The Role of Working Memory and Organizational Skills in Academic Functioning for Children with ADHD

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Abstract

Objectives: Children with ADHD exhibit difficulties with organizational skills such as task planning, managing materials, and organizing activities that have downstream consequences on academic functioning. At the same time, deficits in working memory have been linked with both the organizational skills difficulties and academic underachievement/underperformance observed in children with ADHD and have been hypothesized to account for the link between organizational and academic functioning. However, the extent to which working memory and organizational skills independently vs. jointly contribute to ADHD-related academic difficulties remains unclear.

Methods: The current study is the first to examine the unique and shared roles of working memory and organizational skills for explaining ADHD-related underachievement and underperformance in a clinically-evaluated sample of 309 children with and without ADHD (M_{age}=10.34, SD=1.42; 123 girls; 69.6% White Not Hispanic or Latino).

Results: Bias-corrected, bootstrapped latent path analyses revealed that working memory and organizational skills together accounted for 100% of the academic achievement (d=−1.09) and 80.6% of the academic performance (d=−0.58) difficulties exhibited by children with ADHD. Working memory (d=−0.95 to −0.26), organizational skills (d=−0.30 to −0.11), and shared variance across working memory and organizational skills (d=−0.13 to −0.06) each independently predicted ADHD-related difficulties in both academic achievement and performance outcomes.

Conclusions: These findings are consistent with models suggesting that working memory has downstream consequences for functional impairments in ADHD, as well as evidence that

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Ethical Approval: All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed Consent: Informed consent was obtained from all individual participants included in the study.

organizational skills and working memory are each important predictors of ADHD-related academic functioning.

Keywords

ADHD; organizational skills; working memory; academic performance; academic achievement

Organizational skills difficulties are an impairing feature of attention-deficit/hyperactivity disorder (ADHD) that increase in severity from childhood through adolescence (Langberg, Molina et al., 2011), portend academic underachievement in both early and later grades (Kent et al., 2011; Langberg, Epstein et al., 2011), and affect outcomes into adulthood (Bicik et al., 2017). These impairments affect children at school and home (Langberg et al., 2008), but are particularly impairing for the acquisition and performance of academic skills (Langberg, Molina et al., 2011), and have been hypothesized to underlie academic difficulties in children with ADHD (Langberg, et al., 2013). At the same time, working memory has been linked with both organizational skills and academic functioning via cross sectional (Cortés Pascual et al., 2019; Kofler et al., 2017, 2018; Spiegel et al., 2021), longitudinal (Ahmed et al., 2019) and randomized controlled trial (RCT; Chan et al., 2023; Singh et al., 2022) studies of school-age children. Thus, working memory may reflect a common, ‘third variable’ mechanism that explains associations between these skills. However, the extent to which working memory may account for the relation between organizational skills and academic functioning in ADHD remains unclear, as to our knowledge no study has examined all three of these constructs together.

Organizational Skills and Academic Functioning in Children with ADHD

Organizational skills difficulties in children with ADHD include problems with task planning, organizing actions, and memory/materials management (Langberg, Epstein et al., 2011). These difficulties often emerge in elementary school and present as problems such as forgetting deadlines, misplacing materials, keeping messy lockers and backpacks, and failing to finish assignments (Kent et al., 2011). Problems with organizational skills become more impairing as children progress through school, task demands increase, and children have difficulty keeping up with higher workloads and increased demands for personal responsibility (Langberg, Molina et al., 2011). Organizational skills training interventions designed to teach strategies to improve organization of materials, time, and planning skills appear promising for improving these behaviors to facilitate learning and improve functional outcomes in academic and other domains (Bikic et al., 2017; Langberg et al., 2008).

Academic difficulties in children with ADHD are evident across two interrelated but distinguishable domains: academic achievement and academic performance (e.g., Singh et al., 2022). *Academic achievement* refers to knowledge of academic information and skills as demonstrated on standardized achievement tests (Langberg, Molina et al., 2011). *Academic performance* refers to day-to-day success and productivity in the classroom as reported by teachers and parents and/or demonstrated through school grades and assignment completion. Academic achievement and performance have different predictors (Langberg, Molina et al., 2011) and show differential response to evidence-based ADHD interventions (Loe &

Feldman, 2007). For example, the literature linking organizational skills and academic *achievement*, although limited, suggests that academic achievement is not concurrently related to organizational skills (Langberg, Molina et al., 2011), does not predict response to organizational skills training, and does not predict or meaningfully improve following organizational skills training (DuPaul et al., 2021). In contrast, compelling evidence suggests that organizational skills are an important predictor of academic *performance* among children with ADHD, such that task planning and materials management predict academic performance outcomes for children ages 7–14 (grades 2–8) based on cross-sectional (Langberg, Epstein et al., 2011), longitudinal (Langberg, Molina et al., 2011; Langberg, Dvorsky et al., 2016), and RCT data (Abikoff et al., 2013; Evans et al., 2021; Pffifner et al., 2013), as well as meta-analytic data for school-age children more broadly (Bicik et al., 2017). Given children with ADHD demonstrate difficulty with both organizational skills and academic functioning (Langberg, Molina et al., 2011), investigating additional predictors associated with these two important domains of functioning may reveal mechanisms that underlie co-occurring difficulties across these domains.

Working Memory and Organizational Skills

Working memory appears to play a critical role in the implementation of organizational skills (Kofler et al., 2018). Working memory is a primary executive function (Karr et al., 2018) that guides behavior via the updating, manipulation, and dual-processing of information held in temporary (short-term) memory (Baddeley, 2007; Kofler et al., 2018). It is estimated that 65–85% of school-age children with ADHD exhibit working memory deficits (Fosco et al., 2020; Kofler et al., 2019), and meta-analytic evidence suggests that up to 98% of children with ADHD have below-average or lower working memory abilities (Kasper et al., 2012).

Several influential models of ADHD suggest that functional impairments in domains such as organizational skills may reflect, at least in part, inconsistent performance of learned skills due to working memory difficulties rather than actual knowledge/skills gaps (Chacko et al., 2014; Kofler et al., 2018; Rapport et al., 2001). In particular, working memory deficits have been proposed to underlie organizational skills deficits in ADHD and maintain difficulties with activities such as planning, tracking assignments, and managing time and materials (Abikoff et al., 2013; Barkley, 2006; Kofler et al., 2018). This hypothesis is supported by (1) empirical evidence that working memory predicts both parent and teacher ratings of organizational skills across domains of memory/materials management, task planning, and organized actions (Kofler et al., 2018), and (2) functional if not causal evidence from a recent randomized clinical trial indicating that directly training working memory produces downstream improvements in these same domains without explicit instruction in organizational skills (Chan et al., 2023). Thus, given compelling evidence that working memory deficits are associated with organizational skills difficulties, and evidence that organizational skills difficulties are further associated with reduced academic performance, examining the manner in which these deficits are interrelated in children with ADHD may help characterize these difficulties more concisely.

