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Attention-Deficit/Hyperactivity Disorder and Academic Functioning: Reading, Writing, and Math Abilities in a Community Sample of Youth with and without ADHD

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Abstract

Previous studies have shown that Attention-Deficit/Hyperactivity disorder (ADHD) is marked by impairments in academic functioning in reading, writing, and mathematics. Yet, virtually no studies have examined academic functioning in terms of both basic skills (e.g., word recognition, handwriting/spelling, arithmetic calculations) and more complex advanced skills (e.g., reading comprehension, writing composition, and mathematical problem-solving) within the same sample. In the present study, 518 children with ADHD were compared to a control group of 851 children without ADHD (ages 8–18) and assessed on a comprehensive battery of reading, writing, and math assessments. It was hypothesized that ADHD diagnostic status would uniquely predict performance on advanced skill measures even after controlling for performance on basic skills in that academic domain. ADHD status was associated with worse performance across all academic tests. Results also indicated that ADHD independently predicted performance for measures of writing composition and one measure of reading comprehension, even after controlling for performance on basic skills in those domains. However, ADHD did not independently predict mathematical problem-solving performance. These findings add to the literature on ADHD and academic functioning and indicate that inattention may weaken skills necessary for effective reading comprehension and writing composition.

Keywords Attention-Deficit/Hyperactivity disorder · ADHD · Academic functioning · Reading comprehension · Writing composition · Math

All students should have the opportunity to become successful learners. Unfortunately, many students with Attention-Deficit/Hyperactivity disorder (ADHD) fall behind their peers in learning the skills to successfully read, write, and do mathematical calculations (Willcutt et al., 2012). ADHD is a developmental disorder that is estimated to affect 5–11% of all children, making it one of the most common disorders to arise in childhood (DSM-5-TR, American Psychiatric Association, 2022). ADHD is characterized by persistent symptoms of inattention and hyperactivity/impulsivity that produce functional impairment across multiple domains, including academic performance (Maniadaki & Kakouros, 2018). Compared to their typically developing peers, children with ADHD achieve lower school grades and lower standardized test scores across a range of academic subject matters. Consequently, they show higher rates of special education placement and grade retention (DuPaul & Langberg, 2015).

Academic impairment in ADHD often persists in adolescence and adulthood, leading to higher rates of high school dropout and lower rates of college enrollment (Kuriyan et al., 2013). Not surprisingly, individuals with ADHD show lower vocational attainment and more job and financial instability (Kuriyan et al., 2013). Thus, improving academic functioning in ADHD is critical to disrupting the negative, long-term trajectories that are characteristic of the disorder.

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Skills and Knowledge Important to Academic Functioning

To effectively target academic functioning, it is important to understand the development of reading, writing, and math abilities. Development within each domain involves the mastery of foundational skills and the subsequent coordination of these skills with higher-order cognitive processes. With regards to reading, one of the most primary skills is *word recognition*. For a child to read a word, they must have a solid grasp on grapheme-phoneme relationships—or an understanding of how to match written letters to the corresponding speech sounds they represent (Vellutino et al., 2004). Word reading then becomes more automatic over time for most children, and the child begins to be able to recognize familiar words and retrieve their meaning quickly. Once the child can read with *fluency*, they can then allocate more mental resources to comprehension (Cain, 2010). Effective *reading comprehension* requires that the child learn and apply several skills in addition to single word reading, including how to adhere to rules of grammar and language structure, make inferences, and monitor their comprehension for errors (Cain, 2010).

The development of writing follows a similar, yet distinct pathway. First, the child learns to correctly transcribe letters and words, which requires both hand–eye coordination and fine motor skills (Feder & Majnemer, 2007). The automaticity at which the child transcribes is foundational for advanced skills, as *handwriting* automaticity predicts overall writing quality, length, and complexity (see Feng et al., 2019 and Santangelo & Graham, 2016 for meta-analyses). It is important that the child's writing is both legible and accurate. *Spelling* accuracy, like word recognition, requires knowledge of grapheme-phoneme relationships, specifically understanding the multiple ways that phonemes are represented in written text (Berninger et al., 2002). As handwriting and spelling become more perfunctory, the child develops greater *writing fluency* (Feng et al., 2019; Santangelo & Graham, 2016), allowing them to focus on using text to convey their ideas. *Writing composition* involves several self-regulatory strategies. The child must be able to plan the ideas they want to communicate, translate those ideas into to text, monitor their progress, and revise their writing as needed to meet goals (Flower & Hayes, 1981).

Finally, as described in the review by Geary (2000), the development of mathematical ability also involves the sequential improvement of multiple skills. Early math learning requires the child to master the counting system. Next, the child must learn to do *calculations* by memorizing basic arithmetic facts and learning computational procedures (e.g., addition, subtraction). With time, the speed at which the child can recall these basic math facts and apply them to problems increases, allowing the child to do calculations with fluency. The child is then expected to solve *word problems* that require the child to comprehend verbal material, identify the problem type and the procedures to calculate the solution, and finally perform the necessary calculations to solve the problem.

Relations Between ADHD and Academic Functioning

Weaknesses in academic functioning are among the most robust findings from decades of research on ADHD. In a meta-analysis of 72 studies, children with ADHD performed worse than their non-ADHD peers across multiple assessments of academic functioning, including parent/teacher ratings, academic attainment (e.g., GPA, years of education), remediation (e.g., grade retention, special education placement), and scores on standardized tests of reading, writing, and math (Frazier et al., 2007). Mean effects of ADHD for all assessment types were in the medium range, with the largest effects observed for scores on standardized tests of reading (d = -0.73) and math (d = -0.67). A second meta-analysis examining impairment in ADHD produced similar results. Across results from 32 studies, youth with ADHD demonstrated consistent impairment in academic functioning. Mean effects of ADHD were in the large range for outcomes determined by parent/teacher ratings and by scores on achievement tests (Willcutt et al., 2012). Findings from Willcutt et al. (2012) suggest that children with ADHD, on average, score approximately one standard deviation below their peers on tests of reading, writing, and math.

