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Effects of Attention-Deficit/Hyperactivity Disorder and Anxiety on Attention, Working Memory, and Academic Achievement in Children and Adolescents: A Structural Equation Modeling Approach

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A thesis submitted in partial satisfaction

of the requirements for the degree Master of Arts

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by

Alexandra Noelle Sturm

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ABSTRACT OF THE THESIS

Effects of Attention-Deficit/Hyperactivity Disorder and Anxiety on Attention, Working Memory, and Academic Achievement in Children and Adolescents: A Structural Equation Modeling Approach

by

Alexandra Noelle Sturm

Master of Arts in Education

University of California, Los Angeles, 2013

Professor Connie L. Kasari, Chair

Attention and working memory, two constructs that affect youth who have ADHD and anxiety, are essential in establishing automaticity and success in academic achievement. Using data from a large study involving 502 children and adolescents (332 diagnosed with ADHD, 145 diagnosed with anxiety disorder, and 126 diagnosed with neither), ages 7 to 15 years, this paper applies structural equation modeling to test the sequential relationship between the latent constructs of attention, working memory, and academic achievement, and the effects of symptoms of ADHD and anxiety on each construct, and also to assess consistency in measurement techniques of each underlying construct. The study establishes that the structural equation model created to replicate a theory of automaticity fit the data from this sample well, and there was significant sequential prediction between attention, working memory, and academic achievement. In addition, better performance on measures of attention and working memory predicts higher academic achievement, as relative weaknesses in academic achievement seen in children and adolescents with ADHD can be explained largely by deficits in attention and working memory. Anxiety symptoms were unrelated to attention, working memory, and academic achievement, when controlling for ADHD. However, a significant negative correlation between harm avoidance, a trait of anxiety, and ADHD symptoms suggest that it may be of value to explore the theoretical underpinnings of the relationship between harm avoidance, ADHD, and academic achievement.

The thesis of Alexandra Noelle Sturm is approved.

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2013

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Effects of Attention-Deficit/Hyperactivity Disorder and Anxiety on Attention, Working Memory, and Academic Achievement in Children and Adolescents:

A Structural Equation Modeling Approach

Attention-Deficit/Hyperactivity Disorder (ADHD) is an externalizing behavioral disorder characterized by inattentive, hyperactive/impulsive, and combined subtypes that onset in childhood (DSM-IV-TR, 2000). Between 5% and 10% of children 8 to 15 years of age are diagnosed with ADHD (Merikangas et al., 2010; Polanczyk, Silva de Lima, Horta, Biederman, & Rohde, 2007). Anxiety disorders occur at a 25% rate of comorbidity with ADHD (Jarrett & Ollendick, 2008) and are primarily characterized by unreasonable fears and worries that may prevent a child from engaging in daily activities (Gaze, Kepley, & Walkup, 2006). Children with ADHD and children with anxiety exhibit deficits in academic achievement, with some evidence that children with ADHD and comorbid anxiety experience more school-related difficulties including lower reading achievement, placement in special classes, need for extra tutoring, and repeated grades (Goldston et al., 2007; Hammerness et al., 2010; Ialongo, Edelsohn, Werthamer-Larsson, Crockett, & Kellam, 1994).

Functional impairment in academic achievement and non-academic school functioning seen in ADHD and anxiety disorders are often areas of chief concern for parents and teachers. However, the many constructs underlying academic achievement contribute to the relative success and failure of each child and thus demand more focus. Two prominent underlying constructs are those of attention and working memory. Attention is complex and is explained by many and varied theories. Attention is broadly defined as directed and selective perception of one’s environment (van Zomeren & Brouwer, 1994). Working memory is the ability to hold information in one’s mind important to the current context so that an adaptive solution can be constructed and executed (Pennington & Ozonoff, 1996). The constructs of attention and working memory also overlap theoretically and it is often difficult to parse these functions apart. As Morris (1996) said, “can one encode information into memory without adequate attention or without an adequate strategy (executive function)"? Here we will further explore the relationship between symptoms of ADHD and anxiety and academic achievement defined as oral reading fluency, reading comprehension, spelling, and math computation through two integrated neural processes, attention and working memory.