Working Memory and Academic Functioning in Children with ADHD

Extant evidence suggests that working memory is related to both academic achievement and academic performance in children with ADHD. In terms of *academic achievement*, meta-analytic evidence shows that working memory abilities strongly predict academic achievement in reading, math, and oral language in school-age children (Cortés Pascual et al., 2019; Spiegel et al., 2021). Among children with ADHD, converging evidence suggests that working memory is uniquely related to academic achievement (St. Clair Thompson & Gathercole, 2006), with underdeveloped working memory accounting for 42%−60% of the difficulties exhibited on standardized tests of reading and math (Friedman et al., 2017; 2018). Further, longitudinal (Miller et al., 2012) and experimental (Kofler et al., 2018) evidence suggests that these relations are functional if not causal for school-age children with ADHD. Additionally, improved working memory following targeted intervention has been linked to clinically meaningful improvements in academic achievement in children with ADHD that were superior to both behavioral parent training and a competing neurocognitive training program (Singh et al., 2022).

In terms of *academic performance*, a review of the literature by Fried et al. (2019) suggests a robust relation between working memory and academic performance across ages and measures. In particular, working memory predicts teacher-rated academic performance (Kofler et al., 2017), and impairments in working memory are associated with parent-reported history of academic problems (e.g., grade retention, placement in special education classes; Fried et al., 2019). Further, similar to the clinical trial results for academic achievement noted above, improvements in working memory have been associated with superior improvements in masked teacher ratings of academic performance relative to both behavioral parent training and a competing neurocognitive training program, providing compelling evidence for a casual relation between these constructs (Singh et al., 2022).

Current Study

Taken together, the current evidence indicates that children with ADHD exhibit impairments in working memory, organizational skills, and academic functioning (Abikoff et al., 2013; Barkley, 2006; Kofler et al., 2017; 2018). However, despite separate sources of cross-sectional, longitudinal, and RCT evidence linking working memory and academic achievement, working memory and academic performance (Kofler et al., 2017; Singh et al., 2022; Spiegel et al., 2021), working memory and organizational skills (Chan et al., 2023; Kofler et al., 2018), and organizational skills and academic performance in children with ADHD (Abikoff et al., 2013), it remains unclear the extent to which working memory impairments reflect a ‘third variable’ mechanism that explain the links between organizational skills and academic functioning.

In terms of academic *achievement*, we hypothesized that working memory would predict organizational skills and account for ADHD/Non-ADHD between-group differences in underachievement, but that organizational skills would not uniquely predict these differences in underachievement after accounting for the shared contribution of working memory. This hypothesis was based on the strong evidence for a functional if not causal role of working memory on both academic achievement and organizational skills, combined with the findings reviewed above that organizational skills training minimally affects academic achievement. In contrast, we hypothesized that working memory and organizational skills would each uniquely predict ADHD/Non-ADHD between-group differences in academic *performance* based on the longitudinal and clinical trial evidence reviewed above.

Method

Participants

The sample comprised 309 children ages 8–13 years (M=10.34, SD=1.42; 123 girls) from the Southeastern United States, recruited by or referred to a university-based children's learning clinic (CLC) through community resources (e.g., pediatricians, community mental health clinics, school system personnel, community recruitment events, website/ Internet postings, self-referral) from 2013 to 2022 for participation in a larger study of the neurocognitive mechanisms underlying pediatric attention, learning, behavioral, and emotional difficulties, with an oversampling of children with ADHD. Sample ethnicity was mixed and included 215 White Not Hispanic or Latino (69.6%), 41 Black (13.3%), 21 Hispanic or Latino (6.8%), 31 multiracial children (10.0%), and 1 Asian (0.3%) child. All parents and children gave informed consent/assent and Florida State University Institutional Review Board approval was obtained.

All children and caregivers completed a detailed, semi-structured clinical interview using the Kiddie Schedule for Affective Disorders and Schizophrenia for School-Aged Children (K-SADS; Kaufman et al., 1997). The K-SADS (2013 Update) allows differential diagnosis according to symptom onset, course, duration, quantity, severity, and impairment in children and adolescents based on DSM-5 criteria (APA, 2013), and was supplemented with parent and teacher ratings scales from the Behavior Assessment System for Children (BASC-2/3; Reynolds & Kamphaus, 2004) and ADHD Rating Scale for DSM-4/5 (ADHD-RS-4/5; DuPaul et al., 2016) for all participants. A psychoeducational report was provided to parents; children selected a small toy (<$5) from a prize box after each session.

Two hundred and three children (75 girls) met all of the following criteria and were diagnosed with ADHD based on the comprehensive psychoeducational evaluation: (1) DSM-5 diagnosis of ADHD combined (n=137), inattentive (n=60), or hyperactive/impulsive (n=6) presentations by the CLC's directing clinical psychologist and multidisciplinary team based on K-SADS and differential diagnosis considering all available clinical information indicating onset, course, duration, and severity of ADHD symptoms consistent with the ADHD neurodevelopmental syndrome; (2) borderline/clinical elevations on at least one parent and one teacher ADHD subscale (i.e., >90th percentile); and (3) current impairment based on parent report. Children with any current ADHD presentation specifiers were eligible given the instability of ADHD presentations (Lahey et al., 2005).

Our standard assessment battery also included norm-referenced child internalizing disorder screeners, with additional standardized measures administered as needed to inform differential diagnosis and accurate assessment of comorbidities. Several children with ADHD also met criteria for common comorbidities based on this comprehensive psychoeducational evaluation, including anxiety (n=65), oppositional defiant (n=17),[1] autism spectrum (n=18), depressive (n=13) and specific learning (n=50) disorders. To improve generalizability, given that comorbidity is the norm rather than the exception for children with ADHD (Wilens et al., 2002), these children were retained in the sample.

An additional 106 children (48 girls) completed the same comprehensive psychoeducational assessment and did not meet criteria for ADHD. The Non-ADHD group was deliberately recruited to include children who were, and were not, diagnosed with clinical disorders other than ADHD because it controls for the presence of these diagnoses in the ADHD group (i.e., it allows us to draw stronger conclusions about processes implicated in ADHD specifically as opposed to processes that may appear to be impaired in ADHD due to the confounding influence of comorbid conditions). Thus, participants in this group included both neurotypical children (n=34) and children with anxiety (n=39), autism spectrum (n=14), depressive (n=12), and specific learning (n=12) disorders. Neurotypical children had normal developmental histories and nonclinical parent/teacher ratings, were recruited through community resources, and completed the same evaluation as clinically-referred children.

None of the children presented with gross neurological, sensory, or motor impairments that would preclude valid test administration, history of seizure disorder, intellectual disability, psychosis, or non-stimulant medication that could not be withheld for testing. Forty-seven (23.2%) of the 203 children with ADHD were prescribed psychostimulant medication. Children prescribed psychostimulant medication received their usual dose on the psychoeducational testing day because results were included in the psychoeducational report provided to families. Psychostimulants were withheld ≥24 hours for research-based neurocognitive testing.

Procedure

Children participated in a standardized psychoeducational assessment followed by 1–2 research sessions. All sessions were approximately 3 hours. Psychoeducational testing was conducted according to standard clinical practice protocols and included the measures of academic achievement described in the current study. The working memory tasks were administered as part of a larger battery of laboratory tasks that were counterbalanced within and across sessions to minimize order effects. Performance was monitored at all times by the examiner, who was stationed just out of the child's view to provide a structured setting while minimizing performance improvements associated with examiner demand characteristics, which refers to the idea that the behavior of participants may change in the presence of the examiner and unintentionally lead to biased research findings (Gomez & Sanson, 1994). All children received brief (2–3 min) breaks after each task and preset longer (10–15 min) breaks after every 2–3 tasks to minimize fatigue.

