

ADHD BEHAVIOR PROBLEMS AND NEAR- AND LONG-TERM SCHOLASTIC
ACHIEVEMENT: DIFFERENTIAL MEDIATING EFFECTS OF VERBAL AND
VISUOSPATIAL MEMORY

by

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ABSTRACT

The current study examined verbal and visuospatial memory abilities as potential mediators of the relationship among ADHD behavior problems and near- and long-term scholastic achievement. Scholastic achievement was measured initially and at 4-year follow-up in an ethnically diverse sample of children ($N = 325$). Nested composite (reading, math, language) and domain-specific reading structural equation models revealed that ADHD behavior problems exerted a negative influence on scholastic achievement measures, both initially and at follow-up. Much of this influence, however, was mediated by verbal memory's contribution to near-term achievement, whereas visuospatial memory contributed more robustly to long-term achievement. For the domain-specific math achievement model, the collective influence of verbal and visuospatial memory fully mediated the direct influence of ADHD behavior problems on near-term math achievement, and visuospatial memory alone contributed to both near- and long-term achievement. In all models, measured intelligence made no contribution to later achievement beyond its initial influence on early achievement. The results contribute to the understanding of the developmental trajectory of scholastic achievement, and have potential implications for developing remedial programs targeting verbal and visual memory deficits in children with ADHD behavior problems.

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LIST OF ACRONYMS

ADHD	Attention-Deficit/Hyperactivity Disorder
BL	Block
CBCL	Child Behavior Checklist
CFI	Confirmatory Fit Index
CLC	Children's Learning Clinic
FSIQ	Full Scale Intelligence Quotient
GFI	Goodness of Fit Index
K-BIT	Kaufman Brief Intelligence Test
K-SADS	Kiddie Schedule for Affective Disorders and Schizophrenia for School-Aged Children
K-TEA	Kaufman Test of Educational Achievement
LTA	Long-term Achievement
MUFT	Matching Unfamiliar Figures Test
NNFI	Non-normed Fit Index
NTA	Near-term Achievement
PAL-T	Paired Associates Learning Test
RMSEA	Root Mean Squared Error of Approximation
SAT	Stanford Achievement Test
SES	Socioeconomic Status
SEM	Structural Equation Model
TRF	Teacher Report Form
VM	Verbal Memory

VS	Visuospatial
VSM	Visuospatial Memory
WISC	Wechsler Intelligence Scale for Children
WM	Working Memory

CHAPTER 1: INTRODUCTION

Attention-deficit/hyperactivity disorder (ADHD) has been of foremost concern to educators, clinicians, and researchers due to its near-, intermediate-, and long-term adverse academic consequences. Near-term difficulties include fewer completed assignments (DuPaul, Rapport, & Perriello, 1991), lower grade point averages, more failing grades, and higher grade retention rates (for reviews, see Barkley, 2006; Frazier, Youngstrom, Glutting, & Watkins, 2007a). Children with ADHD also score lower on standardized achievement tests relative to their typically developing peers ($d = 0.71$; Frazier et al., 2007a), and between 7% to 44% and 15% to 60% meet criteria for reading and math disabilities, respectively (Faraone et al., 1993; Frick et al., 1991; Mayes & Calhoun, 2006; Shaywitz, Shaywitz, Fletcher, & Escobar, 1990; Willcutt & Pennington, 2000).

The intermediate and long-term academic consequences for children with ADHD are similarly disabling. ADHD symptoms at age eight correlate negatively with teacher-rated achievement at 18-month follow-up (Diamantopoulou, Rydell, Thorell, & Bohlin, 2007), and findings gleaned from 13- and 17-year longitudinal studies reveal that 23-32% of children with ADHD fail to complete high school. In addition, significantly fewer enter (22% vs. 77%) and complete college (5% vs. 35%) compared to their typically developing peers (Barkley, Fischer, Smallish, & Fletcher, 2006; Mannuzza, Klein, Bessler, Malloy, & Hynes, 1997; Mannuzza, Klein, Bessler, Malloy, & LaPadula, 1993). In adulthood, ADHD-related academic failure is associated with functional impairment as reflected in lower socioeconomic status, poor job performance, and unstable employment (Barkley et al., 2006; Mannuzza et al., 1993). These adverse academic and occupational outcomes appear to be independent of comorbid conduct problems (Fergusson & Horwood, 1995; Fergusson, Lynskey, & Horwood, 1997; Frick et al.,

1991; Hinshaw, 1992), and are mediated by both behavioral and cognitive factors (Rapport, Scanlan, & Denney, 1999).

Extant studies examining the potential behavioral and cognitive processes underlying near-term academic achievement deficits in ADHD reveal mixed and often equivocal results. For example, executive functioning deficits (Beiderman et al., 2004), inattentive and hyperactive behavior severity (Barry, Lyman, & Klinger, 2002), and deficient academic enabling behaviors (DuPaul et al., 2004) have been linked to academic underachievement, but the interrelationships among these variables differ across studies. Specifically, Thorell (2007) found that executive functioning deficits partially mediated the relationship between ADHD symptoms and early math and language functioning, whereas Barry and colleagues (2002) reported that executive functioning failed to predict underachievement after controlling for ADHD symptoms. Other studies, however, have found that deficient academic enabling behaviors (e.g., study skills, task engagement), rather than ADHD-related inattentiveness, are better predictors of underachievement for these children (DuPaul et al., 2004).

Longitudinal investigations reveal a more consistent pattern of results. Individual differences in attention, memory, and classroom behavior fully attenuate the direct effects of attention deficits on long-term scholastic underachievement, even after controlling for IQ and socioeconomic status. Specifically, Rapport and colleagues (1999) found that verbal memory was the strongest predictor of long-term scholastic achievement, but failed to examine the potential mediating effects of near-term achievement and visuospatial abilities on long-term achievement. The importance of controlling for the effects of near-term achievement is highlighted by a recent study involving typically developing children. In that study, neither working memory nor IQ predicted long-term academic outcomes after accounting for the impact

of working memory on near-term academic achievement (Alloway & Alloway, 2010). Whether this mediation model can adequately explain the relationship between attention and long-term scholastic achievement remains unknown, although current evidence indicates that early inattention partially influences later achievement through its direct effects on early academic development (Rabiner & Coie, 2000). Collectively, previous investigations have explained individual differences in long-term scholastic achievement as a function of early attention, memory, or achievement, but no study to date has concurrently investigated the explanatory power of these factors for predicting the longitudinal scholastic outcomes associated with attention problems.

The potential differential mediating influence of verbal and visuospatial memory must also be considered in models examining the continuity between ADHD behavior problems and scholastic underachievement. Verbal and visuospatial memory deficiencies are identified frequently in children with attention problems (Brocki, Randall, Bohlin, & Kerns, 2008; Cornoldi et al., 2002; Martinussen, Hayden, Hogg-Johnson, & Tannock, 2005; Rapport et al., 2008; Willcutt, Doyle, Nigg, Faraone, & Pennington, 2005), and are integrally involved in the development and acquisition of academic skills (Gathercole, Pickering, Knight, & Stegmann, 2004). For example, verbal working memory capacity predicts reading comprehension (Cain, Oakhill, & Bryant, 2004; Sesma, Mahone, Levine, Eason, & Cutting, 2009), paired associate learning predicts word recognition skills (Hulme, Goetz, Gooch, Adams, & Snowling, 2007), and verbal short-term memory is associated with reading and math performance (Durand, Hulme, Larkin, & Snowling, 2005; Gathercole, Alloway, Willis, & Adams, 2006; Hulme et al., 2007; Swanson & Kim, 2007) in typically developing children. In addition, visuospatial abilities are associated with visual reasoning (Kane et al., 2004) and speech production (van Daal,

Verhoeven, van Leeuwec, & van Balkom, al., 2008), and are related more closely to mathematical performance than are verbal abilities. This latter finding is illustrated in recent studies demonstrating that visuospatial problem solving (Fuchs et al., 2006) and visual processing speed (Bull & Johnston, 1997; Geary, Hoard, Byrd-Craven, Nugent, & Numtee, 2007; Hecht, Torgesen, Wagner, & Rashotte, 2001) are robust predictors of children's mathematical competence, and that visuospatial processing discriminates between children with and without mathematical disabilities (Hanich, Jordan, Kaplan, & Dick, 2001; Jordan, Hanich & Kaplan, 2003; Swanson & Jerman, 2006).