Logan's Instance Theory of Automatization

The ability to process information automatically, or with speed, effortlessness, autonomy, and lack of awareness, is a crucial skill in the development of academic ability (Logan, 1997). Attention to an object or event allows that event to be encoded into memory and accessed later. Practice and exposure make processes more automatic, and therefore the processes become faster and require less effort (Logan, 1997). Logan's instance theory can explain the automaticity developed in reading, spelling, and math. For example, when learning to read children engage in phonemic decoding, or sounding out components of words (Schatschneider, Fletcher, Francis, Carlson, & Foorman, 2004). As a child ages, they begin to recognize whole words rather than allocating as many mental resources to decoding each word. This makes the process of reading more *effortless, speedy,* and requires less *awareness.* Generally, if one cannot encode information to memory due to deficits in attention and working memory then subsequent academic achievement may suffer. This study will draw on Logan's theory of automatization to explore the relationship between attention, working memory and academic achievement.

Figure 1. Logan's Instance Theory

Working Memory

Working memory is composed of three subsystems (1) the central executive, (2) the visuo-spatial sketchpad, and (3) the phonological or articulatory loop. In other words, a system controller, visuo-spatial working memory, and auditory-verbal working memory, respectively (Baddeley & Hitch, 1974). Each of these unique subsystems requires not only attention in order to obtain information, but also the simultaneous storage and manipulation of information.

Working memory deficits are associated with both ADHD and anxiety (Jacobsen et al., 2011; Owens, Steventson, Norgate, & Hadwin, 2008; Martinussen, Hayden, Hogg-Johnson, & Tannock, 2005). Children with ADHD show deficits in both auditory-verbal and visuo-spatial working memory (Martinussen et al., 2005). Although working memory impairment seems to be a shared deficit between ADHD and anxiety, working memory deficits in ADHD and anxiety may have different loci and therefore different implications for affected processes including academic achievement (Bedard & Tannock, 2008). In anxiety, the consistent presence of worry affects the ability to encode information into memory as well as retrieve information from memory (Eysenck & Calvo, 1992). Worry about negative expectations and concerns about oneself, the situation, and consequences typical of anxiety disorders (Morris, Davis & Hutchings, 1981) can also negatively impact working memory. While findings about deficits in working memory in anxiety are mixed (see Visu-Petra, Ciairano, & Miclea, 2006 for a review), Tannock, Ickowicz, and Schachar, 1995 found poorer auditory-verbal and central executive working memory performance in children with ADHD and comorbid anxiety. Lack of consistency in findings regarding working memory and anxiety underscore the need for further research.

Attention

The quantity and quality of our memory traces are largely dependent on the mental attentional resources allocated to an event (Baddeley, 1990). The components of attention most frequently include arousal (physiological readiness to complete a task), orientation (physiological and behavioral changes upon detection of novel stimulus), divided attention (parallel processing of two or more stimuli using appropriate attention allocation strategies), selective attention (ability to focus on relevant stimuli and ignore conflicting or extraneous stimuli), and sustained attention (maintenance of vigilance following an orienting stimulus) (Halperin, 1996; van Zomeren & Brouwer, 1994).

"Difficulty concentrating" is a shared symptom of generalized anxiety disorder and ADHD, and can appear phenomenologically similar in the two disorders. However, neuropsychologically, attention in the two disorders is distinguishable by attentional type. Children with ADHD show impairment on tasks of sustained and selective attention, presumably as a result of the inability to process extraneous information and exclude irrelevant information from memory (Carnoldi et al., 2001). In contrast to the consistent attentional deficit seen in children with ADHD, children with anxiety exhibit specific attentional bias toward threat (Weissman, Chu, Reddy, & Mohlman, 2012). Inefficiently allocated attentional resources can make it difficult to encode information into memory quickly and easily (Morris, 1996). Interestingly, the presence of comorbid anxiety in children with ADHD results in improved performance on measures of sustained and selective attention compared to children with ADHD alone (Vloet, Konrad, Herpertz-Dahlmann, Polier, & Günther, 2009). There continues to be a need to articulate the impact of attention on academic achievement in children with ADHD and anxiety.

Academic Achievement

Academic achievement as a measure of academic success or failure is a well-studied field in the ADHD literature, however there is a gap in research investigating the relationship between anxiety and academic achievement. Oral reading fluency is defined as the combination of a reasonable reading rate and accuracy in addition to appropriate prosody and comprehension (Hudson, Pullen, Lane, & Torgesen, 2008). Math computation is defined as an individual's ability to count, identify numbers, solve simple oral math problems, and calculate written math problems (Wilkinson & Robertson, 2006).

Originally, researchers used solely phonological awareness to explain the relationship between psychiatric diagnosis and deficits in reading ability (Wigal et al., 2012). The literature has since shifted to a focus on higher order processes including attentional skills, working memory and processing speed to explain lower reading achievement evident in the heterogeneous group of children with ADHD and children with anxiety (Wigal et al., 2012; Jacobsen et al., 2011; Owens et al., 2008).