[1]As recommended in the K-SADS, oppositional-defiant disorder (ODD) was diagnosed only with evidence of multi-informant/multi-setting symptoms.

Measures

Working Memory

Rapport Working Memory Reordering Tests.: The Rapport et al., (2009) computerized phonological and visuospatial working memory tests and administration instructions are identical to those described in Kofler et al. (2018). Psychometric support includes high internal consistency (α=.81–.97) and 1–3-week test-retest reliability (.76–.90; Sarver et al., 2015), and expected relations with criterion working memory complex span (r=.69) and updating tasks (r=.61; Wells et al., 2018). Six trials per set size were administered in randomized/unpredictable order (3–6 stimuli/trial; 1 stimuli/second) as recommended (Kofler et al., 2017). Five practice trials were administered before each task (80% correct required). Task duration was approximately five to seven minutes. Partial-credit unit scoring (i.e., stimuli correct per trial) was used as recommended (Conway et al., 2005). Higher scores reflect better working memory.

In the phonological working memory reordering task (PHWM), children were presented a series of jumbled numbers and a capital letter on a computer monitor. Each number and letter (4 cm height) appeared on the screen for 800 ms, followed by a 200 ms interstimulus interval. The letter never appeared in the first or last position of the sequence to minimize potential primacy and recency effects, and was counterbalanced across trials to appear an equal number of times in the other serial positions (i.e., position 2, 3, 4, or 5). Children were instructed to recall the numbers in order from least to greatest, and to say the letter last.

In the visuospatial working memory reordering task (VSWM), children were shown nine squares arranged in three offset vertical columns. A series of 2.5 cm diameter dots (3, 4, 5, or 6) were presented sequentially in one of the nine squares during each trial, such that no two dots appeared in the same square on a given trial. All but one dot presented within the squares was black—the exception being a red dot that was counterbalanced across trials to appear an equal number of times in each of the nine squares, but never presented as the first or last stimulus in the sequence to minimize potential primacy and recency effects. Children reordered the dot locations (black dots in serial order, red dot last) and responded on a modified keyboard.

Letter Updating.: The letter updating working memory (LUWM) test and administration instructions are identical to those described in Fosco et al. (2020). Psychometric support includes high internal consistency (α=0.75), expected magnitude relations with other working memory tests (Kofler et al., 2018), and large magnitude ADHD/Non-ADHD between group differences (Fosco et al., 2020; Kofler et al., 2018). In this computerized task, letters were presented on the screen one at a time, and children were instructed to keep track of the last three letters presented. To ensure the task required continuous updating, children were instructed to rehearse out loud the last three letters by mentally adding the most recent letter and dropping the fourth letter back, before saying the new string of three letters out loud (Miyake et al., 2000). The number of letters presented (4–8 stimuli presented/trial, 1200 ms presentation, 2400 ms ISI) was varied randomly across trials to ensure that successful performance required continuous updating until the end of each trial. A practice block was administered; children advanced to the test phase following three correct practice trials. Four blocks of three test trials each were administered. Children responded via mouse click. Higher stimuli correct per trial reflects better working memory.

Organizational Skills—The Children's Organization Skills Scale (COSS; Abikoff & Gallagher, 2009) consists of 66 parent-rated and 42 teacher-rated items to assess organizational problems in children ages 8–13 across home and school settings (2–3-week test-retest=.88–.99; α=.89–.98). The COSS provides three subscales: Task Planning, Organized Actions, and Memory/Materials Management. A Total Score is also reported that reflects overall organization, time management, and planning (OTMP) skills. Raw scores were selected a priori as recommended for research purposes (Farmer et al., 2020). Higher scores indicate more difficulties with organizational skills.

Academic Functioning

Academic Achievement.: The Kaufman Test of Educational Achievement (KTEA-3; Kaufman & Kaufman, 2014) was used to assess academic achievement (1–2-week test-retest=.80–.96; α=.92–.99). The Reading Composite (reading comprehension and letter & word recognition subtests) and Math Composite (math computation and math concepts & applications subtests) scores were used in this study. Standard scores were obtained for each of these measures (age norms), with higher scores indicating greater academic achievement. Between-group comparisons of standard scores on the KTEA-3 are shown in Table 1.

Academic Performance.: The Academic Performance Rating Scale (APRS; DuPaul, Rapport, & Perriello, 1991) was completed by each child's teacher to assess academic performance (two-week test-retest=.93–.95, α=.94–.95). The APRS contains subscales that assess academic productivity and success. The academic productivity scale consists of 12 items assessing: academic efficiency (e.g., percentage classwork correctly completed) and consistency, following group instructions, and timely completing work. The academic success scale consists of 7 items assessing quality of reading/spoken work, speed children learn new material, and how well they retain new information. Raw scores were selected a priori as recommended for research purposes (Farmer et al., 2020). Higher scores reflect better academic performance.

Socioeconomic Status (SES) and Intellectual Functioning (IQ)

Hollingshead SES was estimated based on caregiver(s)' education and occupation (Cirino et al., 2002). Higher scores indicate higher SES. IQ was estimated using the 4-subtest Short-Form IQ (Vocabulary, Similarities, Matrix Reasoning, Figure Weights), which has a validity coefficient of $r = .90$ and correlates $r_{ss} = .96$ with the full, 7-subtest WISC-V Full Scale IQ (Sattler et al., 2016).

Transparency and Openness

We report how we determined our sample size, all data exclusions (if any), all manipulations, and all study measures. The study was not pre-registered; however, all measure inclusion/exclusion decisions and analytic plans were made *a priori*, prior to accessing the data. Data/code are available by emailing the corresponding author. Data were analyzed using structural equation modeling (SEM) via Mplus software (Version 8.8; Muthén & Muthén, 2017).

Data Analysis

For all confirmatory models, absolute and relative fit were tested. Adequate model fit is indicated by CFI and TLI ≥ .90, and RMSEA ≤ .10. Age, sex, and socioeconomic status (SES) were included as covariates in all models. All items showed the expected range of scores and were screened for normality (all skewness<|0.62|; all kurtosis<|.59|). Delta scaling with maximum likelihood estimation with robust standard errors (MLR) was used to handle any non-normality. Standardized residuals were inspected for magnitude (all positive and <1, indicating no evidence of localized ill fit). Directionality of parameter estimates was inspected.

Our primary analyses are organized into three analytic Tiers. In Tier 1, measurement models were created for working memory, organizational skills, academic performance, and academic achievement using the indicators for each construct described above. In Tier 2, conditional effects path models were created for working memory and organizational skills separately to examine the extent to which these constructs predict ADHD-related academic underachievement and ADHD-related academic underperformance when considered independently. Significant conditional effects from these models were then used in the Tier 3 serial conditional effects path models. These serial path models evaluated the extent to which children with ADHD exhibit impairments in academic functioning (path c), as well as the extent to which these hypothesized impairments are related to ADHD-related difficulties unique to working memory (path ab_1), unique to organizational skills (path ab_2), and shared between working memory and organizational skills (path ab_3). The combined impact of these three distinct pathways is also estimated (ab_{total}).