The present study uses a series of nested structural equation models to test empirically three potential hypotheses that may explain interrelationships among attention deficits, verbal/visuospatial memory abilities, and near- and long-term academic achievement using a cross-sectional sample of children. The models were tested initially using a composite index of achievement consisting of reading, mathematics and language measures. Domain-specific models (reading, math) were examined subsequently based on past findings demonstrating distinct contributions of verbal and visuospatial abilities to specific academic domains. An initial model (Figure 1-a) was created to test the hypothesis that the continuity between attention problems and long-term achievement is mediated by near-term achievement (Rabiner & Coie, 2000). A second model (Figure 1-b) was constructed to test the hypothesis that verbal and visuospatial memory abilities mediate the relationship between attention problems and long-term achievement through their influence on near-term achievement (Alloway & Alloway, 2010). No specific hypotheses were offered concerning the potential mediating effects of these pathways on the relationship between attention problems and near-term achievement due to the previously reviewed contradictory findings (Barry et al., 2002; Thorell, 2007). A third model (Figure 1-c)

tested the hypothesis that verbal and visuospatial memory would contribute directly to long-term academic achievement (Rapport et al., 1999), even after accounting for their impact on near-term achievement. Finally, the verbal/visuospatial memory-achievement relationships were hypothesized to be moderately stronger for domain-specific models (i.e., verbal with reading, visuospatial with math) relative to composite achievement models based on extant literature (Gathercole et al., 2004).

CHAPTER 2: METHODOLOGY

Participants

The sample consisted of 325 children (146 males, 179 females) between 7 and 16 years of age ($M = 10.67$, $SD = 2.39$) attending public and private schools in Honolulu (Oahu), Hawaii. Approximately 72% of the state's population resides in the city and county of Honolulu (U.S. Bureau of the Census, 1990). Schools were selected based on available data suggesting that their ethnic and sociodemographic composition was a close approximation of children residing in Hawaii (State of Hawaii Data Book, 1996).

The public school is a research arm associated with the University of Hawaii whose primary mission is to develop and test curricula suitable for children of differing abilities and sociodemographic backgrounds. Children are admitted to the school based on ethnicity, gender, parental socioeconomic and marital status, residence location, and academic achievement to approximate the State's census.

A private school was selected for participation to obtain a sample reflecting the relatively large number of children (i.e., 19%) attending private schools in the state (State of Hawaii Data Book, 1996). The school admits students from throughout the state, although the majority of children reside in the urban Honolulu area.

An informal letter, consent form, and demographic information form were mailed to parents of children attending both schools. The letter provided a basic description of the research project. The latter two forms were used to obtain written consent for children's participation and sociodemographic information (Duncan, 1961) concerning family members, respectively. Parental consent was obtained for all children in the study, reflecting response rates of 100% and 54% for the university-affiliated public school (participation in approved research studies is a

required condition of admission) and private school, respectively. The ethnic composition of the sample was as follows: East Asian (35%), Part-Hawaiian (25%), Caucasian (9%), Southeast Asian (3%), Pacific Islander (1%) and Mixed (27%). Participants were labeled as “Part-Hawaiian” if any ethnicities within their ethnic background included Hawaiian. Participants were labeled “Mixed” if the ethnicities within their ethnic background could not be categorized by a single ethnic category. Institutional Review Board approval for the study was granted prior to data collection.

Measures

Attention.

The Child Behavior Checklist (CBCL) Teacher Report Form (TRF) is a standardized teacher rating scale that includes eight clinical syndrome scales, as well as composite indices of externalizing and internalizing broad-band syndromes, adaptive functioning, and academic performance. The psychometric properties of the CBCL-TRF are well-established and detailed by Achenbach (1991). A manifest variable termed “ADHD” was used in the models and derived from the attention problems scale. Past research indicates strong convergence between CBCL attention problem scale scores and a diagnosis of ADHD (Biederman et al., 1993; Hudziak, Copeland, Stanger, & Wadsworth, 2004).

ADHD is viewed intentionally as a continuous dimension of behavior problems in accordance with the normative-developmental view of child psychopathology (Achenbach, 1990). In addition, evidence from genetic (Gjone, Stevenson & Sundet, 1996; Levy, Hay, McStephen, Wood, & Waldman, 1997) and latent profile analyses (Frazier, Youngstrom, & Naugle, 2007b), as well as previous pathway models of childhood disorders (e.g., Fergusson & Horwood, 1995;

Fergusson, et al., 1997) provide persuasive empirical arguments favoring a scalar view of attention problems. The moniker ADHD used throughout this study thus refers to behaviors characteristic of children with ADHD as defined by the CBCL-TRF clinical syndrome scale. Raw scores (versus T-scores) were used in the analyses as recommended by Achenbach (1991) to account for the full range of variations in CBCL-TRF syndrome scale scores.

Near term scholastic achievement

The Kaufman Test of Educational Achievement Brief Form (KTEA) is a standardized, individually administered battery that measures children's mathematics, reading, and spelling achievement. Its psychometric properties and expected patterns of relationships with other measures of educational achievement are well established (Sattler, 2001). Subtest scores combine to yield a composite achievement score. A latent variable representing early scholastic achievement corrected for measurement error was derived using the KTEA composite score (termed Near-term Achievement) and fixing its error term based on published test-retest reliability (Kaufman & Kaufman, 1998) as recommended by Kline (2005). For academic domain-specific models, latent variables representing early mathematics and reading achievement corrected for measurement error were derived using the separate mathematics and reading subtest score and fixing its error term based on its published test-retest reliability coefficient.

Long-term scholastic achievement

The Stanford Achievement Test (SAT; 1996) is a national, group-administered test for 3rd to 12th grade children that is used to assess long-term scholastic achievement across multiple

domains and for purposes of college entry. The SAT is often used as a measure of scholastic achievement in studies examining the relationships between children's cognitive performance and scholastic functioning (e.g., Buckhalt, El-Sheikh, Keller, & Kelly, 2009). A latent variable termed Long-term Achievement was used in the models and derived from total reading, total math, and total language scale scores. For models examining academic domain-specific relations, the reading and mathematics subscales scores were used separately. Scale scores represent approximately equal units on a continuous scale, using numbers that range from 1 through 999, and are suitable for studying change in performance over time. SAT scores were collected between 3 and 4 years after children were initially tested at the clinic¹.

Verbal memory

Paired Associate Learning Tasks (PAL-T) are related to classroom learning (Baddeley, Papagno & Vallar, 1988; Stevenson, 1972) and academic achievement (Gathercole, Hitch, Service, & Martin, 1997). The task was selected because it places heavy demands on phonological storage and rehearsal, particularly when the paired associations involve learning arbitrary relationships (Baddeley et al., 1988; Douglas & Benezra, 1990; Douglas & Peters, 1979).