Moreover, preliminary evidence suggests that ADHD is associated with weaknesses in multiple levels of each of these academic domains. With regards to reading, numerous studies find that children with ADHD show impairments in word recognition, reading fluency, and reading comprehension (DuPaul et al., 2004; Efron et al., 2014; Ghelani et al., 2004; Jacobson et al., 2011; Miller et al., 2013; Rucklidge & Tannock, 2001; Willcutt et al., 2005). These studies demonstrate small to large effects of ADHD on word recognition (Efron et al., 2014; Rucklidge & Tannock, 2001), and medium to large effects of ADHD on reading fluency and reading comprehension (DuPaul et al., 2004; Jacobson et al., 2011; Miller et al., 2013).

Although fewer studies have examined writing or math, initial meta-analytic evidence demonstrates similar results. Across results from 45 studies, youth with ADHD attained lower scores on foundational writing skills (i.e., handwriting, spelling) and on more advanced writing skills (i.e., writing quality; Graham et al., 2016). Mean effects of ADHD on writing ability ranged from medium to large, with the largest effects observed for writing quality (d = -0.78) and spelling (d = -0.80; Graham et al., 2016). Moreover, the meta-analysis did not include studies where writing performance was used as a means for selecting students with ADHD, reducing the potential influence of writing weaknesses not attributable to ADHD.

With regards to math, in a meta-analysis of 34 studies, ADHD consistently predicted worse performance across multiple, standardized assessments of math performance (Tosto et al., 2015), including tests of calculation, fluency, and word problems. Similarly, this meta-analysis excluded studies where children were selected for learning disabilities in addition to ADHD, to further ensure that reported effects on math ability were specific to ADHD. Among studies that compared math performance between ADHD and non-ADHD groups, effects of ADHD were in the medium to large range for calculation, fluency, and word problems (e.g., DuPaul et al., 2004; Efron et al., 2014; Lewandowski et al., 2007; Rucklidge & Tannock, 2001).

What factors lead to problems with academic functioning? One possibility is that any academic difficulties exhibited by individuals with ADHD may be restricted to students with ADHD who also meet criteria for a specific learning disability (LD), a developmental disorder characterized by significant impairment in the development of reading, writing, or mathematics despite adequate intelligence and instruction (Maniadaki & Kakouros, 2018). It is estimated that 31–45% of children with ADHD meet criteria for LD and vice versa (DuPaul et al., 2013). However, comorbidity alone cannot fully explain academic underachievement in ADHD. Even when they do not meet criteria for LD, many children with ADHD still exhibit significant academic weaknesses. With regards to reading, children with ADHD alone score lower than their typically developing peers on standardized measures of word reading, reading fluency, and reading comprehension (e.g., Ghelani et al., 2004; Willcutt et al., 2005). Children with ADHD alone also score lower than their peers on standardized measures of global writing and math abilities (e.g., Barry et al., 2002).

While these studies demonstrate consistent effects of ADHD on functioning across academic domains, almost none examined functioning at multiple levels within the same sample to determine if ADHD independently predicts advanced skill performance. Hence, the mechanisms by which ADHD influences reading comprehension, writing composition, and mathematical problem-solving are not well-understood. It is unclear whether ADHD exerts an indirect influence on these advanced skills by undermining the development of foundational skills, or whether ADHD has a direct and unique impact on reading comprehension, writing composition, and mathematical problem-solving. Although research on the topic is limited, extant findings from studies of ADHD and reading provide initial support for the latter hypothesis. Specifically, two prior studies demonstrated that children with ADHD still exhibited difficulties in reading comprehension *even after* controlling for word reading abilities (Brock & Knapp, 1996; Miller et al., 2013). Additionally, an intervention study by Denton et al. (2020) provides more compelling evidence for a direct, causal impact of ADHD on reading comprehension. Participants in the study were children with both ADHD and word-reading deficits who received either an ADHD treatment protocol, a word-reading intervention, or a combination of the two treatments. Only participants who received the ADHD treatment (i.e., medication and parent trainings) showed a significant improvement in reading comprehension. Those who received the word-reading intervention alone showed no gains in reading comprehension. These results suggest a possible, direct effect of ADHD on advanced skill performance in the domain of reading; however, to the authors' knowledge, there is an absence of similar data for the domains of writing and math.

Findings also align with research that demonstrates a unique relationship between inattention and academic functioning. Inattention has been shown to be a strong predictor of classroom performance and achievement test scores across reading writing, and math for children with ADHD (e.g., Garner et al., 2013; Polderman et al., 2010; Tosto et al., 2015; Willcutt et al., 2005). There are numerous pathways by which inattention is theorized to impact reading comprehension, writing composition, and mathematical problem-solving. Due to lack of attention to detail, children with ADHD may make more comprehension errors while reading (e.g., Miller et al., 2013; Spiel et al., 2016, 2019), make more spelling and grammar errors while writing (e.g., Graham et al., 2016), or make careless errors when doing math computations and multistep problems (e.g., Benedetto-Nasho & Tannock, 1999). Poor focus and high levels of distractibility may also result in less persistence in children with ADHD, leading to shorter or incomplete work (e.g., Graham et al., 2016). Finally, low motivation and avoidance of tasks requiring sustained mental effort could lead to less practice with academic skills (e.g., Smith et al., 2020), exacerbating weaknesses in these areas for children with ADHD.

Ultimately, more research is needed to examine whether ADHD is associated with advanced reading, writing, and math skills even after controlling for performance in basic academic skills. This topic has received little attention in the reading literature, and, to the authors' knowledge, has not yet been explored in prior studies of the relations between ADHD and writing or math. Rather, the majority of prior studies on ADHD and academic functioning have examined the effect of ADHD for only one level of performance (e.g., basic or advanced skills) in a singular academic domain (e.g., reading, writing, or math). Virtually no studies have examined functioning at multiple levels and across academic domains to determine if ADHD independently contributes to advanced skills in reading, writing, and math. Thus, research that examines relations between ADHD and functioning within and across academic domains using the same sample is critical to addressing this gap in the literature.