Pathway directionality was specified a priori given the evidence reviewed above that working memory likely reflects an underlying functional if not causal factor contributing to organizational skills difficulties and academic underachievement in ADHD (Chan et al., 2023; Kofler et al., 2018; Singh et al., 2022). Organizational skills were modeled as predictors of academic achievement and performance given extensive evidence supporting effects in this direction – at least for academic performance (Abikoff 2013; Bikic et al., 2017; Evans et al., 2021; Pffifner et al., 2013).

Separate models were run for the latent academic performance and achievement outcomes given the evidence reviewed above. Bias-corrected bootstrapping with 5,000 resamples was used as recommended (e.g., Preacher et al., 2007). For all pathways, effects are considered statistically significant if their 95% confidence intervals (CIs) do not contain zero. Effect ratios for significant indirect effects indicate the proportion of the total effect (c pathway) that are conveyed via the indirect pathway (ab; i.e., effect ratio=ab/c).

Results

Preliminary Analyses

Outliers beyond 3.00 *SD* were winsorized relative to the within-group distribution (ADHD, Non-ADHD). This affected 3 data points (0.13%) from the ADHD group and 2 data points (0.17%) from the non-ADHD group. Missing data was low for both the ADHD (3.1%) and non-ADHD (6.6%) groups and was handled using full information maximum likelihood estimation. Task data from subsets of the current battery have been reported for subsets of the current sample to examine conceptually unrelated hypotheses (see Cole et al., 2023). Demographic information for the full sample is shown in Table 1. Intercorrelations among manifest study variables are shown in Table 2. All working memory, organizational skills, academic achievement, and academic performance variables used in the primary models were significantly intercorrelated as expected. ADHD diagnostic status was significantly correlated with all variables in the model in the expected directions.

Tier I: Measurement Models

We specified two measurement models, separately for academic achievement and academic performance outcomes. The latent academic achievement outcome variable was comprised of two indicators: the KTEA-3 reading and math composites. The latent academic performance outcome variable was comprised of two indicators: the APRS academic performance and academic success subscales. The latent working memory variable was comprised of three indicators: total stimuli correct from the PHWM, VSWM, and LUWM tests. We also initially specified a latent variable for organizational skills that was comprised of the three subscales of the teacher COSS, but this latent variable provided poor fit to the data (both TLI<.90, RMSEA>.10). Given this finding, we then specified a latent organizational skills variable comprised of two indicators, parent and teacher COSS total scores, but this also provided unsatisfactory fit (TLI<.80, RMSEA>.20). Thus, we created a single-indicator latent estimate of organizational skills based on the teacher COSS total score with its error variance fixed based on the test's published test-retest reliability (.94) as recommended (Kline, 2016). Teacher-rated organizational skills were selected over parent-rated organizational skills given evidence that organizational skills in the classroom setting are more impairing and better predictors of academic functioning (Langberg et al., 2008; Langberg, Epstein, et al., 2011). Models with parent-rated organizational skills are included as exploratory/supplementary analyses.

The final measurement model consisting of latent variables for working memory, organizational skills, and academic achievement or academic performance provided a good fit to the data (both CFI>.99; TLI>.96; RMSEA<.09, SRMR<.04).

Tier 2: Individual Conditional Effect Path Models

Total Effects for Academic Achievement and Performance (c pathways)— As noted above, separate models were tested for academic achievement and academic performance outcomes; reporting is truncated for readability. Full model results are reported in Supplementary Tables 1–5. Examination of the total effects of ADHD diagnostic status on academic achievement revealed children with ADHD exhibit medium magnitude deficits in academic achievement (c pathways; Cohen's d=−0.66; β=−.30) and academic performance (d=−0.79; β=−.35; both 95%CI excludes 0.0). We use the term "ADHD-related academic difficulties" to refer to these between-group differences in subsequent models.

Working Memory Models—Results of the working memory conditional effects models are shown in Figure 1. ADHD diagnostic status predicted large magnitude deficits in working memory (a pathway; d=−1.06; β=−.45). Further, working memory was significantly associated with academic *achievement* (b pathways; β=.99) and academic *performance* (β=.55; all 95%CI exclude 0.0) after accounting for ADHD status. Examination of indirect effects revealed that a significant proportion of the ADHD/academic relation was shared with working memory for both academic achievement (ab pathways; d=−1.06; β=−.45; Effect Ratio [ER]=1.0) and academic performance (d=−.55; β=−.25; ER=.71; both 95%CI exclude 0.0).

The relation between ADHD and academic *performance* (d=.15; β=.07; 95%CI includes 0.0) was no longer significant after accounting for the indirect effect of ADHD status on academic functioning via the working memory pathway, consistent with the effect ratios suggesting that working memory accounted for 71% of ADHD-related academic underperformance. A similar but more pronounced effect was seen in the academic achievement model: Interestingly, the negative total effect of ADHD on academic *achievement* described above became significant in the positive direction (c' pathway; d=.30; β=.14; 95%CI excludes 0.0) after accounting for the working memory pathway. This occurred because of a common phenomenon referred to as 'inconsistent mediation' (MacKinnon, Krull, & Lockwood, 2000), which is present when the total indirect effect – in this case ADHD status predicting underachievement via the working memory pathway (β=−.49) – is larger than the total main effect (ADHD → underachievement total effect: β=−.30), resulting in the residual direct effect (c' pathway) occurring in the opposite direction of the total (c pathway) and indirect (ab pathway) effects. In other words, working memory appears to have a suppression-like effect on the ADHD/academic achievement relation, such that children with ADHD may be *over*achieving academically if not for the interfering effects of their working memory deficits. Altogether, ADHD status and working memory abilities accounted for 68% (academic achievement; R^2=.68) and 34% (academic performance; R^2=.34) of the variance in children's academic functioning.

Organizational Skills Models—Results of the organizational skills conditional effects models are shown in Figure 2. ADHD diagnostic status predicted medium-to-large impairments in school-based organizational skills difficulties (d=0.79; β=.35; 95%CI excludes 0.0). Further, organizational difficulties were significantly associated with both academic achievement (β=−.36) and academic performance (β=−.57; both 95%CI exclude 0.0) after accounting for ADHD status. Examination of the indirect effects revealed that a significant proportion of the ADHD/academic relation was shared with organizational difficulties for both academic achievement (d=−.28; β=−.13) and academic performance (d=−.43; β=−.20; both 95%CI exclude 0.0). In contrast to the working memory models reported above, ADHD status continued to be associated with significant, albeit attenuated, difficulties in both academic achievement (d=−.38; β=−.18) and academic performance (*d*=−0.29; β=−.14; both 95%CI exclude 0.0) after accounting for the indirect effect of ADHD status on academic functioning via the organizational skills pathway. Specifically, inspection of the effect ratios indicates that organizational difficulties account for 37% (academic achievement) to 57% (academic performance) of ADHD-related academic difficulties. Altogether, ADHD status and organizational difficulties accounted for 30% (academic achievement; R^2=.30) and 43% (academic performance; R^2=.43) of the variance in children's academic functioning.