Children are required to identify letters of the alphabet and digits 0 through 9 to ensure letter and number recognition ability, respectively, prior to participating in a brief practice session. The task requires children to learn arbitrary associations between letter bigrams (e.g., "GJ") and a single numerical digit (e.g., "3") in six blocks of five bigram-digit pairs. Bigram-digit stimuli are

¹ The difference in time frame for collecting SAT data is related to when subsequent testing was conducted by schools, viz., 3rd, 6th, 9th, 11th, and 12th grades).

pre-programmed in a library file and presented on a color monitor. A single bigram is presented in the middle of the computer screen with its associate digit below. To ensure orientation and facilitate learning, children are required to use a track ball device to place the arrow on the digit and click it. Following presentation of five bigram-digit pairs to be learned, a test phase ensues and requires children to correctly identify (using the track ball device) the digit (digits 0 through 9 are shown at the bottom of the screen) that was previously associated with the bigram. Incorrect responses during the test phase are followed by a computer tone and corrective feedback. Bigram-digit pairs are assessed three times in random order during the test phase. Following the test phase, a new block consisting of five bigram-digit associations is presented then tested for recall. The procedure continues until all six blocks of paired associations are presented, and assessed for recall.

A higher order latent variable termed Verbal Memory was used in the models and derived by averaging the number of correct responses separately for the three, two-block combinations (i.e., blocks 1 and 2, 3 and 4, 5 and 6, respectively).

Visuospatial memory.

Visuospatial memory was assessed using the Matching Unfamiliar Figures Task (MUFT). The MUFT is a visual match-to-sample paradigm employing complex geometric visual and spatial designs and arrangements. Children are shown an abstract visual stimulus (target stimulus) surrounded by eight (10 cm²) figures (i.e., seven nearly identical foils and one identical stimulus) and instructed to locate the one exact matching stimulus from the stimulus field (see Figure 2). At the beginning of each trial, children use a track ball device and position the icon (a small plane) inside the red box in the center of the screen to ensure orientation to the target

stimuli. A single click anywhere within the center box illuminates the target stimulus and eight surrounding stimuli. The target stimulus is programmed to disappear after 10s or after the child makes an incorrect response, but can be re-illuminated by clicking the center stimulus box. An auditory tone is emitted following a correct response. A distinctly different tone follows incorrect responses. Children continue with the task until they successfully solve each of the 20 visuospatial trials.

Total MUFT errors across the 20 trials served as the dependent variable for assessing short-term visuospatial memory ability. These values were reversed-scored to maintain numerical valence continuity across cognitive and academic variables. A latent variable termed *Visuospatial Memory* was used in the models and derived by dividing the task into three indicator blocks (7, 7, and 6 trials, respectively) and separately averaging the reverse-scored number of errors for each block.

Intelligence

The Kaufman Brief Intelligence Test (K-BIT) consists of two subtests –Vocabulary and Matrices – that assess domains parallel to the crystallized-fluid (Horn, 1998) and verbal-performance (Wechsler, 1991) intellectual dichotomies. The two subtests can be combined to yield a composite IQ score. The psychometric properties of the K-BIT and expected patterns of relationships with other measures of intelligence are well established and detailed by Kaufman and Kaufman (1990). A manifest variable was created using the composite IQ score residualized for both verbal and visuospatial memory performance owing to the overlap between verbal and visuospatial ability and IQ (Engle, Tuholski, Laughlin, & Conway, 1999).

Socioeconomic factors and age.

Socioeconomic status (SES) was computed for each child's family using the Duncan Index (Duncan, 1961). SES and age were both partialled out of all variables in the model to control for their potentially confounding effects on modeled relationships. This was accomplished by residualizing variables before entry in the SEM models that were (a) significantly associated with age or SES, and (b) not previously age adjusted (see Table 1).

Procedures

Each child was evaluated once per week over a 2-week time period at a university-based child learning clinic. Children's intelligence (K-BIT), early scholastic achievement (KTEA), verbal memory abilities (PAL-T), and visuospatial memory abilities (MUFT) were assessed individually by trained graduate students for approximately 1.5 hrs during each of the two clinic visits. Ordering of testing was counterbalanced across sessions. Breaks (5-10 minutes) were scheduled between tests to minimize fatigue. Children were seated such that the computer monitor was approximately 0.5 m from the child with the center of the screen at eye level. An experimenter was present throughout all testing.

CHAPTER 3: RESULTS

The covariance matrix of study variables and standard deviations are shown in Table 1. Data from two children were excluded owing to missing MUFT scores. An additional six children were excluded after being identified as multivariate outliers based on Mahanalobis distances ($p < .001$), bringing the total N to 317. All variables were centered as recommended by Kline (2005).

A series of nested structural equation models (SEM) were constructed to examine the contribution of ADHD, intelligence, verbal and visuospatial memory, and near-term scholastic achievement to later scholastic achievement. The hypotheses in this investigation were examined by imposing a hierarchical sequence of constraints on the values of the raw path coefficients in the model and assessing the impact of these constraints on model fit. Models were fitted to the covariance matrix using AMOS version 18.0 with maximum-likelihood estimation (Arbuckle, 2009). The disturbance terms of the verbal and visuospatial memory latent variables were allowed to correlate in all models to control for expected shared method and setting variance. A chi-square difference test was used to contrast the models. This test evaluates whether increasing model complexity is justified by concurrent increases in the variance accounted for by the more complex relative to the less complex model. Overall goodness-of-fit for all models was evaluated using the following indices: Non-normed Fit Index (NNFI), the Confirmatory Fit Index (CFI), the Goodness of Fit Index (GFI), and the Root Mean Squared Error of Approximation (RMSEA). NNFI, CFI and GFI values $\geq .90$ and $.95$ are indicative of adequate and good fit, respectively; RMSEA values $\leq .08$ and $.05$ are indicative of adequate and good fit, respectively (Schweizer, 2010).

The measurement component of the models describes the relationships among the manifest variables (e.g., Reading, Math, and Language) and their respective latent constructs (e.g., Long-

term Scholastic Achievement). The factor loading of an indicator variable represents its correlation with the construct it is presumed to measure. The psychometric reliability of the indicator is equal to the proportion of its variance explained by the underlying construct. Thus, an indicator's reliability is determined by squaring its factor loading. The proportion of its variance that is unexplained (i.e., unique) is the complement of this value (i.e., 1 minus squared loading) and is displayed by the value labeled "E" in Figures 3-5.

The measurement component of the model showed good internal consistency. The squared loadings for reading, math, and language SAT composite scores were .81, .75, and .75, respectively. Verbal (Paired Associates Learning blocks 1&2, 3&4, 5&6) and visuospatial (blocks 1, 2, & 3) indicator loadings showed a similar pattern of internal consistency (ranges = .67 to .79 and .70 to .79, respectively).

Composite Achievement

Model 1

The initial model established the relationship among ADHD, IQ, and near- and long-term scholastic achievement. The model (Figure 3-a) is based on the premise that later scholastic achievement is a function of the early influence of ADHD and IQ – but not verbal and visuospatial memory – and that near-term scholastic achievement mediates these relationships (Rabiner & Coie, 2000). The model was estimated by allowing all hypothesized pathways between variables to be freely estimated with the exception of those involving verbal and visuospatial memory, which were constrained to equal zero due to their hypothesized non-

contributory influence in the model².