Contrary to the extensive research examining the relationship between ADHD and reading achievement, relatively few studies have examined math achievement in children with ADHD and/or anxiety and often lack appropriate sample size. Achievement in math is predicted by a measure of processing speed, the WISC-IV coding subtest (Mayes, Calhoun, Bixler, & Zimmerman, 2009), however few other studies have examined the predictive relationship between other neuropsychological variables and achievement in math. It is known that children with ADHD exhibit deficits in math achievement (Jensen et al., 2001). Immature computation strategies (i.e. a carried number is added to the wrong column) in children with ADHD only (Bendetto-Nasho & Tannock, 1999) and poor math reasoning in children with ADHD and anxiety (Jensen et al., 2001) have both been found. Math achievement in ADHD and anxiety is an understudied and important area, in addition to the neuropsychological variables that explain the relationship.

The Relationship Between Attention, Working Memory, and Academic Achievement

In anxiety, the overlap between attention and working memory may be considered differently than in the case of ADHD. Memory encoding may be an issue for children with both ADHD and children with anxiety, but for different reasons. Generally, as explained in Logan's instance theory of automatization, inattention affects encoding of memory traces. Children with anxiety may exhibit deficits on tasks of working memory as a result of attentional bias to threatening stimuli, such as a testing scenario, thereby reducing the ability to encode information to working memory. In contrast, children with ADHD are inattentive due to an inability to exclude subjectively interesting irrelevant information from processing. In both ADHD and anxiety, irrelevant information, albeit of different nature, restricts the ability to encode information into memory.

Anxiety is also a highly heterogeneous disorder; two children diagnosed with anxiety can experience non-overlapping symptoms including harm avoidance, physical symptoms, separation anxiety, and social anxiety (March, Parker, Sullivan, Stallings, & Conners, 1997). While many traits of anxiety frequently co-occur with ADHD, this paper will also explore the nature of the relationships between ADHD and specific anxious traits in the context of academic achievement.

Finally, there are many different tasks that are used to measure different aspects of attention and working memory. For example, factor analysis of simple span tasks and probed-recall tasks loaded on different factors, indicating that different tests of working memory differentially explain variance in reading comprehension (Engle, Cantor, & Carullo, 1992). The same may be true for explaining variance in reading fluency, reading comprehension, spelling, and/or math computation. Tasks used to measure different types of attention and working memory also may not show consistency in measurement, thus necessitating the use of a few different tasks of a construct when measuring the relationship between diagnosis, attention and working memory, and oral reading fluency, reading comprehension, and math computation. These findings highlight the importance of exploring the relationships between different measures of a single construct (i.e. working memory or attention) and academic achievement. There is little consistency in the neuropsychological tasks used to predict academic achievement and these analyses will also focus on the strength of relationships between tasks purportedly measuring the same constructs.

Many studies have highlighted working memory and attentional deficits in ADHD and anxiety, however none have focused on viewing academic achievement in ADHD and anxiety as a component of a larger structural model that includes attention and working memory to assess relative contribution of each construct to impairment in academic achievement. In this study, I hope to answer the following questions (1) Does a structural model of Logan's instance theory of automatization fit sample data in a study of children and adolescents? (2) How do symptoms of ADHD and symptoms of anxiety predict attention, working memory, and academic achievement within Logan's instance theory of automatization? (3) How well do tasks purportedly measuring the same construct load onto latent variables representing that construct?

Method

Participants

Participants were 502 children and adolescents ages 7 to 15 (356 male and 146 female, *M* age = 10.3 years) who all participated in the Translational Research to Enhance Cognitive Control, National Institutes of Mental Health funded, research study that investigated the effects of medication on cognitive control in ADHD and the effects of cognitive behavioral therapy (CBT) on cognitive control in chronic tic disorders, both relative to typical controls. Participants were originally screened to participate in one of the three groups, 323 were screened for ADHD, 86 for chronic tic disorders, and 93 for control. Of the 502 participants screened, 332 received a diagnosis of ADHD, either inattentive or hyperactive type, 145 received a diagnosis of an anxiety disorder (e.g. specific phobia, separation anxiety, social anxiety, obsessive-compulsive disorder, etc), and 126 did not receive an ADHD or anxiety diagnosis. Participants and their families were recruited from the greater Los Angeles area through flyers, radio ads, and school and health practitioner referrals. To be eligible for participation in the ADHD medication treatment arm, children had to be ages 7 to 14, meet DSM-IV criteria for ADHD-Inattentive type, ADHD-Hyperactive type, or ADHD-combined type, and have a full scale IQ greater than 70. Children with a diagnosis of an autism spectrum disorder, major depressive disorder (MDD), psychosis, bipolar disorder, or chronic tic disorder were excluded from participation in the ADHD medication treatment project. To be eligible for participation in the chronic tic disorder and CBT treatment arm, children had to be ages 7 to 14, meet DSM-IV-TR criteria for a chronic tic disorder, and had an FSIQ greater than 70. Children with a diagnosis of PDD, mania, depression, psychotic disorder, substance abuse, or conduct disorder were excluded from the chronic tic disorder CBT treatment arm. According to parent report of ethnic and racial affiliation, the sample was 27.9% Hispanic or Latino (n=140), 72.3% white (n=363), 15.1% Black or African American (n=76), 0.2% Native Hawaiian or Pacific Islander (n=1), 6.6% Asian (n=33) and 4.6% identified as other (n=23).