Tier 3: Serial Latent Path Models

In the serial latent path analyses, we examined the extent to which working memory abilities and organizational problems independently and jointly accounted for ADHD-related differences in academic achievement and academic performance. Once again, separate models were created for achievement and performance outcomes; reporting is truncated for readability (Figures 3 and 4). As reported in Tier 2, when modeled separately working memory and organizational difficulties each accounted for significant variance in both the ADHD/academic achievement and the ADHD/academic performance relations. Thus, in Tier 3 we included both predictors together in the final latent path models. Working memory was modeled as a predictor of organizational skills problems, rather than vice versa, based on evidence suggestive of directionality described above. The c pathway results for both models were identical to those reported above as expected.

In the academic *achievement* model, examination of the indirect effects revealed that a significant proportion of the ADHD/academic underachievement relation was accounted for by ADHD-related working memory difficulties uniquely (ab_1 pathway; *d*=−0.95, β=−.41, ER=1.0), organizational difficulties uniquely (ab_2 pathway; *d*=−0.11, β=−.05, ER=.17), and shared variance between ADHD-related working memory and organizational skills deficits (ab_{12} pathway; *d*=−0.06, β=−.03; all 95%CIs exclude 0.0). Similar to the individual conditional effects model for working memory, with both working memory and organizational problems included in the model, the negative total effect of ADHD on academic achievement (c pathway; *d*=−0.66, β=−.30) became significant in the positive direction (c' pathway; *d*=0.41; β=.19; 95%CI excludes 0.0), suggesting once again that children with ADHD may be overachieving academically if not for their working memory and organizational skills deficits. Together, ADHD status, working memory, and organizational problems explained 71% of the variance in academic achievement (R^2=.71).

A similar but less pronounced effect was found in the academic *performance* serial latent path model. Examination of the indirect effects revealed that a significant proportion of the ADHD/academic performance relation was accounted for by ADHD-related working memory deficits uniquely (ab_1 pathway; *d*=−0.26, β=−.12, ER=.34), ADHD-related organizational problems uniquely (ab_2 pathway; *d*=−0.30, β=−.14, ER=.40), and shared variance between ADHD-related working memory and organizational problems (ab_{12} pathway; *d*=−0.13, β=−.06, ER=.17; all 95%CIs exclude 0.0). With both working memory and organizational difficulties in the model, the direct effect of ADHD status on academic performance was nonsignificant (*d*=−0.08, β=−.04; 95%CI includes 0.0), consistent with the total indirect effect (ab_{total}; β=−.31) being highly similar to the total main effect (c pathway, β=−.35; ER=.91). Together, ADHD status, working memory, and organizational skills problems explained 49% of the variance in academic performance.

Exploratory Analyses

As an exploratory analysis, we replicated the serial mediation models described above, with the exception that parent-rated organizational skills were included in place of teacher-rated organizational skills. A single-indicator latent estimate of parent-rated organizational skills based on COSS total score was created with its error variance fixed based on the rating scale's published test-retest reliability (.99), and the revised measurement models provided good fit to the data (CFI>.96; TLI>.92; RMSEA<.07).

For the academic *achievement* outcome model, the results were generally consistent with those reported above, except that the indirect effect of parent-rated organizational skills (ab_2 pathway; *d*=−.00; β=.00) and the indirect effect shared between working memory and parent-rated organizational skills (ab_{12} pathway; *d*=−.002; β=−.001; 95%CIs include 0.0) were not significant. The indirect effect of working memory remained significant as expected (ab_1 pathway; *d*=−1.03, β=−.44, ER=1.29; 95%CI excludes 0.0), and the direct effect of ADHD diagnostic status on academic achievement was no longer significant (c' pathway; *d*=.32; β=.15; 95%CI includes 0.0).

The academic *performance* outcome model was also generally consistent with the primary models results above. The indirect effects of working memory difficulties (*d*=−0.48; β=−.22; ER=.62), parent-rated organizational skills problems (*d*=−.08; β=−.04, ER=.11) and the shared effect of working memory and organizational skills problems (*d*=−.02; β=−.01, ER=.03; all 95%CIs exclude 0.0) each uniquely accounted for ADHD-related academic underperformance, together explaining 80% of the relation between ADHD diagnosis and academic performance (ab_{total}; *d*=−.62; β=−.28; ER=.80) and resulting in the main effect of ADHD diagnostic status on academic performance becoming nonsignificant (c' pathway; *d*=−.13; β=−.06; 95%CI includes 0.0).

Discussion

The current study was the first to examine the unique roles of working memory and organizational skills, as well as the combined role of working memory via organizational skills, for understanding ADHD-related academic difficulties. Specifically, we examined the extent to which these two factors account for the difference in academic achievement between our ADHD and Non-ADHD groups on standardized measures (i.e., ADHD-related academic underachievement), as well as ADHD-related academic performance difficulties in the classroom. The findings suggest unique contributions of both working memory and organizational skills, as well as a shared contribution of working memory via organizational skills, that collectively account for a substantial proportion of ADHD-related academic achievement and performance difficulties as described below.

Working Memory and Academic Functioning

As expected, working memory was a unique predictor of both ADHD-related academic achievement and performance. This is consistent with prior literature suggesting that working memory is a strong and functional, if not causal, predictor of academic achievement and performance for children with ADHD (Kofler et al., 2018; Miller et al., 2012; Singh et al., 2022) and accounts for 42–60% of ADHD-related reading and math underachievement (Friedman et al., 2017; 2018). The current study builds on this prior work via the use of latent working memory and academic achievement estimates. To that end, results from the current study indicate that working memory difficulties – both uniquely and via the impact of working memory on organizational skills performance (Kofler et al., 2017) – may fully account (100%) for academic underachievement and substantially account (71%) for day-to-day academic underperformance in ADHD. These findings highlight working memory as a critical target for promoting academic functioning for children with ADHD, particularly in light of evidence that newer, more focused working memory interventions for children with ADHD may have downstream effects on academic functioning (Singh et al., 2022),

Organizational Skills and Academic Functioning

Organizational skills also uniquely accounted for both domains of ADHD-related academic difficulties. The unique role of organizational skills for predicting ADHD-related academic *performance* was consistent with extensive evidence suggesting that organizational skills play a role in children's implementation of academic skills, assignment completion, and overall success in the academic setting (Langberg, Molina et al., 2011; Langberg, Epstein et al., 2011), and findings that organizational skills training for children with ADHD have downstream effects on academic performance in the classroom (Bikic et al., 2017). In contrast, the finding that organizational skills uniquely predict academic *achievement* was more surprising given prior evidence that organizational skills training does not consistently improve academic achievement when using standardized outcome measures (DuPaul et al., 2021). Importantly, unlike these prior studies, the current results examined the cross-sectional association between these constructs and may not reflect a strictly causal or unidirectional target for intervention. Alternatively, the current study's sample size (N=309) may have been better powered to detect true effects relative to prior work, and the smaller magnitude relation between organizational skills and academic achievement (if causal) may indicate that organizational skills interventions may need to increase potency (e.g., longer intervention periods, supplementary components) to produce statistically detectable improvements in achievement. Finally, the null effects of organizational skills interventions on academic achievement in prior studies may be an artifact of those studies using standard scores from achievement tests that are not sensitive to change – particularly for children with ADHD who tend to fall further behind their peers over time (e.g., Farmer et al., 2020; Singh et al., 2022).