Inspection of the pathways revealed significant relationships between ADHD and near- ($\beta = -.18, p < .001$) and long-term ($\beta = -.26, p < .001$) scholastic achievement after accounting for its negative association with intelligence ($r = -.20, p < .001$). Intelligence showed a strong association with near-term ($\beta = .64, p < .001$) but not long-term scholastic achievement ($p = .19$) after accounting for its shared variance with ADHD. Finally, near-term scholastic achievement showed moderately strong continuity ($\beta = .46, p < .001$) with long-term academic achievement after accounting for IQ and ADHD. The disturbance terms (D) can be squared and subtracted from 1 (i.e., $1-D^2$) to determine the percentage of variance accounted for in near- (i.e., 48%) and long-term (i.e., 30%) scholastic outcomes. The fit indices, however, were slightly below recommended values (CFI = .88, NNFI = .84, GFI = .89, RMSEA = .12; 90% confidence interval .10 to .13).

Model 2.

The expanded model tested the plausibility that verbal and visuospatial memory mediate the relationship between ADHD and long-term scholastic achievement through their impact on near-term achievement (Alloway & Alloway, 2010). The model also tested whether these variables mediate the direct relationship of ADHD on near-term scholastic achievement by evaluating the degree to which the strength of this relationship was attenuated relative to Model 1. The model was estimated by constraining the two paths between verbal and visuospatial memory and long-

² This model was recomputed by deleting the verbal and visuospatial memory variables to match the schematic shown in Figure 1-a. All parameters and R^2 values were identical to those reported for Model 1. In addition, model fit was determined to be similar based on comparison of fit indices. Verbal and visuospatial memory were thus included in all models to enable nested model comparisons (Kline, 2005).

term scholastic achievement to zero, and allowing all other pathways between variables to be estimated freely (Figure 3-b).

The chi-square difference test between Models 1 and 2 revealed that allowing verbal and visuospatial memory to mediate near-term achievement significantly improved model fit ($\Delta\chi^2(4) = 60.07, p < .001$). Overall model fit was determined to be marginally acceptable based on fit indices slightly above (CFI = .91, GFI = .91) and slightly outside established cutoff values (NNFI = .87, RMSEA = .11; 90% confidence interval .09 to .12). Inspection of model pathways revealed a significant negative relationship between ADHD and verbal ($\beta = -.30, p < .001$) and visuospatial memory ($\beta = -.16, p = .01$) after accounting for its covariation with intelligence. Intelligence, in turn, showed strong continuity with near-term ($\beta = .60, p < .001$) but not long-term scholastic achievement ($p = .18$). Verbal memory contributed to near-term scholastic achievement ($\beta = .31, p < .001$) and partly attenuated the relationship between ADHD and near-term scholastic achievement ($\Delta\beta = .07$)³. Visuospatial memory did not predict near-term achievement ($p = .55$). The magnitude of ADHD's association with long-term scholastic achievement remained significant and unchanged ($\beta = -.26, p < .001$). Finally, the continuity between near-term and long-term scholastic achievement remained virtually unchanged ($\beta = .45, p < .001$) despite the significant contribution of verbal memory to near-term scholastic achievement. Percentage of variance accounted increased somewhat (i.e., 5%) for near-term but did not change for long-term achievement relative to Model 1 (i.e., remained at 29%).

³ Partial mediation was tested in this and all subsequent models by fitting an alternate model in which the direct pathway was constrained to equal the parameter found in the previous model, with a significant degradation in model fit indicating partial mediation. For example, constraining the Model 2 ADHD-NTA pathway to -.18 (its value in Model 1) resulted in a significantly worse model fit ($\Delta\chi^2(1) = 12.00, p < .001$), indicating a significant decrease in parameter magnitude.

Model 3.

The final model tested the hypothesis that verbal and visuospatial memory mediate the relationship between ADHD and long-term scholastic achievement through their direct contributions to long-term scholastic outcomes. The model also tested whether these variables mediate the continuity between near- and long-term achievement by evaluating the magnitude of change in this relationship. The model was estimated by relieving all constraints and allowing all paths between model variables to be estimated freely (Figure 3-c).

The chi-square difference test between Models 2 and 3 revealed significantly improved model fit ($\Delta\chi^2(2) = 115.03, p < .001$). All fit indices fell at or above recommended cutoff values, indicating excellent model fit (CFI = .97, NNFI = .96, GFI = .96, RMSEA = .06; 90% confidence interval .04 to .08). Inspection of pathways revealed that visuospatial ($\beta = .54, p < .001$) but not verbal ($p = .34$) memory showed strong continuity with long-term scholastic achievement. Despite visuospatial memory's large impact on long-term achievement, the direct effect of ADHD on long-term scholastic achievement ($\beta = -.18, p < .001$) was only partially mediated ($\Delta\beta = .08$). Intelligence continued impact near-term ($\beta = .60, p < .001$) but not long-term ($p = .96$) scholastic achievement⁴. Furthermore, the magnitude of the continuity between near- and long-term achievement was partially mediated by visuospatial memory ($\Delta\beta = .07$). Percentage of variance accounted increased substantially ($\Delta R^2 = .30$) for long-term but did not change for near-term achievement relative to Model 2 as expected.

⁴ The same series of models were repeated to determine whether the nonsignificant IQ-LTA relationship was due to our use of a residualized IQ variable (see Method). The pattern of results, however, remained unchanged when overlapping variance with verbal and visuospatial memory was not removed from intelligence. All paths from IQ to long-term achievement were nonsignificant for the composite, math, and reading achievement models (all $p > .05$).

Domain-specific Achievement

A final series of structural equation models were created to evaluate whether the results reported for overall scholastic achievement vary when examining reading and math achievement separately. The models were identical to the composite achievement models with respect to the sequence of applied constraints.

Reading Achievement.

Relieving constraints within Models 2 and 3 significantly improved model fit ($p < .001$), with only Model 3 achieving all fit indices within recommended parameters (see Table 2). The results revealed a pattern of effects comparable to the final composite achievement model (i.e., Model 3) with one exception. Visuospatial memory predicted long-term reading achievement ($p < .001$) independent of the continuity between near-term and long-term reading achievement (see Figure 4).

Math achievement.

Relieving constraints within Models 2 and 3 significantly improved model fit ($p < .001$), with only Model 3 achieving all fit indices within recommended parameters (see Table 2). The results revealed a somewhat comparable pattern of relationships relative to the final composite achievement model (i.e., Model 3) with two noteworthy exceptions. Visuospatial memory was significantly related to near-term math achievement ($p < .001$), and the collective contribution of verbal and visuospatial memory fully attenuated ADHD's relationship with near-term math achievement (see Figure 5).

Table 1. Matrix of Correlations and Standard Deviations of Measures of ADHD, IQ, Verbal Memory, Visuospatial Memory, Scholastic Achievement, Age, and SES.

