Response Inhibition and Academic Abilities in Typically Developing Children with Attention-Deficit-Hyperactivity Disorder-Combined Subtype

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Abstract

Research in Attention-Deficit/Hyperactivity Disorder (ADHD) generally utilizes clinical samples or children with comorbid psychiatric diagnoses. Findings indicated that children with ADHD experience academic underachievement and poor performance on measures of response inhibition (RI). Less is known, about the neuropsychological profile of typically developing children with ADHD. The aim of the current study was twofold: (1) determine if academic skills and RI were impaired in typically developing children with ADHD-combined subtype (ADHD-C) and (2) determine to what extent RI may predict academic abilities. Children with ADHD-C did not differ on any academic domain from controls. Children with ADHD-C performed more poorly than controls on RI measures. Regression analyses suggest that Written Expression ability was significantly influenced by RI. No other academic domain was related to RI. Results suggest that children with ADHD-C may experience impairments in RI despite adequate academic functioning. Impaired RI is not solely responsible for difficulties found in academic skills in ADHD-C.

Keywords: ADHD; Achievement; Executive functions; Response inhibition

ADHD, Academic Functioning, and Executive Functions

Background

Attention-Deficit/Hyperactivity Disorder (ADHD) is characterized by impairments in attention control, impulsivity, and hyperactivity (American Psychiatric Association, 2000). ADHD is considered to be one of the most common psychiatric disorders with prevalence estimates of 3%–7% among school-aged children (APA, 2000). Children with ADHD are often diagnosed with comorbid disorders including approximately 50%–60% with oppositional defiant disorder or conduct disorder (Gillberg, Gillberg, Rasmussen, Kadesjo, & Soderstrom, 2004). In addition, ADHD has been found among those with academic learning disabilities, in particular, 25%–40% with reading disorder (RD), 10%–60% with mathematics disorder, and in general, learning disabilities have been shown to be 5–10 times more likely in ADHD (Barkley, DuPaul, & McMurray, 1990; Gillberg et al., 2004; Gillberg, Carlstrom, Rasmussen, & Waldenstrom, 1983; Gillberg & Gillberg 1983; Semrud-Clikeman et al., 1992).

Many children with ADHD have difficulty with higher order cognitive processes often described as executive functions (Barkley, 1997; Pennington & Ozonoff, 1996). One of the most commonly studied executive functions in children with ADHD is response inhibition (RI, i.e., inhibiting an automatic response for a more favorable and task appropriate response).
In addition, children with ADHD often experience academic underachievement (Frick et al., 1991). The relationship between academic skills and RI, however, has received less attention in the ADHD literature. Study of the connection between these two domains may provide information regarding the interplay of RI deficits and academic difficulties.

**Academic Functioning and RI**

It is estimated that up to 30% of children with ADHD do not achieve at the grade level or with age-expected intellectual functioning (Frick & Lahey, 1991; Kamphaus & Frick, 1996). Research suggests that children with ADHD experience more academic impairments than children without ADHD (Barkley, Anastopoulos, Gueremont, & Fletcher, 1991; Biederman et al., 2004; DeShazo Barry, Lyman, & Grofer Klinger, 2002; Faraone et al., 1993). It is unclear if symptoms of ADHD impede academic performance, or if children with ADHD have specific deficits related to the cognitive aspects of academic skills.

There is evidence that children with ADHD may perform below grade-expected levels on reading, writing, and mathematics even after controlling for intelligence, number of ADHD symptoms, and executive functioning ability (DeShazo Barry et al., 2002). For example, after removing a subsample of their ADHD group due to learning difficulties (24.2% with learning disability and 42.4% in special education classroom), no executive functioning measure (e.g., Tower of Hanoi, Wisconsin Card Sorting Test, Trail Making B) was statistically related to academic underachievement. Specifically, executive functioning performance did not predict a significant amount of unique variance on any measure of academic achievement (Basic Skills, Reading, Writing, and Mathematics) in children with ADHD without learning problems. This finding suggests that the cognitive processes involved in executive functioning (defined by the measures in the reported study) may be distinct from those required for academic work.