Unique Versus Shared Predictors of ADHD-related Academic Functioning

In addition to the unique effects of working memory and organizational skills, the current results further suggest a shared contribution of working memory and organizational skills. Inspection of the single vs. serial path models (i.e., without vs. with organizational skills in the model) suggests that the joint working memory/organizational skills pathway reflects a small portion of the total effect of working memory on *achievement* (working memory's ab_1 pathway reduced from $\beta=-.45$ to $-.41$ when organizational skills were added, with a small unique role of organizational skills of β=−.05; Figures 1, 3), relative to a larger portion of the total effect of working memory on academic *performance* (ab_1 pathway reduced from β=−.25 to −.12, with a larger unique role of organizational skills of β=−.14; Figures 2, 4). Combined with the longitudinal, experimental, and RCT evidence reviewed above, these findings are consistent with conceptual models suggesting that underdeveloped working memory may lead, in large part, to organizational skills deficits that in turn have additional downstream academic consequences for children with ADHD (e.g., Abikoff et al., 2013; Kofler et al., 2017).

Interestingly, there was evidence for a suppression-like effect in the serial academic achievement outcome model, such that after accounting for working memory and organization skills difficulties, the negative relation between ADHD and academic achievement became significant in the positive direction. This likely occurred because working memory and organizational skills are stronger predictors relative to ADHD status for understanding academic underachievement. At the same time, this pattern may indicate children with ADHD have the potential to demonstrate somewhat *higher* achievement than their peers, if not for the interfering effects of their well-documented working memory and organizational difficulties (Kasper et al., 2012; Langberg et al., 2008). Stated differently, these findings may be inconsistent with conceptual models suggesting that ADHD is a disorder of low effort/low motivation, and instead consistent with models acknowledging that underlying neurocognitive deficits may require children with ADHD to work *harder* than their peers to achieve the same result (e.g., Kofler et al., 2016; Sarver et al., 2015). This hypothesis is of course speculative, but is generally consistent with strength-based work identifying resilient children with ADHD (e.g., Chan et al., 2022).

Limitations and Future Directions

The current results should be interpreted with consideration to the following limitations. First, given that comorbidity is the rule rather than the exception in ADHD, inclusion of clinically evaluated children with and without ADHD allowed stronger and more generalizable conclusions about ADHD-specific academic difficulties because the groups are matched on the proportions of these co-occurring conditions. However, this sample selection may limit the specificity of conclusions for children with "pure" ADHD and neurotypical children specifically. Replication of these results for children without comorbid diagnoses may improve specificity and inform differences across clinical and nonclinical populations. In addition, even though the results were robust to control for age (and sex/SES), longitudinal research that also includes older and younger children is needed given the development of working memory and the increased importance of organizational skills as workloads and personal responsibility increase (Langberg, Molina et al., 2011). Similarly, despite robust associations between working memory and academic achievement/performance, these relations may be underestimates given that a subset of children with ADHD were prescribed psychostimulant medication, which was withheld prior to working memory testing but not academic achievement testing. Next, although the models accounted for a substantial 49–71% of individual differences in children's academic functioning (and 71–100% of ADHD-specific academic underachievement/performance), we did not examine other neurocognitive or behavioral processes that may provide alternative accounts for ADHD-related academic difficulties (DuPaul et al., 2009). For example, additional neurocognitive, cognitive, and behavioral processes have been linked with academic outcomes, including inhibitory control, processing speed, short-term memory, intelligence, attention problems, and academic anxiety (Alfonso & Lonigan, 2021; Kofler et al., 2019; Spiegel et al., 2021). Interestingly, experimental and longitudinal evidence suggests that many of these abilities appear affected by working memory as well (e.g., Fosco & Hawk, 2017; Kofler et al., 2010; Tourva et al., 2016). Future research is needed to elucidate the most parsimonious set of mechanisms and processes that explain this critical area of impairment for children with ADHD. Similarly, given our interest in overall academics, we created a latent model to examine factors that contribute to variance common across standardized math and reading tests. The current findings do not rule out the potential for domain-specific relations with math or reading, and examination of these relations is an important direction for future research. In addition, despite separate sources of experimental and longitudinal evidence suggesting functional if not causal links between working memory and academic achievement, working memory and organizational skills, and organizational skills and academic achievement in child and adolescent ADHD, future studies are needed to clarify the directionality and interplay between all three of these constructs over time. Finally, the slight discrepancy between parent and teacher models is consistent with prior research suggesting different associations between working memory and organizational skills across informants (Kofler et al., 2018) and may reflect differences in informant characteristics or perceptions, as well as contextual factors that influence behavior (De Los Reyes & Kazdin, 2005). Nonetheless, future studies may examine the extent to which organizational skills at home and school are related to working memory deficits and differentially predict academic functioning in ADHD.

Conclusions and practitioner implications

Academic functioning is a critical area of functional impairment for children with ADHD (Loe & Feldman, 2007). Overall, we found that working memory, organizational skills, and shared variance across working memory and organizational skills each independently predict between-group differences in academic achievement and academic performance for children with and without ADHD. Our findings are consistent with prior evidence that academic difficulties unique to ADHD are primarily attributable to underlying working memory difficulties (e.g., Friedman et al., 2017; 2018) and/or organizational skills difficulties (e.g., Langberg, Epstein et al., 2011), particularly in the classroom setting. Given that each of these factors played a unique role in predicting academic difficulties, interventions designed to target working memory (Singh et al., 2022) and organizational skills (Bicik et al., 2017) appear to each be promising targets for improving academic functioning in children with ADHD.

Our findings also suggest that working memory difficulties may have downstream effects on organizational skills and academic functioning, supporting conceptualizations of ADHD-related functional impairment as, at least in part, behavioral manifestations of working memory deficits (Chacko et al., 2014). Consistent with conceptual models proposing that combining skills-based training with targeted neurocognitive training may produce more robust outcomes for children with ADHD (Chacko et al., 2014; Kofler et al., 2020), these findings may support future efforts to simultaneously target working memory and organizational skills to test for potential augmentative benefits on academic outcomes. Alternatively, given the relatively disappointing findings from ADHD cognitive training studies to date (e.g., Rapport et al., 2013; Sonuga-Barke et al., 2013; Dekkers & van der Oord, 2022; cf. Kofler et al., 2020), the findings may still have applied value in terms of promoting efforts to improve the specificity of academic accommodations, as well as helping families understand *why* their child is having academic difficulties, even if interventions to remediate the underlying difficulties are not currently available (Evans et al., 2021). Of course, these hypotheses are speculative because the current study was not an intervention trial – at present, the first line intervention for academic difficulties in children with ADHD remains targeted academic skills training/practice, especially given recent meta-analytic evidence that targeted reading interventions are effective for at-risk readers with ADHD (Chan et al., 2022).

