CPRS-R:L; Conners, Parker, Sitarenios, & Epstein, 1998). The CPRS-R:L *DSM-IV* Inattentive index was used in the statistical analysis. Intellectual functioning (Verbal, Performance, and Full Scale IQ) was assessed using the WISC-IV (Wechsler, 2003), WISC-III (Wechsler, 1991), or the WASI (Wechsler, 1999). Academic achievement was measured using three subtests from the *Wechsler Individual Achievement Test–Second Edition*

(WIAT-II; Wechsler, 2001) Word Reading, Numerical Operations, and Spelling.

Nine subtests of the TEA-Ch were used to measure selective attention, sustained attention, or attentional control. The TEA-Ch is standardized for children ages 6 to 16 and consists of nine "game-like" tasks designed to measure selective attention, sustained attention, and attentional control/switching. For each subtest, raw scores are converted to age and gender corrected scaled scores, with a scale mean of 10 and standard deviation of ±3. The TEA-Ch manual presents reliability and validity data for the nine subtest scores. Test-retest reliability coefficients averaged .74 (range = .57–.85). Ceiling effects made correlations unrealistic for some subtests; thus, percentage agreement within one standard deviation was reported and ranged from 71% to 76% (Manly et al., 1999). Convergent validity of the TEA-Ch has been demonstrated through correlations with other measures of attention, such as the *Stroop Task*, the *Trail Making Test*, and the *Matching Familiar Figures Test* (Manly et al., 1999). Although the TEA-Ch consists of nine subtests, there are 13 total scores that are acquired. The TEA-Ch manual, however, reports the results of a factor analysis, which yielded an ideal model using only 9 of the 13 scores (Manly et al., 1999). The current study followed this model and therefore utilized the following 9 scores: Sky Search Attention Score; Map Mission; Creature Counting Timing Score; Opposite Worlds; Score!; Code Transmission; Walk, Don't Walk; Score DT; and Sky Search DT. A brief description of the subtests follows below for readers unfamiliar with this battery. For a more detailed description, the reader is referred to a previous study by Heaton et al. (2001) or to the TEA-Ch administration manual (Manly et al., 1999). Composite scores were created for each attentional domain by summing the respective subtests for each domain and dividing the sum by the total number of subtests included, therefore creating an average scaled score for each attentional domain.

Sustained Attention includes the following subtests: Score! (a task of auditory attention to tones); Score! DT (dual auditory task requiring the participant to count tones while listening for an animal name in a "news report"); Sky Search DT (a multimodal dual task involving visual target identification while counting tones); Walk, Don't Walk (a test of auditory attention requiring the participant to mark steps that correspond to a target sound while inhibiting response to a nontarget sound); and Code Transmission (auditory attention requiring identification of the number that follows a specific sequence, such as the number following two consecutive "3s"). *Selective Attention* was assessed by the following subtests: Sky Search (Attention score) and Map Mission, which both involve rapidly identifying visual targets among distracters. *Attentional Control* was measured by Creature Counting (Timing score; rapid switching between counting forward and backward in response to visual stimuli) and Opposite Worlds (Opposite World score; rapid cognitive reversal of an overlearned response; e.g., saying "1" while seeing "2").

Results

Primary Analyses

For all statistical tests, the level of significance was set at $\alpha = .05$. All statistical tests were performed using the SPSS statistical analysis package (SPSS for Windows, 2007). Participants had a mean Full Scale IQ score of 96.24 (SD = 11.61), a mean Verbal IQ (VIQ) of 97.36 (SD = 12.49), and a mean Performance IQ of 95.93 (SD = 12.06). Participants had a mean score of 71.60 (SD = 10.46) on the CPRS-R:L *DSM-IV Inattentive Scale*. Participants generally performed in the average range on WIAT-II subtests (Word Reading = 99.27, Numerical Operations = 99.98, Spelling = 94.13). On measures of the TEA-Ch, participants performed in the low average range on Selective Attention (scaled score = 8.88, SD = 2.42) with more impairment on tests of Sustained Attention (scaled score = 6.50, SD = 2.60) and Attentional Control/Switching (scaled score = 6.11, SD = 2.97). Results are depicted in Table 2.