Others have found children with ADHD and significant executive function impairments at increased risk of academic underachievement. Using a large sample \((N = 259)\), Biederman and colleagues (2004) grouped children with ADHD into those with significant executive dysfunction (impairment on at least two of six executive functioning measures: Rey-Osterrieth Complex Figure, WCST, Stroop Color-Word, Freedom from Distractibility, WRAML or CVLT % words learned, and Auditory Continuous Performance Task) and ADHD without executive dysfunction. In this study those with ADHD and impaired executive functioning were at a greater risk of being retained in school and having academic underachievement. The observed group difference remained statistically significant after controlling for intelligence, socioeconomic status, learning disabilities, social functioning, and psychiatric comorbidity.

The disparity between DeShazo Barry and colleagues (2002) and Biederman and colleagues (2004) may be accounted for the inclusion of an ADHD with executive dysfunction group by Biederman and colleagues (2004). By dividing their sample into those with ADHD without executive dysfunction impairments and those with ADHD and executive dysfunction impairments, the authors were able to demonstrate the considerable negative effect of executive dysfunction in some children with ADHD. Biederman and colleagues (2004) found that children with ADHD and no executive dysfunction had lower academic achievement and more psychosocial impairments than controls. Thus, the connection between academic skills and executive processes may be orthogonal. These data suggest that children with ADHD may experience lower academic achievement despite normal executive functioning. Further complicating the picture are data that suggest the opposite is also true; many children with ADHD may experience executive functioning impairments despite normal academic achievement (Willcut, Doyle, Nigg, Faraone, & Pennington, 2005). Therefore, it is unclear how or if executive functioning is related to specific aspects of academic achievement.

Some speculate that executive processing is often utilized in organized writing. For example, in order to construct coherent sentences that are the building blocks for organized and articulate paragraphs, one must be able to self-regulate cognitive resources, inhibit responses that are extraneous to the task at hand, and manipulate and organize many pieces of information simultaneously (Zimmerman & Risenberg, 1997). In a sample of college-aged adults with ADHD, Semrud-Clikeman and Harder (2010) found a statistically significant relationship between executive functioning performance (Delis–Kaplan Color-Word Interference and Tower and Controlled Oral Word Association) and Writing Mechanics performance from the Scholastic Abilities Test for Adults (SATA). This study was one of the first to look at the relationship between academic skills and executive function performance. There are few studies evaluating the relationship between executive functioning domains and writing skills particularly in regard to RI; one of the purposes of the current study.

**Response Inhibition**

Executive functioning encompasses a broad range of cognitive processes, therefore looking at the relationship between academic skills and specific executive functions may be theoretically important. Executive functions are often equated with
“real-world” skills (e.g., planning ability on neuropsychological tests and planning ability in school), yet this connection has received limited empirical study. For example, foundational theories of ADHD suggested key impairments in RI (Barkley, 1997). RI is often studied using the Stroop task (Stroop, 1935). In the classic Stroop task, color words are presented in differently colored fonts (e.g., the word GREEN printed in blue ink) and participants are instructed to name the ink color of multiple lines of these conflicting color words as quickly as possible. The difficulty in the task is in attending to the color feature while ignoring the salient and natural tendency to read the word. RI, as measured by the Stroop task, has been found to differentiate between children with ADHD and children without ADHD. Using the Delis–Kaplan Executive Function System (D-KEFS, Delis, Kaplan, & Kramer, 2001), researchers found children with ADHD performed more poorly than controls on all trials of the Color-Word Interference subtests (Wodka et al., 2008).