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Key Points

Question:

Working memory and organizational skills are both associated with academic difficulties in ADHD, but to what extent do these factors uniquely vs. jointly contribute to ADHD-related academic functioning?

Findings:

Both working memory and organizational skills account for ADHD-related academic underachievement and underperformance, as well as a shared contribution of working memory and organizational skills.

Importance:

ADHD-related academic difficulties appear to be associated with working memory deficits independently, organizational skills deficits independently, and overlapping deficits in these domains, thus informing potential targets for cognitive and behavioral interventions.

Next Steps:

Experimental and/or longitudinal work is needed to clarify the directionality and interplay between working memory, organizational skills, and academic functioning over time.

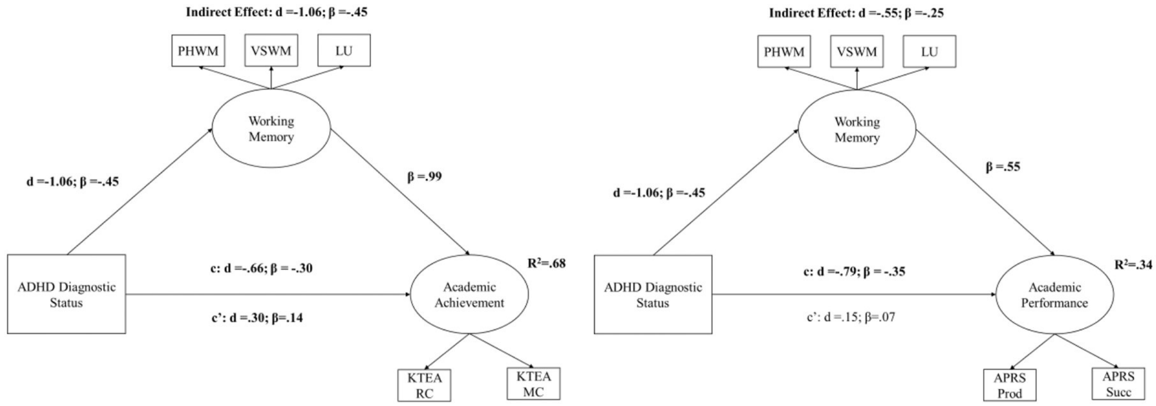

Figure 1.

Latent path analyses with working memory as the conditional effect. Bolded values reflect significant pathways (95%CIs exclude 0.0). Age, sex, and SES are controlled for but not depicted for clarity.

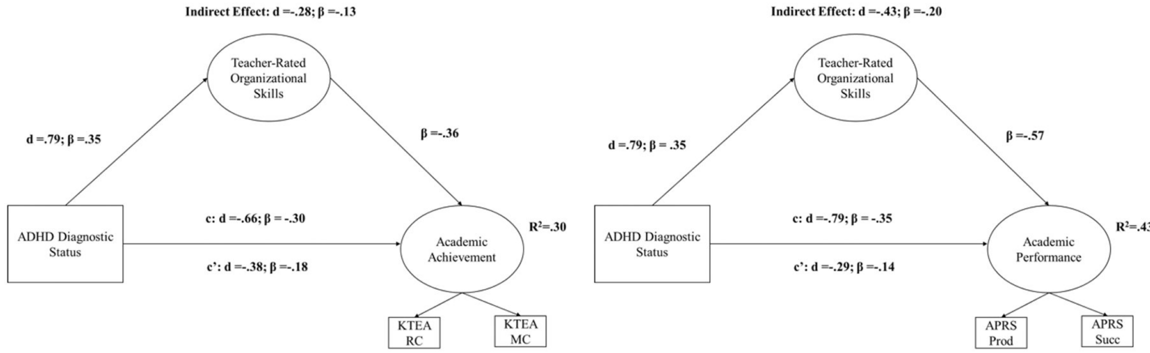

Figure 2.
Latent path analyses with organizational skills as the conditional effect. Bolded values reflect significant pathways (95%CIs exclude 0.0). Age, sex, and SES are controlled for but not depicted for clarity.

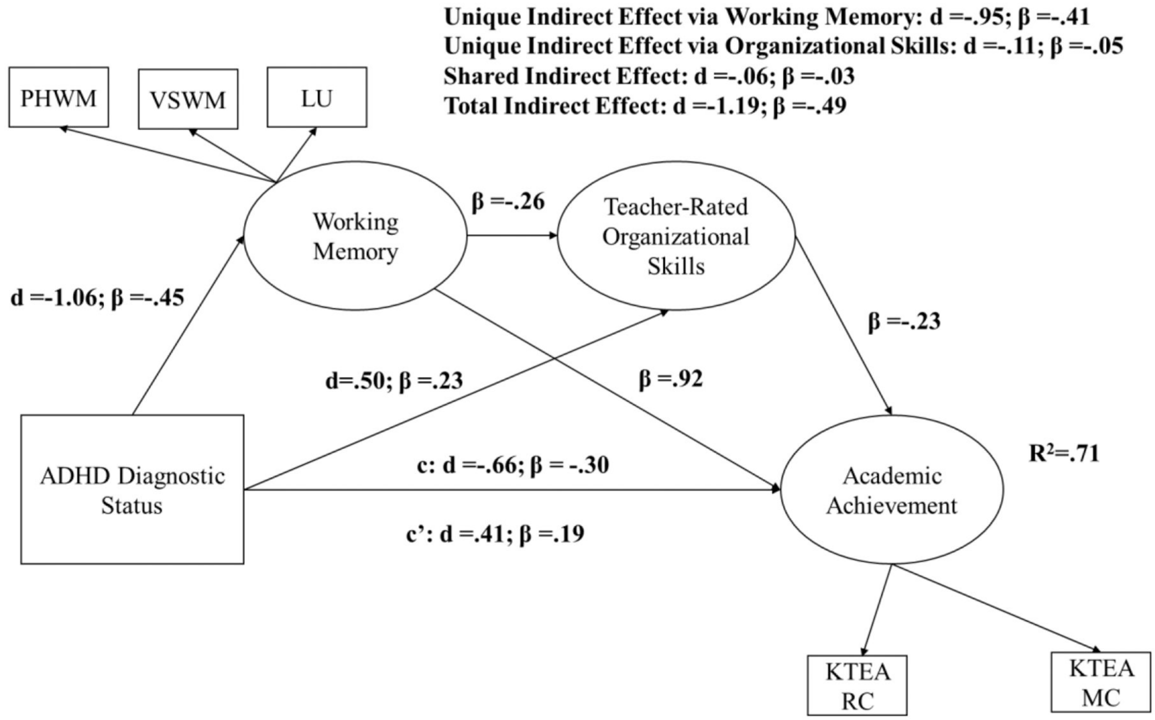

Figure 3.

Serial latent path analysis predicting academic achievement. Bolded values reflect significant pathways (95%CIs exclude 0.0). Age, sex, and SES are controlled for but not depicted for clarity.