Hierarchical regression analyses were conducted to determine the amount of variance that VIQ, CPRS-R:L *DSM-IV Inattentive Scale*, and TEA-Ch composite scores predicted on Word Reading, Numerical Operations (math), and Spelling subtests of the WIAT-II. We conducted separate regression analyses for each domain of achievement—Word Reading, Numerical Operations (math), and Spelling. In each analysis, we entered VIQ as the covariate in Step 1, CPRS-R:L *DSM-IV Inattentive Scale* score as the covariate in Step 2, and TEA-Ch composites (Selective Attention, Sustained Attention, and Attentional Control/Switching) simultaneously in Step 3. This model was used to determine whether performance on objective tests of attention were useful predictors of academic achievement beyond intellectual performance and parent-reported behaviors. Tables 3, 4, and 5 provide summaries of these analyses. These models found that the overall construct of attention comprising the three domains (sustained, selective, attentional control/switching) moderately predicted academic achievement in Word Reading, $F(5, 39) = 6.86$, $p < .001$,

Table 2
Parent Ratings of Inattention and Child Performance on Attention and Academic Tasks

Variable	*M*	*SD*	Range Min	Range Max
Parent ratings of inattentive behavior				
CPRS-R:L *DSM-IV Inattentive Scale* (*t* score)	71.60	10.46	41.0	90.0
Attentional performance				
Selective Attention scaled score	8.88	2.42	3.5	14.0
Sustained Attention scaled score	6.50	2.60	1.6	12.2
Attentional Control/Switching scaled score	6.11	2.97	1.0	11.0
Academic performance				
Word Reading standard score	99.27	14.30	62.0	125.0
Numerical Operations standard score	99.98	14.85	68.0	133.0
Spelling standard score	94.13	13.59	63.0	122.0

Note: CPRS-R:L = *Conners Parents Rating Scales–Revised* (Long Version); *DSM-IV* = *Diagnostic and Statistical Manual of Mental Disorders–Fourth Edition*.

Table 3
Hierarchical Regressions of Variables Predicting Reading Achievement

Variables	Reading *R*	R^2	ΔR^2	ΔF
Control variables				
VIQ	.563	.317	.317	19.982***
CPRS	.564	.318	.001	0.072
Attention variables	.684	.468	.150	3.653*
Selective attention				
Sustained attention				
Attentional control/switching				

Note: CPRS = *Conners Parents Rating Scales*; VIQ = Verbal IQ.
*$p < .05$. **$p < .01$. ***$p < .001$.

Table 4
Hierarchical Regressions of Variables Predicting Math Achievement

Variables	Math *R*	R^2	ΔR^2	ΔF
Control variables				
VIQ	.680	.462	.462	36.934***
CPRS	.680	.462	.000	0.000
Attention variables	.823	.677	.215	8.661***
Selective attention				
Sustained attention				
Attentional control/switching				

Note: CPRS = *Conners Parents Rating Scales*; VIQ = Verbal IQ.
*$p < .05$. **$p < .01$. ***$p < .001$.

Table 5
Hierarchical Regressions of Variables Predicting Spelling Achievement

Variables	Spelling *R*	R^2	ΔR^2	ΔF
Control variables				
VIQ	.509	.259	.259	15.047***
CPRS	.511	.262	.002	0.132
Attention variables	.676	.457	.196	4.692**
Selective attention				
Sustained attention				
Attentional control/switching				

Note: CPRS = *Conners Parents Rating Scales*; VIQ = Verbal IQ.
*$p <.05$. **$p < .01$. ***$p < .001$.

$R^2 = .47$; Numerical Operations (math), $F(5, 39) = 16.36$, $p < .001$, $R^2 = .68$; and Spelling, $F(5, 39) = 6.58$, $p < .001$, $R^2 = .46$, after accounting for the variance predicted by VIQ and parent-rated inattention. Interestingly, whereas VIQ predicted a significant amount of variance in each academic domain, parent-rated inattention did not predict significant variance in any domain.