Measures	ADHD	Near-Term Scholastic Achievement			Long-Term Scholastic Achievement			Verbal Memory			Visuospatial Memory			Age	SES	IQ
		KTEA Composite	KTEA Math	KTEA Reading	SAT Math	SAT Reading	SAT Language	BL12	BL34	BL56	M1	M2	M3			
ADHD	--															
KTEA Composite	-.331**	--														
KTEA Math	-.232**	.831**	--													
KTEA Reading	-.295**	.797**	.497**	--												
SAT Math	-.363**	.381**	.461**	.217**	--											
SAT Reading	-.291**	.421**	.466**	.359**	.801**	--										
SAT Language	-.418**	.508**	.470**	.381**	.737**	.777**	--									
BL12	-.197**	.123*	.258**	.043	.541**	.517**	.470**	--								
BL34	-.177**	.172**	.259**	.097	.545**	.555**	.499**	.662**	--							
BL56	-.149**	.210**	.317**	.107	.581**	.622**	.511**	.632**	.722**	--						
M1	-.082	.111*	.244**	.036	.373**	.368**	.337**	.321**	.388**	.365**	--					
M2	-.145**	.101	.206**	.027	.444**	.431**	.432**	.454**	.519**	.529**	.533**	--				
M3	-.139*	.085	.222**	.032	.444**	.464**	.433**	.453**	.455**	.495**	.575**	.573**	--			
Age	.054	-.265**	-.074	-.319**	.514**	.514**	.337**	.489**	.515**	.551**	.356**	.451**	.441**	--		
SES	-.123*	.249**	.180**	.274**	.075	.114*	.121*	-.005	-.017	.031	.010	.043	.058	-.132*	--	
IQ	-.273**	.721**	.675**	.615**	.375**	.450**	.448**	.209**	.231**	.239**	.220**	.192**	.214**	-.166**	.312**	--
SD	4.810	15.035	17.429	14.005	50.517	44.435	37.676	2.755	3.114	3.474	2.950	3.798	4.556	2.377	18.451	11.927

ADHD = CBCL-TRF Attention Problems raw score; BL = Paired Associates learning for blocks 1-2, 3-4, or 5-6; M = Matching Unfamiliar Figures Test trials 1-7 (M1), 8-14 (M2), and 15-20 (M3); IQ = Kaufman Brief Intelligence Test; KTEA = Kaufman Test of Academic Achievement-Brief Form; SAT = Stanford Achievement Test; SES = socioeconomic status * p < .05 ** p < .01

Table 2. Summary of Model Fit Statistics for Scholastic Domain-Specific Models.

						RMSEA	NTA	LTA
	<i>df</i>	$\Delta \chi^2$	CFI	NNFI	GFI	(90% CI)	R^2	R^2
Reading								
SEM 1	32	--	.84	.76	.90	.12 (.11-.14)	.36	.16
SEM 2	28	41.53***	.88	.81	.93	.12 (.10-.13)	.38	.16
SEM 3	26	104.23***	.99	.97	.98	.04 (.01-.07)	.39	.45
Mathematics								
SEM 1	32	--	.84	.78	.91	.13 (.11-.14)	.35	.29
SEM 2	28	81.32***	.92	.87	.94	.10 (.08-.12)	.46	.29
SEM 3	26	65.32***	.98	.97	.97	.05 (.02-.07)	.46	.46

CFI =Confirmatory Fit Index; *df* = degrees of freedom; GFI = Goodness of Fit Index; NNFI = Bentler-Bonnett Nonnormed Fit Index; NTA = near-term scholastic achievement; LTA = long-term scholastic achievement; RMSEA = Root Mean Squared Error of Approximation; SEM = structural equation model. *** $p \leq .001$

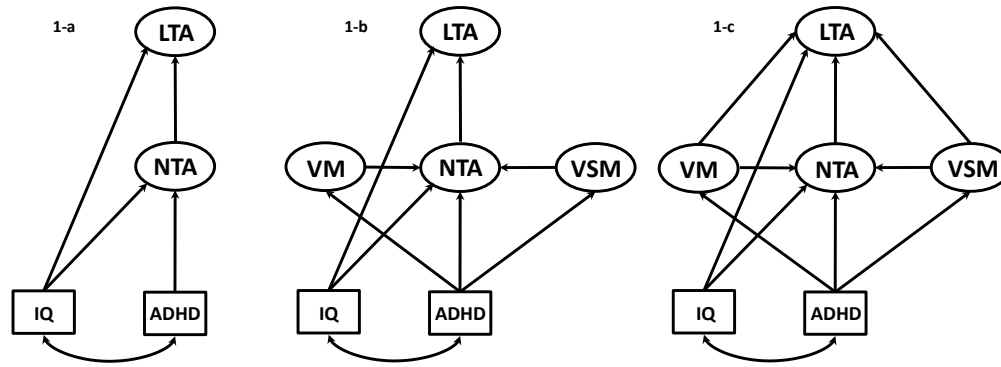


Figure 1. Hypothesized conceptual models depicting the relationships among ADHD, IQ, near- and long-term scholastic achievement: (1-a) baseline model; (1-b) verbal/visuospatial memory as mediators of near-term academic achievement; and (1-c) verbal/visuospatial memory as mediators of near- and long-term academic achievement. ADHD = attention-deficit/hyperactivity disorder; IQ = intelligence quotient; NTA = near-term achievement; LTA = long-term achievement; VM = verbal memory; VSM = visuospatial memory.

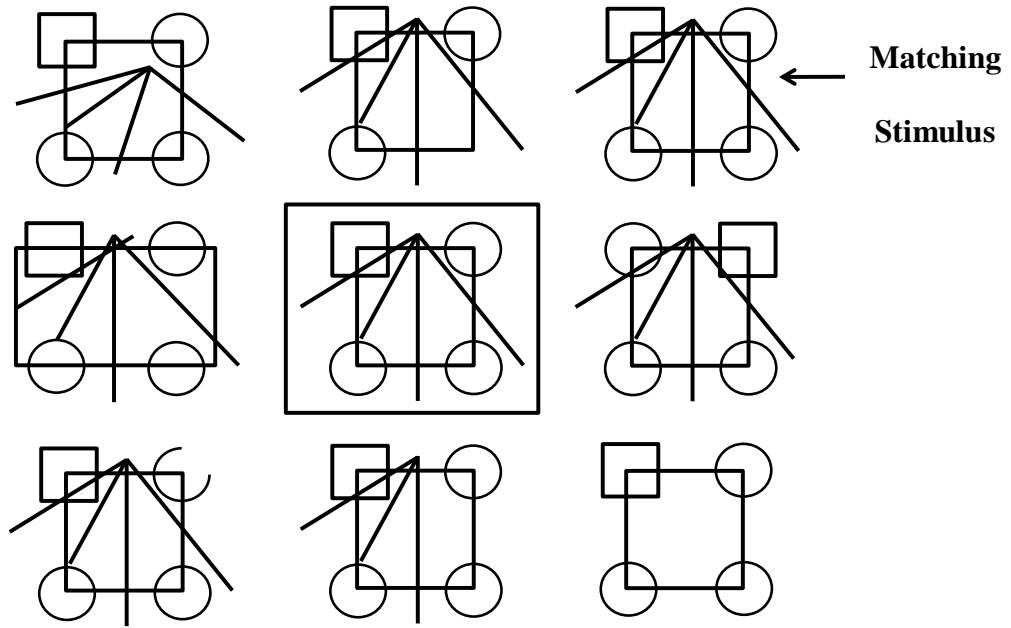


Figure 2. Visual schematic of one trial taken from the Matching Unfamiliar Figures Test