To date, four meta-analytic studies have demonstrated a broad range of the specificity of a Stroop interference impairment in ADHD (Frazier, Demaree, & Youngstrom, 2004; Hervey, Epstein, & Curry, 2004; Homack & Riccio, 2004; van Mourik, Oosterlaan, & Sergeant, 2005). Effect sizes range from small to large (corresponding order above: 0.56, 0.15, 0.75, 0.35). The diversity of findings may, however, be explained by differences in Stroop methodology (Lansbergen, Kenemans, & van Engeland, 2007). These authors point out that the two most common methods for calculating Stroop interference scores (i.e., difference score and Golden’s method, Golden, 1978) may yield different outcomes, and conclude that Golden’s method (correction for word reading; interference score subtracted from Color-Word score) is not sensitive enough to predict RI deficits when compared, statistically, to the use of the difference score (difference between color and Color-Word scores). Furthermore, when Langsergen and colleagues (2007) conducted a meta-analysis on all Stroop studies excluding those that used Golden’s method, they found a mean effect size of 0.24 (difference scores versus control scores) across all studies and 1.11 for studies that measured time per individual item. Thus, when Stroop interference is calculated using the difference score, response interference does appear to be significantly impaired in those with ADHD.

Neuroimaging findings suggest that performance on the Stroop test is related to brain networks that have been hypothesized to be deficient in individuals with ADHD. The anterior cingulate cortex, dorsolateral and ventrolateral prefrontal cortex, and the posterior parietal lobe have all been implicated in the modulation of attention-based neural activity during Stroop (Banich et al., 2001; Bush et al., 1999; Coderre, Filippi, Newhouse, & Dumas, 2008; Liu, Banich, Jacobsen, & Tanabe, 2006; MacDonald, Cohen, Stenger, & Carter, 2000). Using a counting Stroop task (different from classical Color-Word interference task but hypothesized to illicit similar interference effects), Bush and colleagues (1999) reported hypoactivation of the anterior cingulate cortex in children with ADHD. Similar observations of abnormal activation of the anterior cingulate cortex during an interference task (Stop Signal Task) have been observed in children with ADHD (Pliszka et al., 2006).

Recent functional imaging studies suggest that when participants attend to color features during the Stroop task, orthographic processing regions show suppression in activation while feature-based regions show an increase in neural activation (Polk, Drake, Jonides, Smith, & Smith, 2008). This supports the idea that the Stroop task elicits competition between distinct brain regions (orthographic processing vs. feature-based processing), causing one to inhibit a pre-potent response in favor of a goal-based response. Such findings suggest that performance on the Stroop task may be an indication of one’s ability to inhibit competing responses to environmental stimuli. This body of research suggests that some children with ADHD have impairments in RI, as measured by the Stroop task, and that the neural correlates of the Stroop task may be modulated by anterior-cingulate and prefrontal brain regions, which have also been found to be abnormal in ADHD.

RI impairments appear to be a consistent difficulty for many children with ADHD. It is unclear, however, if RI is related to other areas of functioning. It is hypothesized that RI is an important cognitive process that may be related to similar cognitive processes involved in academic skills. The aim of the current study was to determine if RI and/or academic skills are impaired in children with ADHD-C compared with typically developing children, and to what extent these distinct domains might predict one another. We hypothesized that children with ADHD-C would be more impaired than controls on a measure of RI, which would be related to performance on measures of reading, writing, spelling, and mathematics. Further, we hypothesize that RI will be differentially related to, and predict, academic impairments.

Method

Participants

Participants were a total of 60 community volunteers between the ages of 9 and 16 (Table 1). Recruitment was done through local advertisements in the community and through contacts with faculty and staff within the university. There were two groups: 40 adolescents with ADHD-Combined Type and 20 healthy adolescent controls. All participants were right handed. Approximately 50% of the sample was treated with stimulant medication. No child was on medication 24–48 h prior to testing. The groups were matched on gender, socioeconomic status, and ethnicity. The study was approved by the appropriate
institutional review board at both UTHSCSA and MSU. Written informed consent was completed by each parent and assent by each participant prior to participation. Medical history was reviewed with parents by child psychiatrist (SP) to rule out any serious or potential medical illness, traumatic injury, or developmental delay.