Moreover, given that competency in reading comprehension, writing composition, and mathematical problem solving are the ultimate goals of education in these domains, it is crucial to understand the pathway by which ADHD impacts the development of these skills.

The Present Study

The present study examines the relations between ADHD and academic functioning across reading, writing, and math domains in a large community twin sample of children and adolescents. We addressed the following research aims:

Research Question 1

Is there a relation between ADHD and academic functioning across the domains of reading, writing, and math? We explored this research question categorically by examining differences in academic performance between children with and without ADHD. We aimed to replicate results from prior literature and hypothesized that children with ADHD would perform worse than children without ADHD across all tests of academic abilities. However, we predicted that ADHD would be most strongly associated with more advanced academic skills that require higher-order cognitive processes (i.e., reading comprehension, writing composition, mathematical problem solving).

Research Question 2

Does ADHD predict performance on tests of advanced reading, writing, and math skills (i.e., reading comprehension, writing composition, mathematical problem solving), when controlling for performances on tests of basic skills (e.g., word recognition, spelling, calculations)? We hypothesized that in addition to the stronger association between ADHD and the more complex academic skills, ADHD diagnostic status would uniquely predict performance on these measures even after controlling for performance on basic skills in that academic domain.

Method

Participants

Participants were recruited as part of the Colorado Learning Disabilities Research Center (CLDRC) twin study, an ongoing population-based study of the etiology of learning disorders (e.g.,Mcgrath et al., 2011; Peterson et al., 2017; Willcutt et al., 2010). The full recruitment procedures for the study are described in detail in previous papers (e.g., Willcutt et al., 2005, 2013), and are summarized more briefly here.

Families of all twins between the ages of 8 and 18 in 22 local school districts were invited to participate in the initial screening procedures for the study. Although the overall twin study has been ongoing for over 30 years, the current subset of the CLDRC twin study sample that completed the full battery of measures of reading, math, and writing was assessed between 2011 and 2021. If either of the twins exhibited a significant history of learning or attentional difficulties during the screening, the pair was invited to participate in the full study (90% of selected families agreed to participate). In addition, a comparison sample was recruited from the remaining twin pairs in which neither twin exhibited a significant history of learning or attentional difficulties. Due to the primary focus of the current paper on groups with and without ADHD, twins with learning difficulties alone were not included in the current analyses (academic achievement was free to vary in the ADHD and control groups).

Exclusion Criteria

As part of the larger study, potential participants with a documented brain injury, significant hearing or visual impairment, or a rare genetic or environmental etiology (e.g., Fragile X syndrome, phenylketonuria, Down syndrome or other chromosomal anomalies) were excluded from the sample. In addition, any twins with a previous diagnosis of a pervasive developmental disorder, psychosis, tic disorder, or bipolar disorder were excluded from the study, and participants with a Full Scale IQ score below 75 on the Wechsler Intelligence Scale for Children, Revised (Wechsler, 1974) were excluded from the current analyses.

The Final Sample

Because twins in a pair are not independent observations, one twin was selected at random from each pair in which both twins met inclusion criteria for the control or ADHD groups. If one twin met criteria for ADHD and one did not, the twin who met criteria for ADHD was included in the study to maximize power for comparisons of the groups. The final sample for analysis included 518 individuals with DSM-IV ADHD and a comparison group of 851 individuals (45% female). The overall sample was 80% Caucasian, 12% Hispanic, 3% African American, 3% Asian American, and 2% American Indian / Native American, with no significant differences between groups with and without ADHD.

Procedure

All study procedures were fully approved by the Institutional Review Boards of the University of Colorado, Boulder and University of Denver, and have therefore been performed in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki. Parents gave their informed consent and children and adolescents assented to participate prior to their enrollment in the study.

Measures were administered in four testing sessions at the University of Colorado, Boulder and University of Denver. All examiners were unaware of the diagnostic status of the child and the results of the testing conducted at the other sites. Parents of participants that were taking psychostimulant medication were asked to withhold medication for 24 h prior to each session of the study to minimize the influence of medication on the results.

Measures

Intelligence

Full Scale IQ was assessed using the Weschler Intelligence Scale for Children, Revised (WISC-R; Wechsler, 1974).

DSM-IV ADHD

The *Disruptive Behavior Rating Scale* (DBRS; Barkley & Murphy, 1998) was used to obtain parent and teacher ratings of the 18 symptoms of DSM-IV ADHD. Each symptom on the DBRS is rated on a four-point scale (*never or rarely*, *sometimes*, *often*, and *very often*). Parent and teacher ratings of ADHD symptoms were combined using an adaptation of the *or rule* algorithm used in the DSM-IV field trials (Lahey et al., 1994). For each symptom the higher of the parent or teacher ratings was used as the score for that item. The mean of the nine items on each DSM-IV symptom dimension was then age-regressed and standardized based on the overall sample to create composite measures of inattention and hyperactivity-impulsivity. Both composite scores had high internal consistency ($\alpha = 0.96$ for inattention and 0.93 for hyperactivity-impulsivity) and 12-month test–retest reliability ($r = 0.84$ for inattention and 0.75 for hyperactivity-impulsivity). For analyses of symptom counts, items rated as *often* or *very often* were scored as positive symptoms and items rated as *never or rarely* or *sometimes* were scored as negative symptoms, consistent with the procedure used in previous studies (e.g., Lahey et al., 1994).

Additionally, parent and teacher ratings were used to assess impairment across the following domains: interactions with peers, interactions with adults, daily responsibilities, and academic achievement. Each domain is rated on a four-point scale (*never or rarely impaired*, *sometimes impaired*, *often impaired*, and *very often impaired).* Domains rated as *often impaired* or *very often impaired* by the parent or the teacher were scored as positive for impairment, and domains rated as *never or rarely impaired* or *sometimes impaired* were scored as negative for impairment.