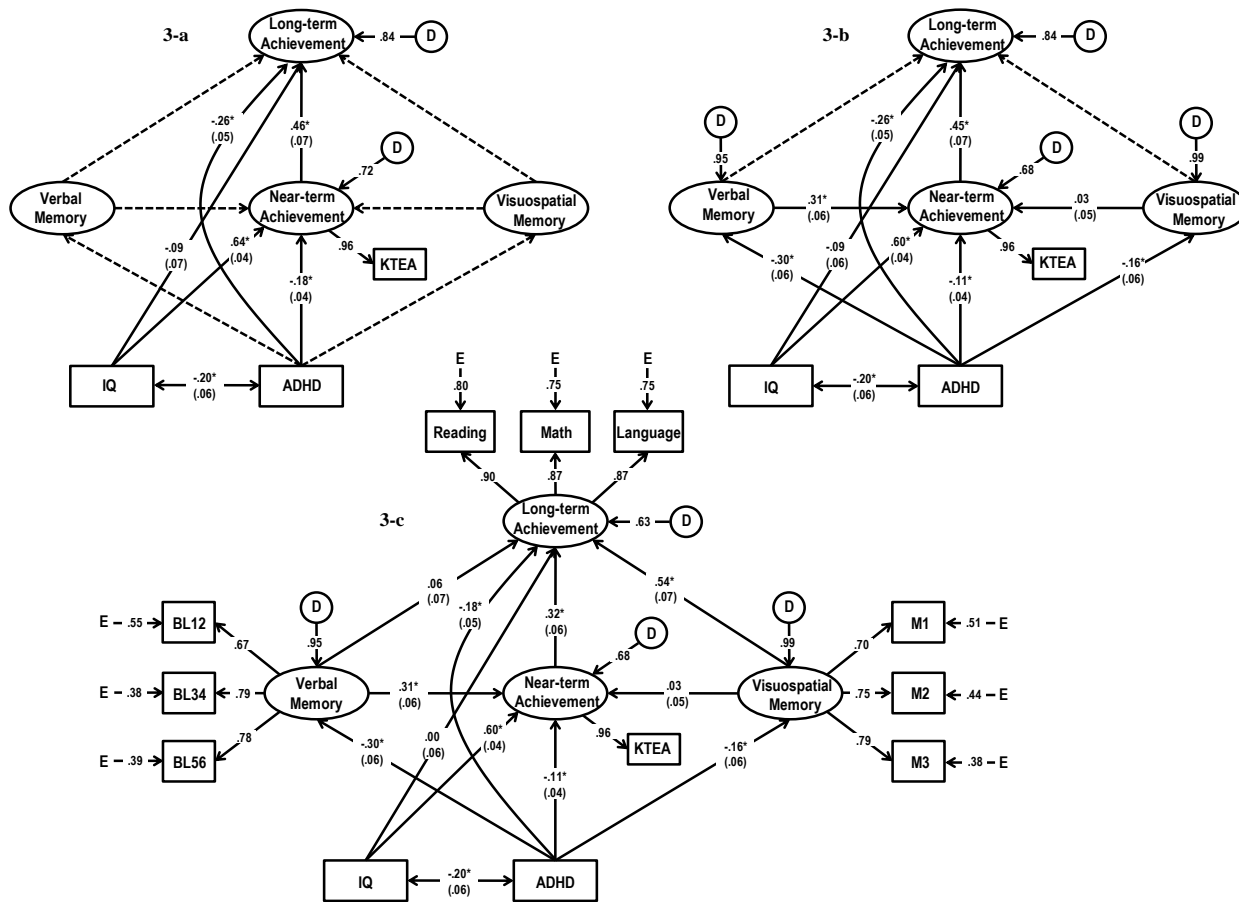


Figure 3. Structural equation models predicting composite long-term scholastic achievement. Factor loadings and error terms (E) associated with latent variables (Long-term Achievement, Verbal Memory, Visuospatial Memory) are identical for all three models, but shown only for Model 3-c for visual clarity. Values reflect standardized β coefficients (standard error in parentheses). Dashed lines represent pathways constrained to zero. BL = Paired Associates learning for blocks 1-2, 3-4, or 5-6; D = disturbance term. IQ = residualized intelligence variable with overlapping variance with memory variables removed. M = Matching Unfamiliar Figures Test trials 1-7 (M1), 8-14 (M2), and 15-20 (M3). R^2 values in text may differ slightly from the R^2 calculated using disturbance terms due to rounding. $*p < .05$

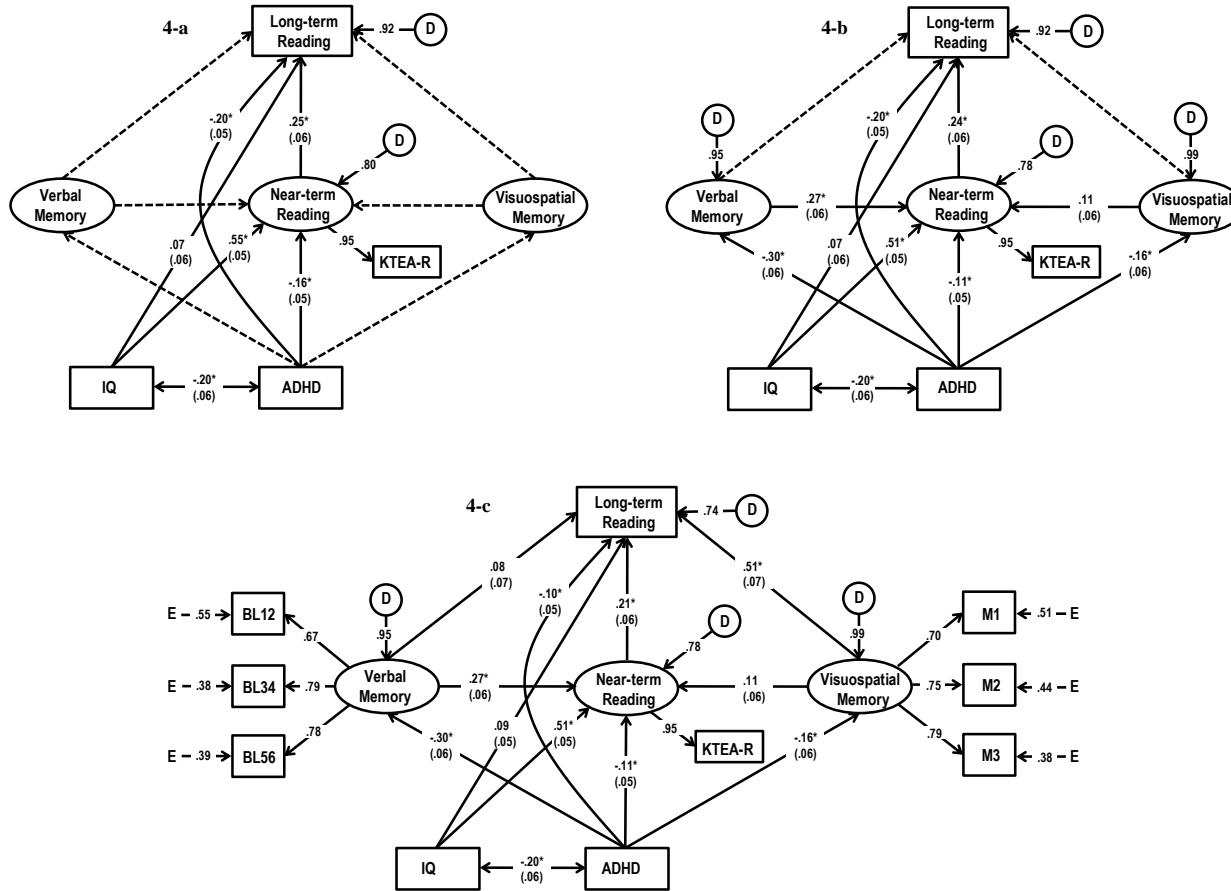


Figure 4. Structural equation models predicting long-term reading achievement. Factor loadings and error terms (E) associated with latent variables (Verbal Memory, Visuospatial Memory) are identical for all three models, but shown only for Model 4-c for visual clarity. Values reflect standardized β coefficients (standard error in parentheses). Dashed lines represent pathways constrained to zero. BL = Paired Associates learning for blocks 1-2, 3-4, or 5-6; D = disturbance term. IQ = residualized intelligence variable with overlapping variance with memory variables removed. M = Matching Unfamiliar Figures Test trials 1-7 (M1), 8-14 (M2), and 15-20 (M3). R^2 values in text may differ slightly from the R^2 calculated using disturbance terms due to rounding. * $p < .05$