All participants were evaluated using the Diagnostic Interview for Children, IV—Parent Version (DISC-IV-P; Shaffer, Lucas, & Fisher, 2000) in order to confirm a Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition (DSM-IV) diagnosis of ADHD-Combined Type (ADHD-C). Parents were interviewed to confirm that significant attention difficulties were present both at home and at school. Control participants did not meet DSM-IV criteria for ADHD according to the DISC-IV-P nor report symptoms for any psychiatric condition and had no prior history of treatment with psychotropic medication. No participant had a history or current diagnosis of speech/language disorder or RD defined by statistically significant discrepancy between a child’s General Conceptual Ability (DAS-GCA) and Word Reading from the Wechsler Individual Achievement Test, 2nd edition (WIAT-II, Psychological Corporation, 2002). No child had a standard score below 85 on Word Reading or Numerical Operations on the WIAT-II. Conners Global Index (Conners, 1997) was collected for each participant. Healthy controls were required to have a Restless/Impulsive (RI) index score that was within 1 SD of the mean for the child’s age and gender on both the parent and teacher ratings. ADHD children were required to have RI index scores that were at least 1.5 SD above the mean for the child’s age and gender on parent ratings.

Neuropsychological and Academic Instruments

Differential Ability Scale (Elliott, 1990). The DAS was used to measure each participant’s current level of cognitive functioning. The DAS consists of six subtests, which yield an overall GCA score. The GCA score is the most reliable and valid measurement of cognitive ability on the DAS and so was used as an overall measure of cognitive ability for all participants. All participants had GCA scores above 85.

Delis–Kaplan Executive Functioning System (Delis, Kaplan, & Kramer, 2001). The D-KEFS comprised nine tests that measure different aspects of executive functioning. The Color-Word Interference subtest comprises four trials: (1) naming colors of ink (Color Naming), (2) reading color-words (Word Reading), (3) reading dissonant color-words (Inhibition), and an interference trial (4) reading dissonant color-words or naming ink color when a box is present around the word (Inhibition/Switching). The first trial, Color Naming, measures processing speed for repetitive stimuli and the second trial, Word Reading, measures one’s ability to rapidly read repetitive words as quickly as possible. The fourth trial, Inhibition/ Switching, is thought to measure cognitive flexibility and verbal processing speed (Delis et al., 2001). The third trial of this test, Inhibition, is thought to be a measure of RI and cognitive flexibility (inhibiting an automatic response in favor of a response that meets task demands) (Lezak, Howieson, Loring, Hannay, & Fischer, 2004; Shum, McFarland, & Bain, 1990).

Table 1. Sample demographics and descriptive data

| Measure     | ADHD (n = 40) | Control (n = 20) |
|-------------|--------------|-----------------|
| Men/Women   | 23/17        | 11/9            |
| Age (years) | 12.09        | 12.93           |
| DAS-GCA     | 111.73       | 114.25          |
| Reading     | 105.15       | 102.20          |
| Math        | 105.36       | 105.70          |
| Spelling    | 100.88       | 105.85          |
| Written     | 101.77       | 108.95          |
| Word        | 98.13        | 101.30          |
| Color       | 91.25        | 100.10          |
| Inhib.      | 95.35        | 105.30          |
| I/H         | 99.23        | 105.58          |

Notes: DAS-GCA = Differential Ability Scales—General Conceptual Ability; Reading = Word Reading from Wechsler Individual Achievement Test, 2nd edition; Mathematics = Numerical Operations from Wechsler Individual Achievement Test, 2nd edition; Spelling from Wechsler Individual Achievement Test, 2nd edition; Written = Written Expression from Wechsler Individual Achievement Test, 2nd edition; Word = Word Reading from the Delis–Kaplan Executive Function System test; Color = Color Naming from the Delis–Kaplan Executive Function System test; Inhib. = Inhibition from Delis–Kaplan Executive Function System test; I/H = Inhibition/Switching from the Delis–Kaplan Executive Function System test.
All scores were computed by time to completion and did not account for number of errors or type of errors committed. All trials of the Color-Word Interference test were used in the analysis of group differences. Test–retest reliability was acceptable for all measures: Color Naming, $r = .79$, Word Reading, $r = .77$, Inhibition, $r = .90$, and Inhibition/Switching, $r = .80$.

Wechsler Individual Achievement Test, 2nd edition (Psychological Corporation, 2002). The WIAT-II was used as a measure of participant’s achievement/academic abilities. For the purposes of this study we used the Word Reading, Numerical Operations, Spelling, and Written Expression subtests in order to compare the academic abilities between ADHD and control participants.