When examining the specific domains of attention, the results demonstrated that TEA-Ch Attentional Control/Switching was consistently significant in explaining variance in all three areas of academic achievement: Word Reading ($\beta = .33$, $p < .05$), Numerical Operations (math) ($\beta = .30$, $p < .05$), and Spelling ($\beta = .42$, $p < .01$), even after accounting for the variance from VIQ and parent-reported inattentive behaviors. This analysis

Table 6
Hierarchical Regressions Predicting Achievement Scores

	Reading			Math			Spelling		
Variables	*B*	*SE*	R^2	*B*	*SE*	R^2	*B*	*SE*	R^2
Control variables			.47			.68			.46
VIQ	.572	.138***		.703	.111		.517	.132***	
CPRS	.001	.163		.040	.132		.131	.156	
Attention variables									
Selective attention	.317	.787		.066	.635		.641	.753	
Sustained attention	.417	.721		1.432	.582*		–.619	.691	
Attentional control/switching	1.578	.701*		1.514	.566*		1.926	.671**	

Note: CPRS = *Conners Parents Rating Scales*; VIQ = Verbal IQ.
*$p < .05$. **$p < .01$.***$p < .001$.

further showed that TEA-Ch Sustained Attention predicted a significant amount of the variance in the WIAT-II Numerical Operations (math) test (β = .25, $p < .05$) but not on Word Reading or Spelling. In contrast, TEA-Ch Selective Attention did not account for a significant amount of variance on any WIAT-II test. Results are depicted in Table 6.

Secondary Analyses

Subtype comparisons. To determine the potential differences of our target variables between ADHD subtypes, an independent samples *t* test was conducted with ADHD–combined type (ADHD-C) and the ADHD–inattentive type (ADHD-I) as the independent variables and VIQ, the CPRS-R:L *DSM-IV Inattentive Scale*, TEA-Ch composite scores, and WIAT-II Word Reading, Numerical Operations (math), and Spelling scores as the dependent variables. No group differences were found between any of these variables based on subtype.

ADHD with and without comorbid Reading Disability. To ensure that the relationship between attention and achievement variables in children with ADHD was not due to comorbid Reading Disability, we performed hierarchical regressions using the same model (VIQ in Step 1, CPRS-R:L *DSM-IV Inattentive Scale* in Step 2, TEA-Ch attention variables in Step 3) without the 11% of participants with comorbid Reading Disability. Results demonstrated the same pattern as with the full sample: Selective Attention did not predict performance in any domain, Sustained Attention continued to account for variance only in the WIAT–II Numerical Operations (math) (β = .30, $p < .01$), and Attentional Control/Switching accounted for a significant amount of variance in Numerical Operations (β = .28, $p < .05$) and Spelling (β = .41, $p < .05$), with a trend in Word Reading (β = .30, $p = .07$).

Medication comparisons. To determine the effects of medication, an independent samples *t* test was conducted with children taking stimulant medication at the time of testing (ON-MED) and the children not taking stimulant medication at the time of testing (OFF-MED) as the independent variables and VIQ, Performance IQ, Full Scale IQ, the CPRS-R:L *DSM-IV Inattentive Scale*, TEA-Ch composite scores, and WIAT-II Word Reading, Numerical Operations, and Spelling scores as the dependent variables. No group differences were found between any of these variables based on stimulant medication use. To further evaluate possible differences in group characteristics between the ON-MED and the OFF-MED groups, the groups were also compared on age, gender, ethnicity, and SES. Independent samples *t* tests found no significant differences on age. Chi-square analyses revealed that the groups did not differ in terms of gender or ethnicity. Similarly, among the subsample of participants with information regarding SES, there were no differences between the ON-MED and the OFF-MED groups in terms of average education for mothers or fathers or in family income. Results comparing the ON-MED and OFF-MED groups are depicted in Table 7.

Discussion

The present study was designed to investigate the impact of a multidimensional construct of attention on children's performance on academic achievement tests. To address this issue, we created a model that after accounting for variance from VIQ and parent ratings of inattentive behavior, explored the contributions of selective attention, sustained attention, and attentional control/switching. Consistent with previous research, these results support the theory that ADHD-related cognitive profiles contribute to poor academic performance. Specifically, this study sought to