For categorical analyses participants were included in the group with ADHD if they met the following two criteria: a) they exhibited six or more symptom of inattention or six or more symptoms of hyperactivity-impulsivity, and b) they exhibited impairment in at least two domains, or they exhibited impairment in one domain and multiple other domains were at least "sometimes" impaired.

Participants were included in the comparison group if they met the following two criteria: a) exhibited three or fewer symptoms of inattention and three or fewer symptoms of hyperactivity impulsivity, and b) they did not have parent reported history of learning nor attention problems.

Measures of Reading Achievement

The test battery for the CLDRC was recently expanded to provide a comprehensive assessment of academic achievement that includes multiple measures of basic and higher-order reading (word reading, reading fluency, reading comprehension), math (calculations, math fluency, word problems), writing (written motor production, grammar, writing fluency, expository writing), and spelling (spelling production and recognition).

Word Reading

The Peabody Individual Achievement Test (PIAT; Dunn & Markwardt, 1970). Reading Recognition subtest is an untimed measure of single-word reading (test–retest $r = 0.94$—0.98), whereas the Test of Word Reading Efficiency (TOWRE; Torgesen et al., 1999) requires the participant to read as many single words as possible in 45 s (test–retest $r = 0.84$—0.97). Finally, the Accuracy score from the Gray Oral Reading Test assesses accuracy of word reading in paragraphs of connected text (GORT-III; Wiederhold & Bryant, 1993). Because these measures are highly correlated in the current sample ($r = 0.66$—0.72), the mean of the age-corrected standardized scores was standardized based on the overall current sample to provide a composite measure of word reading accuracy.

Reading Fluency

A similar approach was used to compute a reading fluency composite score based on two measures that required participants to fluently read connected text. The Woodcock-Johnson Tests of Achievement, Third Edition (WJ-III) Reading Fluency subtest requires the participant to read a series of simple sentences and indicate whether or not each sentence is true or false (test–retest $r = 0.86$—0.91; McGrew & Woodcock, 2001). The Fluency score on the third edition of the Gray Oral Reading Test (GORT-III) assesses the time required to read aloud multiple sentence passages (test–retest $r = 0.86$).

Reading Comprehension

On the WJ-III Passage Comprehension subtest, participants silently read short passages of one or two sentences and provide a missing word to demonstrate their comprehension (test–retest $r = 0.88$—0.95). In contrast, the GORT-III requires the participant to read aloud longer passages, which are then followed by five multiple-choice comprehension questions ($\alpha > 0.90$). The Qualitative Reading Inventory (QRI-3; Leslie & Caldwell, 2001) requires the participant to read aloud stories. The participant is asked to recall each story and then respond to short answer comprehension questions. Scores on the individual comprehension measures were age-corrected and standardized based on the current sample, then the mean of the three measures was restandardized to provide a standardized composite measure of overall reading comprehension.

Writing Achievement

Handwriting Production

Motor production of handwriting was measured by the Copying subtest from the *Group Diagnostic Reading and Aptitude and Achievement Tests* (Monroe & Sherman, 1996). This task requires the participant to copy a paragraph as quickly as possible without making any mistakes for 90 s, and provides a reliable measure of handwriting ability (test–retest $r = 0.88$; Graham et al., 1998).

Spelling

A spelling composite was computed based on two measures that were used to assess spelling achievement. The Spelling subtest from the Wide Range Achievement Test, Revised (WRAT-R; Jastak & Wilkinson, 1984) is a paper-and-pencil measure that requires the participant to spell words of increasing difficulty that are presented orally by the examiner. In contrast, the PIAT Spelling subtest is a multiple-choice test that requires the participant to select the correct spelling of a word among four potential choices.

Writing Fluency

The WJ-III Writing Fluency subtest assesses the child's ability to formulate sentences quickly. For each item, the child is given three prompt words and asked to write a simple sentence that includes all three words. The child is asked to complete as many items as possible within 7 min.

Writing Composition

Several measures were used to create a composite measure of writing composition. The WJ-III Writing Samples subtest is an untimed test that requires participants to write a single sentence in response to the tester's oral directions and a pictorial prompt (test–retest reliability = 0.83—0.87). On the Essay Composition subtest from the third edition of the *Wechsler Individual Achievement Test (WIAT-III;* Pearson, 2009*)*, the participant is given 10 min to write an essay in response to a prompt, which is then scored for content and organization and grammar and mechanics. The Overall score on the WIAT subtest was included in the current analyses (test–retest r = 0.90). Finally, the Contextual and Story Composition subtests from the fourth edition of the Test of Written Language (TOWL-IV; Hammill & Larsen, 2009) require the handwritten production of an extended story in response to a picture of a complex situation. Correlations between the writing measures were moderate to high ($r = 0.45$—0.65), and a written language composite score based on these measures had adequate internal consistency ($\alpha = 0.80$).

Math Achievement

Math Calculations

The Math subtest of the WRAT-R and the WJ-III Calculations subtest involve paper-and-pencil calculations using different mathematical operations (reliability = 0.90—0.94). In contrast, on the PIAT Math subtest a series of problems are presented orally, and the participant then selects among four potential responses. The majority of the specific items on the PIAT measure explicit math computation abilities, and a smaller percentage of items assess understanding and application of math concepts (split-half reliability for the total score = 0.90—0.96). Scores on the three measures of math calculations are significantly correlated in the current sample ($r = 0.67$—0.73), so a standardized composite measure of mathematics calculations was created using the procedures described above.

Word Problems

Finally, the WJ-III Applied Problems subtest was used as a single measure of performance on more complex mathematics word problems.