Procedures

All parents were interviewed via telephone prior to enrolling their children in the study in order to screen for additional psychiatric disorders, injury, or disease that would render them ineligible to participate. The DISC-IV-P was administered by one of the authors (SP) to parents of participants prior to testing. Children that met study requirements completed a neuropsychological test battery that included assessments of intelligence, attention, executive functioning ability, mathematical computation ability, reading ability, spelling ability, and writing ability in a quiet setting with an advanced doctoral student supervised and trained by the second author. The examiner was blind to the diagnosis of the participant. Twenty children in the ADHD group had either previously taken medications or were currently taking stimulant medication at the time of study; however, children taking stimulant medication were required to discontinue medications 24–48 h prior to participation in order to ensure medication washout.

Results

Sample Statistics

Analysis of variance revealed no statistically significant group differences between ADHD and control participants with respect to age, $F(1, 58) = 2.39, p = .128$, or GCA, $F(1, 58) = 0.673, p = .415$. A $\chi^2$ analysis revealed no statistically significant gender differences between the groups, $\chi^2(1) = 1.07, p = .302$. Sample statistics are provided in Table 1.

Achievement

There were no significant group differences in academic performance. The effect sizes for the achievement measures (eta-squared, $\eta^2$) suggest that other than the Written Expression subtest, there were few statistically significant differences between ADHD and control groups. This finding was not altogether surprising given that our ADHD participants were screened for academic difficulties prior to participation. We also ran simple correlation matrices in order to determine the relationship between academic domains and RI measures. In general, Written Expression was significantly correlated (all correlations were $p < .05$) with all measures from the Color-Word Interference subtest from the D-KEFS. Significant correlations were observed between D-KEFS Word-Reading and WIAT-II Mathematics, Spelling, and Word Reading subtests (Table 2).

Response Inhibition

Consistent with our main hypothesis, there were statistically significant group differences between ADHD and control participants on the D-KEFS Color-Word Interference test. Specifically, analyses of variance found statistically significant group differences in three Color-Word Interference subtests: Color Naming, $F(1, 58) = 10.366, p = .002, \eta^2 = 0.154$; Inhibition, $F(1, 58) = 7.49, p = .008, \eta^2 = 0.122$; Inhibition/Switching, $F(1, 57) = 4.06, p = .049, \eta^2 = 0.067$. The second subtest, Word Reading, however, did not differentiate between ADHD and controls: Stroop Word, $F(1, 58) = 1.99, p = .164, \eta^2 = 0.035$ (Table 2). We also calculated the percentage of each group that fell 1 SD below average ($\leq 85$) on each measure of the D-KEFS. These results show that nearly 25% of those in the ADHD group were impaired on the Color Naming and Inhibition trials. Only two subjects (5%) in the control group performed at or below 85 (Table 3) on the Inhibition subtest.

RI and Academic Skills

Linear regression models were used to determine the relationship between RI ability (here defined as the D-KEFS Inhibition subtest standard score) and academic measures (Table 4). For this analysis we utilized both ADHD and control subjects as
individual regressions would likely suffer attenuation due to limited variance within the separate groups. These models illustrate the impact of Inhibition performance on academic skills. Regression analyses indicated that Inhibition performance did not explain a statistically significant amount of the variance in Word Reading ($R^2 = 0.020$, $b = 0.140$, $t = 1.080$, $p = 0.285$), Numerical Operations ($R^2 = 0.010$, $b = 0.098$, $t = 0.741$, $p = 0.461$), or Spelling ($R^2 = 0.027$, $b = 0.165$, $t = 1.272$, $p = 0.209$). Inhibition performance did, however, predict a significant amount of the variance in Written Expression performance ($R^2 = 0.123$, $b = 0.351$, $t = 2.597$, $p = 0.012$). The coefficient of determination suggests that 12.3% of the variance in Written Expression performance can be explained by Inhibition performance. Fig. 1 shows the regression model for Inhibition and Written Expression.