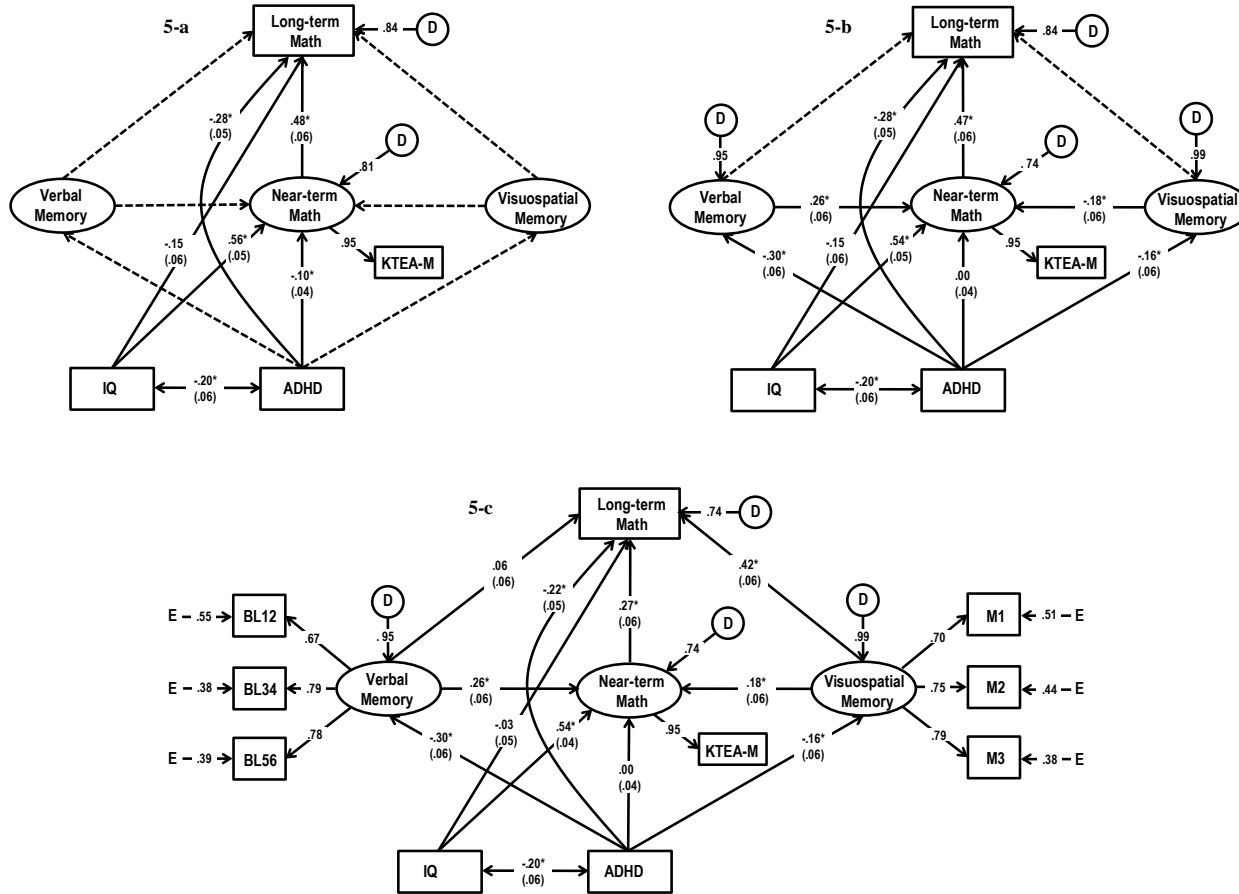


Figure 5. Structural equation models predicting long-term math achievement. Factor loadings and error terms (E) associated with latent variables (Verbal Memory, Visuospatial Memory) are identical for all three models, but shown only for Model 5-c for visual clarity. Values reflect standardized β coefficients (standard error in parentheses). Dashed lines represent pathways constrained to zero. BL = Paired Associates learning for blocks 1-2, 3-4, or 5-6; D = disturbance term. IQ = residualized intelligence variable with overlapping variance with memory variables removed. M = Matching Unfamiliar Figures Test trials 1-7 (M1), 8-14 (M2), and 15-20 (M3). R^2 values in text may differ slightly from the R^2 calculated using disturbance terms due to rounding. * $p < .05$

CHAPTER 4: DISCUSSION

The present study used a series of nested structural equation models to test hypotheses concerning the potential mediating effects of children's verbal and visuospatial memory on the relationship between ADHD behavior problems and near- and long-term scholastic achievement. Results of the initial composite model were consistent with previous studies demonstrating that ADHD behavior problems are associated negatively with near- (Frick et al., 1991) and long-term (Barkley et al., 2006; Fergusson et al., 1997) scholastic achievement, even after controlling for intelligence, age, and socioeconomic status. The full composite model, however, indicated that children's verbal and visuospatial memory abilities differentially mediated the continuity between ADHD and both near- and long-term scholastic achievement. Specifically, the continuity between ADHD behavior problems and near-term achievement was mediated by verbal memory, whereas visuospatial memory attenuated the direct effects of both ADHD and near-term achievement on long-term achievement.

The contribution of verbal memory to early but not long-term achievement in all models is consistent with previous findings documenting the reliance on phonological abilities at school entry, and underscores its importance in the development of early academic abilities (Gathercole, Brown, & Pickering, 2003; Thorell, 2007). The contribution of visuospatial memory to long-term but not near-term achievement, in contrast, replicates developmental patterns between cognition and scholastic achievement reported in the literature (Meyer, Salimpoor, Wu, Geary, & Menon, 2010), and provides context for understanding the divergent associations. Specifically, visuospatial memory underlies complex fluid reasoning skills (Kane et al., 2004), and its association with later but not near-term scholastic achievement may reflect increasing demands on reasoning and comprehension as children advance in school. For example, phonological

abilities play an important role in early computation and number fact retrieval performance, whereas visuospatial abilities contribute to more advanced mathematic abilities such as comprehension performance (Meyer et al., 2010). Collectively, accounting for verbal and visuospatial memory doubled the explained variance in long-term achievement (from 30% to 60%)—highlighting the important contribution of these abilities to the development of academic skills in children.