Table 7
Group Differences Between ON-MED and OFF-MED Groups

Variable	ON-MED (n = 22)	OFF-MED (n = 23)
Demographic variables		
Age	10.4 (1.9)	10.2 (2.8)
Ethnicity (% Caucasian)	82%	78%
Gender (% male)	73%	74%
Intellectual performance		
Verbal IQ	97.7 (13.6)	97.0 (11.6)
Performance IQ	97.1 (12.3)	94.8 (12.0)
Full Scale IQ	97.3 (12.2)	95.2 (11.2)
Parent ratings of inattentive behavior		
CPRS-R:L *DSM-IV Inattentive Scale* (t score)	69.4 (12.9)	73.7 (7.1)
Attentional performance		
Selective Attention scaled score	8.8 (2.2)	8.8 (2.6)
Sustained Attention scaled score	6.4 (2.9)	6.7 (2.4)
Attentional Control/Switching scaled score	6.2 (3.1)	6.0 (3.0)
Academic performance		
Reading standard score	98.8 (16.3)	99.9 (12.9)
Numerical Operations standard score	100.2 (14.4)	99.6 (15.9)
Spelling standard score	93.7 (15.6)	94.8 (11.9)

Note: Values reflect group mean (standard deviation), unless otherwise noted. CPRS-R:L = *Conners Parents Rating Scales–Revised* (Long Version); *DSM-IV* = *Diagnostic and Statistical Manual of Mental Disorders–Fourth Edition*; OFF-MED = children not taking stimulant medication at the time of testing; ON-MED = children taking stimulant medication at the time of testing.

clarify the nature of the attentional deficits that led to poor academic achievement. Findings presented here suggest that academic achievement was significantly predicted by performance on tests of attentional control/switching. Although children with ADHD have previously demonstrated impaired performance on tests of academic achievement, this impairment appears to be accounted for by the attentional domain that requires more executive control than the other domains of attention. Specifically, the TEA-Ch subtests comprising the Attentional Control/Switching composite utilize inhibition, working memory, and set shifting, all subdomains of executive functioning.

These findings are in fact consistent with previous studies (Biederman, Monuteaux, & Doyle, 2004) showing that children with ADHD who have executive functioning deficits are more likely to have academic problems than children with ADHD who do not have executive functioning deficits. A meta-analysis of 83 studies (Wilcutt, Doyle, Nigg, Faraone, & Pennington, 2005) reported that executive functioning deficits were found to be an important component of ADHD but were neither consistent nor large enough to account for all ADHD deficits. In our study, we demonstrated that attentional control/switching plays a significant role in academic achievement. Conversely, previous studies (Clark, Prior, & Kinsella, 2002) have suggested that executive functioning had only a small correlation with reading ability and accounted for only 5% of the variance in reading performance after vocabulary was factored out. The present study differs from the cited research in that previous studies were unable to measure multiple domains of attention with the same test battery, allowing direct comparison of performance across attentional domains. This approach allowed us to eliminate possible variation that was due to different normative data or extraneous differences among different measures. It should be noted, however, that the TEA-Ch contains some inherent task stimulus (e.g., auditory, visual) and response (e.g., verbal, motor) modality differences across domains. This potential confound could not be fully controlled using this test battery.

The current study may allow for better understanding of academic difficulties in children with ADHD. Significant predictors of academic achievement were found beyond parent ratings of behavior, suggesting that tests of attention, specifically those that utilize attentional control/switching, could be useful tools in predicting difficulties in academic performance. These results suggest that at least some of the academic difficulties experienced by children with ADHD are due to their inability to adequately inhibit and shift their attention rather than the presence of a specific learning disability per se. It is well known that ADHD and learning disabilities are often comorbid, but the current study suggests that some children with ADHD may have academic problems that are independent of a learning disability. Treating attentional deficits effectively would theoretically result in improved academic performance as proposed by this model.

Although the current study included some children that were taking stimulant medication, no significant differences were found between medicated and unmedicated children in terms of the target variables or other important demographic variables (age, gender, ethnicity, SES), suggesting that stimulant medication or associated characteristics of children taking stimulant medication did not affect the relationship between attention profile and academic achievement. It is important to note that these results do not purport to dismiss stimulant medication effect on academic performance; this study was not a controlled examination of medication effects, and previous studies have shown academic improvement from stimulant medication. Furthermore, it is well documented that children with ADHD experience deficits in sustained attention, and it may be the case that children in our sample with the greatest deficits in sustained attention were receiving medication, thus biasing our sample and truncating the scores on sustained attention tasks, which may in turn weaken any relationship between achievement scores and scores on sustained attention. Therefore, although sustained attention predicted variance only on math achievement, it may play a more important role in other areas of academic achievement than noted in this study.