Table 1 Means of ADHD and control groups on demographic, cognitive, and ADHD symptom measures

Sample demographics	ADHD		Control		Full sample		t
	($n=518$)		($n=851$)		($n=1369$)		
	M	*SD*	*M*	*SD*	*M*	*SD*	
Gender	380 male 138 female		375 male 476 female		755 male 614 female		
Age	11.11	2.50	11.47	2.57	11.34	2.55	-2.57*
Parent Education (Years)	15.02	2.32	15.63	2.18	15.39	2.25	-4.69**
IQ	102.75	13.65	108.72	12.75	106.46	13.41	-8.17**
Inattention Symptoms	7.33	1.72	0.47	0.86	3.07	3.56	98.17**
Hyperactive-Impulsive Symptoms	4.04	2.96	0.30	0.70	1.72	2.63	35.23**

**$p \leq 0.001$; *$p \leq 0.01$

Data Analysis

To examine differences between ADHD and control groups, independent sample t-tests comparing the performances of the two groups were computed for all reading, writing, and math measures. To examine whether ADHD diagnosis independently predicted advanced skill performance, a series of analyses of covariance (ANCOVAs) were conducted to determine whether there were statistically significant differences between the ADHD and control groups on each advanced skill measure when controlling for the effects of basic skill performance.

Results

Demographic Characteristics

Table 1 presents the mean scores of the ADHD and control groups on the demographic variables and measures of IQ and ADHD symptoms. The mean age of the two groups was significantly different, as children in the ADHD group were approximately 4 months younger than children in the control group on average. Family SES, as measured by the mean of both parents' years of education, was significantly lower for the ADHD group, with parents of children with ADHD completing approximately 7 fewer months of school than parents of children in the control group on average. As expected, the mean IQ score was significantly lower for the ADHD group than the control group, and the mean number of symptoms for both ADHD dimensions were significantly higher for the ADHD group than the control group.

Relations between ADHD and Academic Functioning

Differences Between ADHD and Control Groups

A series of independent sample t-tests were calculated to test for differences in academic performance between the ADHD and control groups (Table 2). Results indicated that

Table 2 Means of ADHD and control groups on academic performance measures

	ADHD		Control			
	n	*M (SD)*	*n*	*M (SD)*	*d*	t
Reading						
Word Recognition	518	-0.26 (1.01)	850	0.27 (0.95)	-0.56	-9.98**
Reading Fluency	363	-0.36 (1.04)	603	0.19 (0.95)	-0.56	-8.34**
Reading Comprehension	359	-0.30 (1.06)	567	0.15 (0.94)	-0.45	-6.72**
Written Language						
Handwriting	262	-0.42 (0.92)	441	0.25 (0.94)	-0.72	-9.18**
Spelling	518	-0.26 (1.00)	851	0.34 (0.93)	-0.63	-11.22**
Writing Fluency	270	-0.39 (1.01)	433	0.24 (0.91)	-0.67	-8.59**
Writing Composition	276	-0.41 (1.04)	444	0.29 (0.87)	-0.74	-9.68**
Mathematics						
Calculation	350	-0.39 (1.01)	643	0.21 (0.91)	-0.63	-9.55**
Word Problems	110	-0.31 (1.08)	236	0.10 (0.99)	-0.40	-3.49**

**$p \leq 0.001$

the group with ADHD obtained lower scores on all composite measures of reading, writing, and math abilities. All differences between the ADHD and control groups in performance were significant ($ps \leq 0.001$). The effect sizes for all performance outcomes fell in the medium range (Cohen, 1992), with the strongest effects obtained for tests of writing abilities (d = -0.63 – -0.74) compared to effects for tests of reading (d = -0.45 – -0.56) and math abilities (d = -0.40 – -0.63).

In addition to the primary analyses of the composite measures of academic achievement, secondary analyses compared the ADHD and control groups on the individual standardized achievement measures to test whether the overall pattern holds for all measures (Online Supplement Tables 1 – 3). While the mean standard scores of the ADHD group consistently fell in the average range (e.g., standard scores between 90 and 103), the ADHD group scored significantly lower than the control group on all individual academic measures.

As part of secondary analyses, a series of two-way analyses of variance (ANOVAs) were conducted to examine the effects of gender and ADHD status on academic performance. Results revealed a significant main effect of gender on word reading $F(1, 1364) = 5.33$, $p = 0.021$, $\eta_p^2 = 0.00$ and on reading comprehension $F(1, 922) = 6.73$, $p = 0.010$, $\eta_p^2 =$ 0.01, such that males attained higher scores than females on these reading measures. Results also showed a significant main effect of gender on handwriting $F(1, 699) = 31.42$, $p = < 0.001$, $\eta_p^2 = 0.04$, writing fluency $F(1,699) = 16.23$, $p = < 0.001$, $\eta_p^2 = 0.02$, and writing composition $F(1, 716) = 14.23$, $p < 0.001$, $\eta_p^2 = 0.02$, such that females attained higher scores than males on these writing measures. Lastly, results revealed a significant main effect of gender on calculation $F(1, 989) = 13.31$, $p < 0.001$, $\eta_p^2 = 0.01$, with higher scores for males compared to females. The effects of ADHD status on performance remained significant even after controlling for the effects of gender, with the ADHD group scoring lower than the control group on all academic tests ($ps \leq 0.001$). There were no significant interactions between gender and ADHD status on any reading, writing, and math composite measure, indicating that the effect of ADHD on academic performance did not differ for males and females.

Unique Associations of ADHD with Advanced Skills

A series of analyses of covariance (ANCOVAs) were then conducted to test whether differences between the ADHD and control groups remained for advanced reading, writing, and math skills after basic skills were controlled. Given the body of research demonstrating the importance of parent education to children's academic performance (e.g., Dubow et al., 2009), mean years of parent education was also included as a covariate in each model.