### Discussion

The current study sought to understand if performance on an executive functioning test was related to academic skills in children with ADHD-C. Because many children with ADHD experience executive function impairments and academic underachievement, it was hypothesized that executive functioning performance (specifically, RI) would be related to lower academic functioning.

Results suggest that typically developing children with ADHD-C with average reading, writing, spelling, and mathematical calculation skills may still score lower than matched peers on tests of RI. Moreover, nearly 25% of the ADHD-C group was impaired (% that fell at or below 1 SD normed average) on the Color Naming and Inhibition subtests. Despite their significantly lower performance compared with controls, the ADHD-C group scored in the average range on all Color-Word Interference measures and demonstrated high-average GCA as a group. This pattern of performance is not altogether surprising given that executive function tests are less sensitive when children with ADHD possess above average intelligence (Mahone et al., 2002).

Regression analyses found a statistically significant relationship between Written Expression and Inhibition performance. No other academic measure was statistically related to Inhibition performance. It is hypothesized that the cognitive demands required for writing may be more strongly related to those important for RI. For example, Written Expression requires
many complex mental operations that may be influenced by RI. The ability to recall correct grammar, use appropriate sentence structure, plan, and organize a coherent paragraph, all under time constraints, is required to achieve an adequate score on Written Expression. We observed significant correlations between Color Naming and Word Reading and Written Expression, which also suggests that the ability to rapidly read and process stimuli may be important for writing ability. Recent investigations on the relative influence of executive functioning on Written Expression ability in adults with ADHD suggest an important relationship. Semrud-Clikeman and Harder (2010) found 31% of the variance in SATA writing mechanics to be accounted for by executive functioning ability (D-KEFS Color-Word Interference, Tower, and Controlled Word Association Test). They reported a nearly significant relationship \( (p \approx .053) \) between D-KEFS Interference and writing mechanics performance. While the ecological validity of executive functions is still up for debate, our results suggest the mental operations involved in writing ability may be influenced in part by one’s ability to inhibit automatic responding.

It is important to note that spelling, mathematics, and reading ability did not appear to be statistically related to RI. This suggests that impairments in RI may be unrelated to some academic skills. There are many cognitive processes under the umbrella of executive functions; we only chose to study one of them. Because we did not find that RI predicted many academic skills (with the exception of Written Expression) it is suggested that other executive functions (e.g., verbal and/or spatial working memory, planning) may be better suited to explain academic deficits in those with ADHD. For example, Clark, Prior, and Kinsella (2002) found that verbal ability was predictive of communication and reading performance in children with ADHD. Thus, research on verbal fluency and verbal working memory functioning in children with ADHD and outcomes for reading and verbal communication may illumine the executive functioning—academic achievement relationship.

Children with ADHD often experience comorbid psychiatric disorders, including learning, mood, and conduct problems. Indeed, the high rate of comorbid disorders and use of clinically referred samples from medical schools and hospitals provides important information for this group of children with ADHD but does not speak to the majority of those with ADHD who do

### Table 4. Achievement and inhibition regression analyses

| Variable | \( R^2 \) | \( B \) | \( \beta \) | \( t \) | \( p \) |
|----------|-----------|---------|-----------|-------|-------|
| Reading  | .020      | .126    | .140      | 1.080 | .285  |
| Math     | .010      | .093    | .098      | 0.741 | .461  |
| Spelling | .027      | .192    | .165      | 1.272 | .209  |
| Written  | .123      | .378    | .351      | 2.597 | .012* |

Notes: Linear regression analyses for D-KEFS Inhibition and achievement measures. All variables were run individually. Reading = Word Reading from Wechsler Individual Achievement Test, 2nd edition; Mathematics = Numerical Operations from Wechsler Individual Achievement Test, 2nd edition; Spelling from Wechsler Individual Achievement Test, 2nd edition; Written Expression from Wechsler Individual Achievement Test, 2nd edition.

![Regression Analysis](image-url)

**Fig. 1.** Regression analysis.
not experience psychiatric comorbidity or receive treatment through major medical schools or hospitals. For this reason, the current study was unique in that it included typically developing children with ADHD-C. Our results suggest that there may be important differences between clinically referred and typically developing (e.g., not clinically referred for treatment) children with ADHD-C.