The unique relationships among attention, intelligence, and memory highlight the complex interactions among these constructs, and extend the findings of previous investigations examining near- and long-term predictors of children’s achievement. Both verbal memory and intelligence, for example, exerted a moderate to robust effect on children’s early scholastic achievement, but provided no incremental benefit beyond this time. The impact of IQ on early scholastic achievement is consistent with findings reported in other investigations (Mayes, Calhoun, Bixler, & Zimmerman, 2009; Rabiner & Coie, 2002); however, its failure to contribute to children’s scholastic achievement in later years is inconsistent with some previous longitudinal models (e.g., Alloway & Alloway, 2010; Rabiner & Coie, 2000; Rapport et al., 1999). The discrepancy in findings may reflect our statistical control for common variance between verbal/visuospatial memory and intelligence in the three models. A post-hoc examination of the models without controlling for common variance, however, yielded nearly identical results. A more convincing explanation for the discrepant findings is the absence of visuospatial memory and near-term achievement measures in some previous longitudinal models, and the likelihood that intelligence contributes marginally to later academic achievement (Rabiner & Coie, 2000; Alloway, 2009) after accounting for its initial impact ($r = .23$ to $.51$) on early achievement (Cain et al., 2004; Mayes et al., 2009; Rabiner & Coie, 2000).

The unique relationship between attention and scholastic achievement was also of interest. Longitudinal studies have conventionally found that the association between attention and scholastic achievement is influenced heavily by early academic learning (Rabiner & Coie, 2000; Volpe et al., 2006), and fully mediated by cognitive and behavioral factors (Rapport et al., 1999). Our findings, in contrast, indicate that ADHD behavior problems exert a sustained negative influence on long-term scholastic achievement and are mediated only partially by near-term achievement and visuospatial memory. The disparity in findings likely reflects the inclusion of classroom performance mediators in previous models—viz., academic success, performance and efficiency—that contribute uniquely to children’s long-term achievement over and above their relationship to near-term achievement. These variables may reflect dispositional (motivation, persistence) and classroom situational factors that contribute to children’s learning in educational settings (cf. Volpe et al., 2006) and merit consideration in future studies of academic outcomes.

Domain-specific models revealed a pattern similar to the composite achievement model with a few noteworthy exceptions. Specifically, verbal but not visuospatial memory significantly mediated the ADHD to near-term reading achievement relationship, with ADHD behavior problems continuing to predict long-term reading achievement. The findings for the math achievement model, in contrast, revealed that visuospatial and verbal memory together fully attenuated the effect of early ADHD behavior problems on near-term math achievement, although these problems continued to predict long-term math achievement. In addition, visuospatial memory impacted both near- and long-term math achievement and partially attenuated the near- to long-term math achievement relationship.

The discrepancies between the current study and past investigations of near-term achievement may be due to at least two factors. One possibility is that past studies have used

widely divergent measures to estimate achievement, including discrepancy score estimates (Barry et al., 2002) and non-standardized screening instruments (Thorell, 2007). A more likely explanation, however, concerns the use of composite indices to estimate memory and other executive functions. Recent studies indicate that ADHD problems may be associated to different degrees with specific executive function domains (Sonuga-Barke, Bitsakou, & Thompson, 2010). If correct, the use of a composite executive function index likely diminishes the magnitude of the relationship between executive function deficits and ADHD-related scholastic problems due to the moderate intercorrelation among tasks (Nigg et al., 2005; Willcutt et al., 2005).

The value of the present study was to identify potential cognitive mediators that account for the impact of ADHD behavior problems on the developmental sequence of scholastic achievement. Several caveats, however, merit consideration when interpreting the current findings. Generalization from community samples to clinical samples of children with ADHD is always limited to some extent; however, extant evidence suggests that scholastic achievement predictors show only minor differences between typically developing children and children with ADHD (DuPaul et al., 2004). Our sample also relied exclusively on teacher ratings of ADHD-related behavior problems, was limited to a 4-year follow-up evaluation period, and did not include measures of other academic domains (e.g., science). Nevertheless, our results are highly consistent with earlier studies examining the developmental trajectory of ADHD behavior problems, IQ, and later scholastic achievement, and provide a strong fit between the hypothesized model and data while controlling for measurement error. Finally, even though verbal and visuospatial memory predict and temporally precede long-term achievement, the reliance on SEM (like ANOVA or regression) precludes causal conclusions and leaves open the possibility that alternative models may better account for the observed relationships.

Collectively, our results indicate that children's early ADHD behavior problems exert a negative influence on their academic achievement, both initially and over time. This influence is mediated partially by the diminished verbal and visuospatial memory abilities that accompany ADHD behavior problems, with the former contributing more heavily to near-term achievement, and the latter to long-term achievement. Recent studies indicate that several of these ADHD-related behavior problems are functionally related and secondary to underlying deficits in phonological and visuospatial working memory abilities (Kofler, Rapport, Bolden, Sarver, & Raiker, 2010; Rapport et al., 2009). Promising evidence also suggests that intensive memory training is associated with neuronal changes (Klingberg, 2010), improved performance on non-trained tasks (Thorell, Lindqvist, Nutley, Bohlin, & Klingberg, 2009), and scholastic performance gains at 6-month follow-up in children with low working memory capacity (Holmes, Gathercole, & Dunning, 2009). If replicated, this emerging literature suggests that early, intensive intervention efforts focused on remediating specific underlying working memory processes may also be useful for improving the academic performance in children with ADHD-related problem behaviors, and that complementary decreases in non-targeted behavior problems may prove to be an unexpected benefit of such efforts.

APPENDIX: IRB APPROVAL LETTER

To: Institutional Review Board
University of Central Florida

From : Mark D. Rapport, Ph.D.
Professor
Department of Psychology
University of Central Florida

Date: November 9, 2010

RE: Dustin Sarver's Thesis

Mr. Sarver is currently a doctoral student in the Department of Psychology at the University of Central Florida and has successfully defended his master's thesis. The data he used for the purposes of his thesis were collected between 1990 and 1994 (currently considered archival data) in cooperation with the University of Hawaii Laboratory School (i.e., the UH Laboratory School reviewed and approved the study and assisted in the collection of data).

Briefly, the study entailed having children between the ages of 7 and 15 at the UH Laboratory School complete the Matching Unfamiliar Figures Test (MUFT) and Paired Associates Learning Task (PAL-T), having classroom teachers complete a brief behavior rating scale for each participant, collecting basic sociodemographic information from each child's parents, and collecting scholastic achievement scores (SAT) four years after the children were initially assessed. The parents of all participants were provided an information packet describing the study and signed an active consent form indicating that their child could participate in the study and that sociodemographic information and SAT scores could be used for purposes of the study. They were also informed that all collected scores could be used for purposes of the study. They were also informed that all collected data and information would be considered highly confidential and kept in locked file drawers by the involved researchers. The MUFT is a match-to-sample paradigm that uses a complex visuospatial figure and requires children to identify the one matching figure among an array of 7 other images that are foils. The target stimulus is displayed in the center of the computer screen with the 7 foils surrounding the central target stimulus. The task assess visuospatial problem solving abilities in children and presents no risk or harm to the child. The PAL-T task requires children to learn associations between letter bigrams (e.g., AG) and numbers (e.g., 2) and assesses the accuracy of their recall after a series of 5 associations are presented. The task is one of the most popular measures used to assess short-term memory in children and presents no risk or harm to the child.

After children (participants) completed the tasks, scores were entered into an interactive data-handling program (Paradox) to allow for statistical analysis. Information obtained from children's parents was also entered into the program. Afterwards, all hard copies of the data, including any identifying information concerning the parents and children, were destroyed. The data-handling program contains only artificial identification numbers that cannot be traced either directly or through identifiers linked to the subjects.

For purposes of Dustin's thesis, he will have access to only the archival raw data values contained in the data-handling program. Published studies derived from this and other studies accessing the aforementioned archival database contain no identifying information about children or families other than stating that many children and teachers at the University of Hawaii Laboratory School participated in the project and thanking them for their participation.

Thank you for considering our request to use archival data for the purposes of Dustin Sarver's thesis.

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