Reading When parent education and word recognition were added as covariates, the difference between the ADHD and control groups in reading comprehension was no longer significant $F(1, 814) = 2.60$, $p = 0.11$, $\eta_p^2 = 0.00$. The final model included reading fluency as a covariate (Table 3). In the final model, parent education $F(1, 807) = 57.12$, $p < 0.001$, $\eta_p^2 =$ 0.07, word recognition $F(1, 807) = 58.93$, $p < 0.001$, $\eta_p^2 =$ 0.07, and reading fluency $F(1, 807) = 15.96$, $p < 0.001$, $\eta_p^2 =$ 0.02 were significant predictors of reading comprehension performance.

The results of the reading comprehension analyses were surprising, given that Brock and Knapp (1996) and Miller et al. (2013) found that ADHD status was a significant predictor of reading comprehension even after controlling for word recognition. Since prior research demonstrated that different measures of reading comprehension vary greatly in the skills they assess (e.g., Cutting & Scarborough, 2006; Keenan et al., 2008), secondary analyses were completed to examine whether the relation between ADHD and reading comprehension differed for the three measures used in the present study. When analyses were run separately for the three reading comprehension measures, ADHD was a significant predictor of reading comprehension performance on the GORT-III $F(1, 807) = 4.31$, $p = 0.038$, $\eta_p^2 = 0.01$, the QRI-3 $F(1, 805) = 32.55$, $p < 0.001$, $\eta_p^2 = 0.04$, and WJ-III $F(1, 811) = 23.98$, $p < 0.001$, $\eta_p^2 = 0.03$, above and beyond the effects of parent education. Once word recognition and reading fluency were added to the models, ADHD remained a significant predictor of the QRI-3 $F(1, 799) = 11.74$, $p < 0.001$, $\eta_p^2 = 0.01$, but it was not a significant predictor

Table 3 GLM analysis of reading skills and ADHD status on reading comprehension

Reading comprehension		Parent education		Word recognition		Reading fluency		ADHD status	
	R^2	F	η_p^2	F	η_p^2	F	η_p^2	F	η_p^2
Composite	0.47	57.12**	0.07	58.93**	0.07	15.96**	0.02	2.69	0.00
Specific Measures									
GORT-3	0.23	25.58**	0.03	10.00*	0.01	13.26**	0.02	0.42	0.00
QRI-3	0.24	31.02**	0.04	12.99**	0.02	5.50^	0.01	11.74**	0.01
WJ-III	0.54	48.39**	0.06	118.35**	0.13	10.45**	0.01	0.57	0.00

GORT-3 $n = 809$, QRI-3 $n = 804$, WJ-III $n = 808$

$^{**}p \leq 0.001$; $^{*}p \leq 0.01$; $^{\wedge}p \leq 0.05$

Table 4 GLM analysis of writing skills and ADHD status on writing composition

Writing composition		Parent education		Handwriting		Spelling		Writing fluency		ADHD status	
	R^2	F	η_p^2	F	η_p^2	F	η_p^2	F	η_p^2	F	η_p^2
Composite	0.43	1.29	0.00	10.53**	0.02	46.64**	0.07	43.78**	0.07	19.76**	0.03
Specific Measures											
TOWL-IV	0.49	0.11	0.00	1.87	0.01	39.50**	0.17	19.54**	0.09	5.47^	0.03
WIAT-II	0.31	2.34	0.01	14.04**	0.05	6.82*	0.02	6.73*	0.02	4.63^	0.02
WJ-III	0.38	0.00	0.00	3.82^	0.01	35.99**	0.06	43.33**	0.07	19.39**	0.03

$^{**}p \leq 0.001$; $^{*}p \leq 0.01$; $^{\wedge}p \leq 0.05$, WIAT-II $n = 284$, TOWL-IV $n = 206$, WJ-III $n = 585$

of reading comprehension performance on the GORT-III $F(1, 804) = 0.42$, $p = 0.52$, $\eta_p^2 = 0.00$ nor the WJ-III $F(1, 803) = 0.57$, $p = 0.450$, $\eta_p^2 = 0.00$ (Table 3).

Writing The next ANCOVA was conducted to test whether ADHD diagnosis independently predicted writing composition performance. Even after spelling, handwriting, and writing fluency were added to the model, the difference between the ADHD and control groups in writing composition remained significant $F(1, 581) = 19.76$, $p < 0.001$, $\eta_p^2 = 0.03$.

To parallel the analyses conducted for reading comprehension, we then examined whether the relation between inattention and writing composition differed for the three writing measures used in the present study. ANCOVAs were conducted to examine whether ADHD uniquely predicted performance on the TOWL-IV, *WIAT-III*, and WJ-III, once handwriting, spelling, and writing fluency were added to the models (Table 4). Results indicated that ADHD was a significant predictor of writing composition performance on the WJ-III ($F(1, 579) = 19.39$, $p < 0.001$, $\eta_p^2 = 0.03$, and a marginally significant predictor of performance on the TOWL-IV $F(1, 200) = 5.47$, $p = 0.02$, $\eta_p^2 = 0.03$ and the *WIAT-III* $F(1, 278) = 4.63$, $p = 0.03$, $\eta_p^2 = 0.02$.

Given the importance of reading skills to writing composition (e.g., Graham et al., 2018), we then examined whether ADHD was a significant predictor of writing composition on the TOWL-IV, *WIAT-III*, and WJ-III after reading skills were added to the models. After controlling for the effects of parent education, basic writing skills, word recognition, and reading fluency, ADHD remained a significant predictor of writing composition performance on the WJ-III $F(1, 541) = 16.32$, $p < 0.001$, $\eta_p^2 = 0.03$, and was a marginally significant predictor of performance on the TOWL-IV $F(1, 198) = 5.70$, $p = 0.02$, $\eta_p^2 = 0.03$ and the *WIAT-III* $F(1, 274) = 4.44$, $p = 0.04$, $\eta_p^2 = 0.02$. When reading comprehension was added to the models, ADHD remained a significant predictor of writing composition performance on the WJ-III $F(1, 497) = 17.54$, $p < 0.001$, $\eta_p^2 = 0.03$, but it was not a significant predictor of performance on the TOWL-IV $F(1, 158) = 2.87$, $p = 0.10$, $\eta_p^2 = 0.02$ nor the *WIAT-III* $F(1, 229) = 1.51$, $p = 0.22$, $\eta_p^2 = 0.01$.