Limitations of the study include the fact that academic performance was assessed via the WIAT-II rather than teacher ratings or other assessments of actual classroom behavior. Unfortunately, we did not have adequate information about grades or repeated grades to assess actual academic performance; 7 of the 45 children reportedly repeated one grade, but we did not have information on the other 38 children. Clearly, children with ADHD may perform differently in a testing environment as compared with the classroom setting, where other forms of attention, namely, sustained attention and selective attention, may play a larger role. It is important to note, however, that even in a controlled one-on-one testing environment, with presumably greater structure and fewer demands on self-regulation than a classroom, executive functions (namely, attentional control/switching) played an important role in performance on academic achievement tests. Future studies should include school and other evaluations to allow for greater ecological validity.

Our sample was heterogeneous in that we did not exclude children based on specific subtypes of ADHD. Although we did not have any children with the Hyperactive/Impulsive (HI) subtype in our sample, this is not surprising given that this subtype is relatively rare and generally occurs only in younger, typically preschool age, children (Elia, Ambrosini, & Berrettini, 2008; Lahey et al., 1994). In fact, recent research suggests that ADHD-HI may not represent a distinct subtype but rather an early diagnosis of ADHD that later develops into ADHD-C (Lahey, Pelham, Loney, Lee, & Wilcutt, 2005; Riley et al., 2008). Therefore, the results of our study are more generalizable to children in elementary school and older and may not be representative of children with ADHD in preschool.

In addition, the current study included children with comorbid conditions such as Reading Disability and Oppositional Defiant Disorder. We included these cases because we believe that a sample of children with pure ADHD and no comorbid conditions would be unrepresentative of the clinical population. Indeed, recent research suggests that almost two thirds of children with ADHD have at least one other impairing comorbid disorder (Elia et al., 2008). Our goal is to provide practitioners, teachers, and parents with guidance that is applicable and generalizable to their patients, students, and children. The current study was able to determine that different ADHD subtypes did not differ in terms of performance on the target variables. In addition, when children with comorbid ADHD and Reading Disabilities were removed, our pattern of findings remained consistent. Unfortunately, however, sample-size limitations make it difficult to further explore the impact of other comorbid conditions due to the low number of each condition.

Future studies should target these issues through subgroup diagnostics composed of children with ADHD, children with ADHD and Reading Disability, and children with Reading Disability alone to learn more about the relationship between executive functions and academic achievement in these populations. In addition, the current findings would be bolstered by future studies that determine whether the relationship between attentional deficits and academic achievement is the same across different populations or is unique to specific disorders. It is possible that the relationship between executive functioning and academic achievement is significant for all children (not just those with ADHD), that a certain level of performance on executive functioning tasks is sufficient, or that certain disorders are differentially affected by executive functioning weaknesses than others.

In addition to more direct comparisons of different diagnostic groups and medication effects, future studies should continue to address the impact of attentional control (e.g., executive functions) on academic achievement. Although our study found a strong relationship between these two domains, the current design was unable to determine whether impairments in executive functioning exacerbate existing learning deficits or directly cause them. This question can be answered only with continued study, ideally longitudinal designs that can follow the development of academic skills in children with and without executive functioning deficits. It is equally important to determine to what extent academic difficulties exacerbate symptoms of ADHD. Clearly, academic difficulties alone do not explain all of the externalizing behaviors and delinquency that occur in ADHD, because children with learning disabilities alone do not demonstrate the same level of externalizing behavior as children with ADHD (Wilson & Marcotte, 1996), but academic difficulties likely exacerbate ADHD-related behaviors and certainly contribute to poorer outcomes at school.

The present study suggests that attentional control/switching within the context of children with ADHD is an integral component to reading, math, and spelling success. Attentional control/switching represents the domain that orchestrates and directs other higher-order cognitive processes. If a student has difficulty with this skill, his or her academic achievement may be compromised above and beyond impairment in verbal intellectual functioning or observed inattentive behaviors. Results suggest that in addition to regular instruction in reading, math, and spelling, the education curriculum should include instruction tailored to developing skills within the attentional control/switching domain.

References

American Psychiatric Association. (1994). *Diagnostic and statistical manual of mental disorders* (4th ed.). Washington, DC: Author.

American Psychiatric Association. (2000). *Diagnostic and statistical manual of mental disorders* (4th ed., text revision). Washington, DC: Author.

Anderson, P. (2002). Assessment and development of executive function (EF) during childhood. *Child Neuropsychology*, *8*, 71–82.