Future work should take into account the natural variation with respect to social, emotional, psychological, academic, and biological differences in individuals with ADHD-C. It is important to attain relatively large numbers of research participants in order to achieve statistical power; however, researchers should consider that including heterogeneous samples in favor of statistical power may increase the likelihood of Type 2 errors. Theory-driven research with clearly defined and homogenous ADHD groups may yield important information about the potential neuropsychologically impaired subgroups (Nigg, Willcutt, Doyle, & Songua-Barke, 2005) under the ADHD umbrella.

Our study had limitations that may limit the generalizability of the findings. RI is a complex cognitive process that is difficult to define. Nonetheless, we defined the cognitive process of RI as one’s standardized score on the D-KEFS Inhibition test. Others have used go/no go tasks as outcome measures for RI and found significant difficulties in children with ADHD (Wodka et al., 2007). The use of different tests and therefore different definitions of neuropsychological processes are a good way of testing theoretically driven hypotheses about the relationship between executive functions and ADHD. Our sample size (40 ADHD and 20 Control) was relatively small yet provided adequate statistical power to detect the effect sizes of interest. While it is difficult to garner large, relatively homogenous samples of children with ADHD, larger sample sizes will provide more externally valid research findings. Our sample was also restricted to those with ADHD-C and did not include children with other ADHD subtypes. Because research suggests that there may be differences between those with ADHD-C and ADHD-PI (Wodka et al., 2008), future work should continue the search for subtype differences. Follow-up studies that include children with ADHD-PI and ADHD-C might provide interesting findings regarding potential differences with regard to the potential mediating effects of executive functions on real-world abilities.

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Conflict of Interest

This study was supported by the National Institutes of Health Grant R01 H63986. Jesse Bledsoe reports no biomedical financial interests or potential conflicts of interest. Margaret Semrud-Clikeman, Ph.D.: Private Foundation funding (not for this study). Dr. Steven Pliszka: Consultant for Shire; research grant from Ortho MacNeil; past consultant for Ortho MacNeil; served as an expert witness for Eli Lilly and Company and received honoraria from Janssen K.K.

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References

American Psychiatric Association (2000). Diagnostic and statistical manual of mental disorders (4th ed. text revision). Washington, DC: American Psychiatric Association.
Banich, M. T., Milham, M. P., Jacobson, B. L., Webb, A., Wszalek, T., Cohen, N. J., et al. (2001). Attentional selection and the processing of task-irrelevant information: Insights from fMRI examinations of the stroop task. Progress in Brain Research, 134, 459–470.
Barkley, R. A. (1997). Behavioral inhibition, sustained attention, and executive functions: Constructing a unifying theory of ADHD. Psychological Bulletin, 121 (1), 65–94.
Barkley, R. A., Anastopoulos, A. D., Guevremont, D. C., & Fletcher, K. E. (1991). Adolescents with ADHD: Patterns of behavioral adjustment, academic functioning, and treatment utilization. Journal of the American Academy of Child and Adolescent Psychiatry, 30, 752–761.
Barkley, R. A., DuPaul, G. J., & McMurray, M. B. (1990). Comprehensive evaluation of attention deficit disorder with and without hyperactivity as defined by research criteria. Journal of Consulting and Clinical Psychology, 58 (6), 775–789.
Biederman, J., Monuteaux, M. C., Doyle, A. E., Seidman, L. J., Wilens, T. E., Ferrero, F., et al. (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.
Bush, G., Frazier, J. A., Rauch, S. L., Seidman, L. J., Whalen, P. J., Jenike, M. A., et al. (1999). Anterior cingulate cortex dysfunction in attention-deficit/hyperactivity disorder revealed by fMRI and the counting stroop. Biological Psychiatry, 45, 1542–1552.
Clark, C., Prior, M., & Kinsella, G. (2002). The relationship between executive function abilities, adaptive behavior, and academic achievement in children with externalising behaviour problems. Journal of Child Psychology and Psychiatry, 43 (6), 785–796.