Mathematics A final ANCOVA was used to test whether ADHD diagnosis independently predicted mathematical problem solving on word problems after controlling for basic calculation skill (Table 5). Results indicated that the difference between the ADHD and control groups in mathematical problem solving was no longer significant $F(1, 242) = 0.16$, $p = 0.70$, $\eta_p^2 = 0.00$, after controlling for the effects of parent education and calculation. Parent education $F(1, 242) = 7.69$, $p = 0.01$, $\eta_p^2 = 0.03$ and calculation $F(1, 242) = 184.51$, $p < 0.001$, $\eta_p^2 = 0.43$ were significant predictors of word problem performance.

Discussion

Academic impairment in ADHD is one of the most well-documented effects in research on the disorder. A large body of literature demonstrates persistent weaknesses in reading, writing, and math for youth with ADHD (e.g., Frazier et al., 2007; Willcutt, 2012), and preliminary evidence suggests that ADHD is associated with impairment in multiple levels of these academic domains (e.g., Graham et al., 2016; Tosto et al., 2015; Willcutt et al., 2005). However, virtually none of this research has examined functioning at multiple levels within the same sample to determine whether ADHD independently predicts advanced skill performance. To support academic development in children with the disorder, it is critical to understand the way ADHD impacts reading comprehension, writing composition, and mathematical problem-solving.

Table 5 GLM analysis of calculations and ADHD status on word problems

		Parent education		Calculations		ADHD status	
	R^2	F	η_p^2	F	η_p^2	F	η_p^2
Word Problems	0.50	7.69*	0.03	184.51**	0.43	0.16	0.00

To address this gap in the literature, the present study examined the relations between ADHD and academic functioning in a large community sample of children and adolescent with and without the disorder. The study used a broad, comprehensive battery of reading, writing, and mathematics assessments to examine relations between ADHD and functioning within and across academic domains. Our findings demonstrated that ADHD status uniquely predicted performance on measures of writing composition and one measure of reading comprehension, even after controlling for basic skills in these domains. These results suggest that ADHD may weaken skills necessary for effective reading comprehension and writing composition, and they provide insights for future interventions to support reading and writing development in youth with ADHD.

Current Results and Integration with Previous Literature

The results provided partial support for our first hypothesis that ADHD would predict academic performance and that the effects of ADHD would be stronger for more advanced academic skills. As expected, the ADHD group scored lower than the control group on all tests of reading, writing, and math abilities. Moreover, results from secondary analyses demonstrated that there were no significant interactions between gender and ADHD status on any reading, writing, and math measure.

The effect sizes for performance outcomes across domains were all in the medium range, with the largest effect sizes observed for tests of writing abilities (d = -0.63 – -0.74) compared to effects for tests of reading (d = -0.45 – -0.56) and math abilities (d = -0.40 – -0.63). Additionally, the effect size for writing composition was slightly larger than effect sizes for spelling and writing fluency. However, in contrast to our initial prediction, effects sizes for advanced reading and math skills were slightly smaller than effect sizes for basic reading and math skills.

Our results provided inconsistent support for our second hypothesis that ADHD would uniquely predict performance in advanced academic skills after controlling for performance in basic skills. In our analyses of the math measures, results indicated that, after controlling for calculation, ADHD no longer predicted performance on word problems. Along with the similar effect sizes for differences between the ADHD and control groups on basic and higher-order measures of mathematics, these results contradict our hypothesis and suggest that the weaknesses in mathematical problem-solving in ADHD may be primarily explained by underlying weaknesses in basic calculation skills.

Our findings for reading provide partial support for our hypothesis and demonstrated.

that the relation between inattention symptoms and reading comprehension differed across the three reading comprehension measures used in the present study. After controlling for word recognition and reading fluency abilities, ADHD status predicted impaired reading comprehension performance on the QRI-3. In contrast, ADHD did not uniquely predict reading comprehension performance on the GORT-III nor WJ-III.

These results suggest that the relative contribution of ADHD to reading comprehension failure may depend on the characteristics of the measure that is used to assess reading comprehension. Specifically, ADHD may be more strongly associated with weaknesses on measures such as the QRI that assess oral language and comprehension skills and that are not as reliant on single word decoding (Cutting & Scarborough, 2006; Keenan et al., 2008). Our results also align with the findings of Miller et al. (2013), which demonstrated that ADHD uniquely predicts reading comprehension performance on the QRI above and beyond the effects of word reading ability.

Our findings for writing provide more consistent support for our initial hypothesis that ADHD would be uniquely associated with higher-order academic skills. Results indicated that ADHD group status predicted lower writing composition performance after controlling for performance on tests of basic writing skills *and* performance on tests of reading abilities. Moreover, these results were consistent across all three measures of writing composition used in the present study (*WIAT-III*, TOWL-IV, and WJ-III). These results indicate that ADHD symptoms uniquely impact writing composition performance, suggesting that inattention symptoms lead to difficulties organizing and communicating ideas in writing.

Our findings that ADHD uniquely predicts writing composition are important for several reasons. First, the goal of writing instruction is composition. The ability to express one's ideas in text form is essential to success in everyday life, yet relatively little attention has been given to the association between ADHD and writing difficulties in the literature, particularly compared to reading difficulties (Graham et al., 2016). The findings from the present study are novel and provide further insights to the relations between ADHD and writing composition. Second, the findings align with theoretical models of ADHD and writing. Writing composition is a complex skill that requires sustained regulation of attention, motivation, and effort (Flower & Hayes, 1981; Graham et al., 2007). Given that distractibility, low motivation, and resistance to tasks requiring sustained effort are associated with ADHD (e.g., Graham et al., 2016; Smith et al., 2020), it is plausible that these weaknesses would lead to weaker writing composition abilities.