Aylward, G. P., Gordon, M., & Verhulst, S. J. (1997). Relationships between continuous performance task scores and other cognitive measures: Causality or commonality? *Assessment*, *4*(4), 325–336.

Baddeley, A. D. (1986). *Working memory*. Oxford, UK: Clarendon.

Biederman, J., Monuteaux, M. C., & Doyle, A. E. (2004). Impact of executive function deficits and Attention-Deficit/Hyperactivity Disorder (ADHD) on academic outcomes in children. *Journal of Consulting and Clinical Psychology*, *72*(5), 757–766.

Cantwell, D., & Satterfield, J. H. (1978). The prevalence of academic under-achievement in hyperactive children. *Journal of Pediatric Psychology*, *3*, 168–171.

Clark, C., Prior, M., & Kinsella, G. (2002). The relationship between executive function abilities, adaptive behavior, and academic achievement in children with externalizing behaviour problems. *Journal of Child Psychology and Psychiatry*, *43*(6), 785–796.

Conners, C. K., Parker, J. D. A., Sitarenios, G., & Epstein, J. N. (1998). The Revised Conners' Parent Rating Scales (CPRS-R): Factor structure, reliability, and criterion validity. *Journal of Abnormal Child Psychology*, *26*, 257–268.

Cooley, E. L., & Morris, R. D. (1990). Attention in children: A neuropsychologically based model for assessment. *Developmental Neuropsychology*, *6*(3), 239–274.

DeShazo, B. T., Lyman, R. D., & Klinger, L. G. (2002). Academic underachievement and attention-deficit/hyperactivity disorder: The negative impact of symptom severity on school performance. *Journal of School Psychology*, *40*(3), 259–283.

Elia, J., Ambrosini, P., & Berrettini, W. (2008). ADHD characteristics: I. Concurrent co-morbidity patterns in children and adolescents. *Child and Adolescent Psychiatry and Mental Health*, *2*(1), 15.

Faraone, S. V., Biederman, J., Monuteaux, M. C., Doyle, A. E., & Seidman, L. J. (2001). A psychometric measure of learning disability predicts educational failure four years later in boys with attention deficit hyperactivity disorder. *Journal of Attention Disorders*, *4*, 220–230.

Heaton, S. C., Reader, S. K., Preston, A. S., Fennell, E. B., Puyana, O. E., Gill, N., & Johnson, J. H. (2001). The Test of Everyday Attention for Children (TEA-Ch): Patterns of performance in children with ADHD and clinical controls. *Child Neuropsychology*, *7*, 251–264.

Heiligstein, E., Guenther, G., Levy, A., Savino, F., & Fulwiler, J. (1999). Psychological and academic functioning in college students with Attention Deficit Hyperactivity Disorder. *Journal of American College Health*, *47*(4), 181–185.

Hinshaw, S. P. (1992). Academic underachievement, attention deficits, and aggression: Comorbidity and implications for intervention. *Journal of Consulting and Clinical Psychology*, *60*(6), 893–903.

Holborow, P. L., & Berry, P. S. (1986). Hyperactivity and learning difficulties. *Journal of Learning Disabilities*, *19*, 426–431.

Kamphaus, R. W., & Frick, P. J. (1996). *Clinical assessment of child and adolescent personality and behavior*. Needham Heights, MA: Allyn & Bacon.

Lahey, B. B., Applegate, B., McBurnett, K., Biederman, J., Greenhill, L., Hynd, G. W., et al. (1994). DSM-IV field trials for attention deficit hyperactivity disorder in children and adolescents. *American Journal of Psychiatry*, *151*, 1673–1685.

Lahey, B. B., Pelham, W. E., Loney, J., Lee, S. S., & Wilcutt, E. (2005). Instability of the DSM-IV subtypes of ADHD from preschool through elementary school. *Archives of General Psychiatry*, *62*, 896–902.

Lambert, N. M., & Sandoval, J. H. (1980). The prevalence of learning disabilities in a sample of children considered hyperactive. *Journal of Abnormal Child Psychology*, *8*, 33–50.

Manly, T., Robertson, I. H., Anderson, V., & Nimmo-Smith, I. (1999). *TEA-Ch: The Test of Everyday Attention for Children: manual*. Bury St. Edmunds, UK: Thames Valley Test Company.