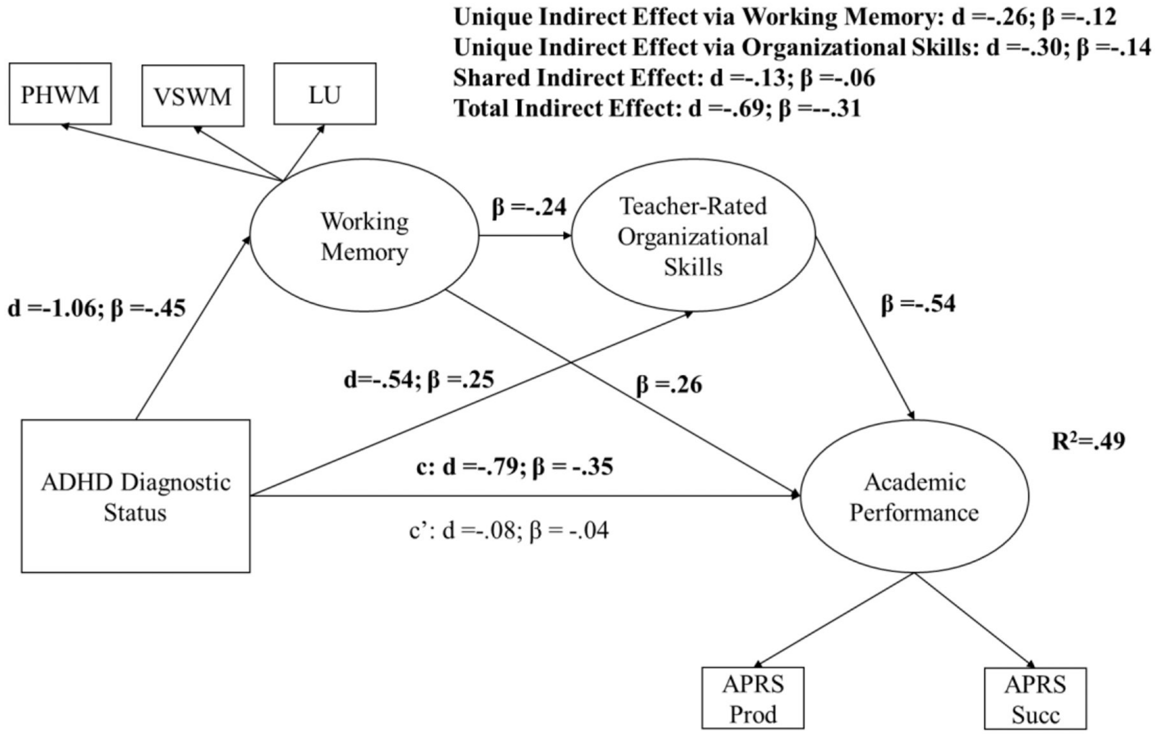

Figure 4.

Serial latent path analysis predicting academic performance. Bolded values reflect significant pathways (95%CIs exclude 0.0). Age, sex, and SES are controlled for but not depicted for clarity.

Table 1.

Sample and Demographic Variables

Variable	ADHD (N=203)		Non-ADHD (N=106)		Cohen's *d*	*p*
	M	***SD***	***M***	***SD***		
Sex (Boys/Girls)	128/75		58/48		--	.16, *ns*
Ethnicity (B/A/W/H/M)	31/0/142/12/17		9/1/73/9/14		--	.29, *ns*
Age	10.13	1.39	10.69	1.42	0.27	<.001
SES	47.61	10.20	47.80	11.75	0.02	.96, *ns*
SFIQ	101.20	14.99	105.70	12.05	−0.33	<.001
ADHD Symptoms						
BASC-3 Attention Problems						
Parent (T-score)	68.39	7.22	60.23	10.37	0.91	<.001
Teacher (T-score)	65.88	8.06	55.42	10.68	1.11	<.001
BASC-3 Hyperactivity						
Parent (T-score)	69.04	12.60	58.46	13.18	0.82	<.001
Teacher (T-score)	63.53	14.64	51.38	11.58	0.92	<.001
Organizational Skills						
COSS-T (Raw score)	93.31	18.30	78.31	22.15	0.74	<.001
COSS-P (Raw score)	161.52	24.01	142.17	31.59	0.69	<.001
Working Memory						
PHWM (Raw score)	75.02	15.20	88.06	12.21	0.95	<.001
VSWM (Raw score)	52.50	18.08	72.05	17.20	1.11	<.001
LUWM (Raw score)	20.88	7.64	25.62	6.39	0.67	<.001
Academic Achievement						
KTEA-3 Reading Composite (Standard score)	96.60	14.72	102.62	13.71	0.42	<.001
KTEA-3 Math Composite (Standard score)	93.26	13.88	102.16	14.18	0.63	<.001
Academic Performance						
APRS Productivity (Raw score)	35.83	8.45	42.65	9.33	0.77	<.001
APRS Success (Raw score)	21.03	6.40	24.37	5.88	0.54	<.001

Note KTEA-3=Kaufman Test of Educational Achievement-3rd Edition (standard scores). BASC=Behavior Assessment System for Children. Ethnicity: B=Black/African American, A=Asian, W=White Non-Hispanic, H=Hispanic/Latino, M=Multiracial. SFIQ=Short Form IQ (WISC-V), SES=Hollingshead socioeconomic status. APRS=Academic Performance Rating Scale. PHWM=Phonological working memory. VSWM=Visuospatial working memory. LUWM=Letter-updating working memory.

Table 2.

Zero-order correlations among variables

	PHWM	VSWM	LUWM	KTEA-3 MC	KTEA-3 RC	APRS AP	APRS AS	COSS-T	COSS-P	Age	Sex (F/M)	SES	ADHD (N/Y)
Phonological Working Memory	--												
Visuospatial Working Memory	.59 *	--											
Letter-Updating Working Memory	.57 *	.48 *	--										
KTEA-3 Math Composite	.50 *	.47 *	.46 *	--									
KTEA-3 Reading Composite	.39 *	.39 *	.46 *	.69 *	--								
APRS Academic Productivity	.29 *	.28 *	.29 *	.55 *	.44 *	--							
APRS Academic Success	.29 *	.29 *	.37 *	.65 *	.64 *	.81 *	--						
COSS Teacher Rated	−.23 *	−.25 *	−.17 *	−.40 *	−.29 *	−.62 *	−.44 *	--					
COSS Parent-Rated	−.13 *	−.13 *	−.09	−.19 *	−.09	−.34 *	−.21 *	.39 *	--				
Age	.41 *	.43 *	.37 *	.08	.05	.00	−.04	−.04	.11	--			
Sex (Female/Male)	.04	.05	−.02	.06	−.06	−.08	−.05	.18	.06	.04	--		
Socioeconomic Status	.17 *	.17 *	.14	.32 *	.31 *	.24 *	.30 *	−.12 *	−.07	.01	.01	--	
ADHD Status (No/Yes)	−.40 *	−.47 *	−.29 *	−.29 *	−.19 *	−.34 *	−.24 *	.36 *	.31 *	−.20 *	.08	.00	--

Note KTEA-3=Kaufman Test of Educational Achievement-3rd Edition (standard scores). APRS=Academic Performance Rating Scale. COSS=Children’s Organizational Skills Scale. Sex (Female=0, Male=1); SES=Hollingshead socioeconomic status; ADHD (No=0, Yes=1).

* $p \leq .05$,

** $p \leq .01$