Implications for Clinical Assessment

The current results clearly illustrate that ADHD is associated with significant academic difficulties in reading, math, and writing with effect sizes that are medium in magnitude. Further, while measures of basic reading, math, and writing account for much of the variance in more complex measures of each academic domain (e.g., the basic measures each accounted for ~ 2–7% of the variance in the complex reading and writing measures when all variables were included in the model), ADHD is uniquely associated with specific aspects of reading comprehension and writing composition even after controlling basic word reading and writing skills.

These results suggest that comprehensive assessments of ADHD should always include an assessment of academic functioning. If it is not feasible to include a comprehensive battery of academic achievement measures in all assessments, it may be useful to at least screen for academic difficulties using a streamlined battery of brief measures of word reading, math calculations, and basic writing skills. The subset of individuals who exhibit significant weaknesses in any of these domains could then complete the measures of more complex academic skills to fully understand their profile of strengths and weaknesses and guide academic interventions.

Strengths, Limitations, and Future Directions

The present study had several strengths, including a large sample size and comprehensive battery of academic assessments. To the authors' knowledge, the present evaluation is the first study to examine the association between ADHD and academic functioning at multiple levels across domains of reading, writing, and math within the same sample. Despite these strengths, results of our study should also be interpreted in the context of several important limitations. The overall sample, although large, was not diverse, as most participants were white (~ 80%), and relatively few participants were from low SES backgrounds (mean years of parental education = 15.4). Additionally, the present study utilized original versions of several assessment measures. Although the current subset of the CLDRC twin study sample that completed the full battery of measures of reading, math, and writing was assessed between 2011 and 2021, the overall CLDRC twin study has been ongoing for over 30 years. Therefore, the original versions of the PIAT and WRAT have been retained for all participants to facilitate analyses of the basic reading and math measures across the entire sample for other purposes. Scores on the original PIAT and WRAT subtests are highly correlated with the corresponding subtests on subsequent editions of these achievement test batteries (e.g., Markwardt, 1989; Wilkinson & Robertson, 2006); however, future studies that replicate the present findings with newer measures would be useful. Also, because the test battery has been refined over time and the measure of math fluency was incorporated later in the investigation, the sample size for math fluency was too small to be included in the current analyses. Moreover, the available sample size for the mathematics analyses was smaller than the sample used for the reading and writing analyses. Lastly, while multiple measures were administered for most constructs, only single measures of handwriting, writing fluency, and word problems were used. Therefore, results based on these measures should be interpreted more cautiously, and future studies that incorporate multiple measures of these constructs will provide a useful extension of this research.

Regarding future directions, more research is necessary to better understand how to apply results from the present evaluation to interventions for ADHD. Our findings on writing composition indicate that interventions must go beyond targeting handwriting and spelling. This conclusion aligns with prior intervention research on writing that suggests students benefit most when they are taught explicit writing composition strategies alongside self-regulation skills (Self-Regulated Strategy Development, SRSD; Graham et al., 2007). This approach has been effective for typically developing children (e.g., Graham et al., 2007), and some research suggests it may also benefit children with ADHD (e.g., Jacobson & Reid, 2010; Lienemann & Reid, 2008).

Our findings for reading suggest that ADHD may influence reading comprehension performance, particularly for tests that are less dependent on decoding. The results also clearly demonstrate that word recognition and reading fluency are important to reading comprehension. Thus, interventions aimed at improving advanced reading skills in ADHD will likely need to target inattention symptoms alongside basic reading skills. This idea is consistent with theoretical models of reading achievement in ADHD that suggest ADHD impacts later reading achievement by weakening early reading skills as well as academic motivation and study skills (Volpe et al., 2006). It is also consistent with emerging intervention research, which demonstrated that that an ADHD treatment was more effective at improving reading comprehension in children with ADHD than a word reading intervention alone, even though the latter lead to gains in basic reading skills (Denton et al., 2020).

Our findings for math suggest that ADHD may primarily impact advanced skills by undermining basic skill development. However, one should take caution before concluding that only basic skill interventions are needed to improve mathematical problem solving in ADHD. As with reading achievement, theoretical models suggest that academic motivation, study skills, and classroom engagement predict math achievement in ADHD, above and beyond the effects of early math performance (Volpe et al., 2006). Similarly, a review by DuPaul et al. (2011) found that a combination of interventions, such as tutoring, computer assisted-instruction, behavioral techniques, and stimulant medication, are important to improve math achievement in children with ADHD. Overall, more research is needed to understand how interventions can target deficits in mathematical skill development.

Conclusions

Relations between ADHD and academic functioning were explored using a comprehensive battery of reading, writing, and mathematics assessments within a community youth sample. Results of dimensional and categorical analyses indicated that ADHD predicted worse performance in reading, writing, and math. Analyses examined whether ADHD independently predicted performance in advanced academic skills when performance in basic skills was controlled. Results indicated that ADHD was a significant predictor of performance on one reading comprehension measure, above and beyond word recognition and reading fluency. Similarly, ADHD was a significant predictor of writing composition, even after controlling for basic writing skills and reading skills. In contrast, ADHD was not a significant predictor of mathematical problem solving after accounting for the association between ADHD and math calculations. These results demonstrate the unique influence of ADHD on reading comprehension and writing composition, providing insights for future reading and writing interventions for children with the disorder.

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Data Availability The data were collected as part of the Colorado learning disabilities research center over two decades, and only a subset of participants provided consent for their deidentified data to be made available to outside researchers. Investigators who are interested in using the subset of data that is available should contact Erik Willcutt, current Director of the CLDRC (willcutt@colorado.edu).

Compliance with Ethical Standards

Ethical Approval Ethical approval for this study was provided by the Institutional Review Boards at the University of Colorado and University of Denver.

Informed Consent Informed consent and assent were obtained from all participants prior to beginning data collection.

Conflict of Interest Authors declare no conflict of interest.

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