Merrell, C., & Tymms, P. B. (2001). Inattention, hyperactivity, and impulsiveness: Their impact on academic achievement and progress. *British Journal of Educational Psychology*, *71*(1), 43–56.

Mirsky, A. F., Anthony, B. J., Duncan, C. C., Dhearn, M. B., & Kellam, S. G. (1991). Analysis of the elements of attention: A neuropsychological approach. *Neuropsychology Review*, *2*, 109–145.

Moffitt, T. E., & Silva, P. A. (1988). Self-reported delinquency, neuropsychological deficit, and history of attention deficit disorder. *Journal of Abnormal Child Psychology*, *16*(5), 553–569.

Pisecco, S., Wristers, K., & Swank, P. (2001). The effect of academic self-concept on ADHD and antisocial behaviors in early adolescence. *Journal of Learning Disabilities*, *34*(5), 450–461.

Riley, C., DuPaul, G. J., Pipan, M., Kern, L., Brakle, J. V., & Blum, N. J. (2008). Combined type versus ADHD predominantly hyperactive-impulsive type: Is there a difference in functional impairment? *Journal of Developmental and Behavioral Pediatrics*, *29*(4), 270-275.

Satterfield, J. H., Hoppe, C. M., & Schnell, A. M. (1982). A prospective study of delinquency in 110 adolescent boys with attention deficit disorder and 88 normal adolescent boys. *American Journal of Psychiatry*, *139*(6), 795–798.

Sergeant, J. A., & van der Meere, J. J. (1990). Additive factor method applied to psychopathology with special reference to childhood hyperactivity. *Acta Psychologica*, *74*, 277–296.

Wechsler, D. (1991). *Wechsler Intelligence Scale for Children–Third Edition (WISC-III)*. San Antonio, TX: Psychological Corporation.

Wechsler, D. (1999). *Wechsler Abbreviated Scale of Intelligence (WASI)*. San Antonio, TX: Psychological Corporation.

Wechsler, D. (2001). *Wechsler Individual Achievement Test–Second Edition (WIAT-II)*. San Antonio, TX: Psychological Corporation.

Wechsler, D. (2003). *Wechsler Intelligence Scale for Children–Fourth Edition (WISC-IV)*. San Antonio, TX: Psychological Corporation.

Wilcutt, E. G., Doyle, A. E., Nigg, J. T., Faraone, S. V., & Pennington, B. F. (2005). Validity of the executive function theory of attention-deficit/hyperactivity disorder: A meta-analytic review. *Biological Psychiatry*, *57*, 1336–1346.

Wilson, J., & Marcotte, A. C. (1996). Psychosocial adjustment and educational outcome in adolescents with a childhood diagnosis of attention-deficit disorder. *Journal of the American Academy of Child And Adolescent Psychiatry*, *35*(5), 579–587.

Zagar, R., Arbit J., Hughes, J. R., Busell, R. E., & Busch, K. (1989). Developmental and disruptive behavior disorders among delinquents. *Journal of the American Academy of Child and Adolescent Psychiatry*, *23*(3), 437–440.

Zentall, S. S., Smith, Y. N., Lee, Y. B., & Wieczorek, C. (1994). Mathematical outcomes of attention-deficit hyperactivity disorder. *Journal of Learning Disabilities*, *27*(8), 510–519.

Andrew S. Preston, PhD, is a postdoctoral fellow at the Warren Alpert Medical School of Brown University Medical School, Department of Psychiatry and Human Behavior. His current interests include pediatric neuropsychology, dyslexia, and ADHD.

Shelley C. Heaton, PhD, is a clinical psychologist and clinical assistant professor at the University of Florida, Department of Clinical & Health Psychology. Her current interests include pediatric neuropsychology, attention and executive functions, learning, and memory.

Sarah J. McCann, MS, is a doctoral student in clinical psychology at the University of Florida, Department of Clinical & Health Psychology. Her current interests include neuropsychology, learning disabilities, and executive functions.

William D. Watson, MS, is a graduate student in clinical psychology at the University of Florida, Department of Clinical & Health Psychology. His current interests include neuropsychology and attention.

Gregg J. Selke, PhD, is a clinical psychologist who specializes in pediatric neuropsychology at Rhode Island Hospital, Department of Psychiatry. His current research interests are in the areas of ADHD, pediatric cancer, and sleep.