Procedures

Screening procedures were completed in a single clinic visit and consisted of questionnaires completed by both a parent and the child as well as computer-based and paper and pencil neuropsychological assessments administered to each child. The following assessments were used to measure the constructs of ADHD, anxiety, attention, working memory, and academic achievement.

Assessments

ADHD.

ADHD symptom list: Schedule for Affective Disorders and Schizophrenia for School-Age Children-Present and Lifetime Version (K-SADS-PL).

The K-SADS-PL is a semi-structured diagnostic interview of present and lifetime psychopathology in children and adolescents that are reflective of DSM-III and DSM-IV diagnoses (Kaufman et al., 1997). Interviews are conducted with a parent and child individually and scores are synthesized by a clinician to determine the presence or absence of symptomatology. The K-SADS-PL has very good inter-rater reliability, test-retest reliability, and concurrent validity (Kaufman et al., 1997). The 18 DSM-IV ADHD symptoms rated as a part of the K-SADS-PL assessment will be used as a continuous measure of ADHD symptoms.

Anxiety.

MASC (Multidimensional Anxiety Scale for Children).

The MASC is a 39 item, 4-point Likert, self-report rating scale that has shown robust psychometric properties in clinical, epidemiological and treatment studies (March et al., 1997). Items are distributed across four scales: harm avoidance, social anxiety, separation anxiety, and physical symptoms. Anxiety symptoms in this study were measured dimensionally using the raw scores of the four MASC self-report subscales, where higher scores are indicative of greater anxiety.

Child Behavior Checklist (CBCL).

The Child Behavior Checklist (CBCL; Achenbach, 1991) is a parent-rated broadband measure of a child or adolescent's emotional and behavioral functioning as well as their adaptive competencies. The CBCL for ages 6 to 18 has 120 items that are rated on a 3-point Likert scale as *0 = not true, 1= somewhat or sometimes true,* and *2 = very true or often true*. The CBCL produces eight syndrome scales broadly grouped into internalizing and externalizing problems. Higher raw scores on the CBCL syndrome scales are indicative of more severe problem behaviors. The anxiety problems scale is made up of 6 items and includes symptoms such as "clings to adults or too dependent," "nervous, highstrung, or tense," and "worries." The CBCL is a well-validated instrument with internal consistency of the scales ranging from 0.78 to 0.97 with excellent test-retest and inter-rater reliability (Achenbach, 1991). For the purpose of these analyses, the raw anxiety problems syndrome scale score was used.

Attention.

Go-NoGo.

The Go-NoGo computerized continuous performance test was used as a measure of attention (Schulz, Newcorn, Fan, Tang & Halperin, 2005). Go-NoGo is a widely used computerized test of sustained attention or vigilance (Conners, 1996) and has shown good discriminant and predictive validity. Go-NoGo involves presentation of a high rate of "Go" trials (83%) and a lower rate of "NoGo" trials (17%) in order to bias a prepotent response towards responding and thus eliciting higher rates of false positive errors of commission. During this 14-minute continuous task, letters A through Z appear on the screen one at a time and subjects are required to press the space bar when any letter ("Go" trial) except the target letter "X" appears ("NoGo" trial). Go-NoGo generates a number of variables sensitive to attention deficits and summary scores include mean "Go" reaction time, percent errors of omission, percent errors of commission, and RT standard deviation (RTSD). The percentage of omitted "Go" trials, considered lapses in sustained attention, was used as a measure of sustained attention. A greater number of omitted "Go" trials are indicative of increasingly poor sustained attention.

Attention Network Test.

The Attention Network Test congruent accuracy score percentage correct was used as a measure of attention and specifically measures selective attention. ANT followed the procedures used by Eriksen and Eriksen (Eriksen & Eriksen, 1974) and required subjects to respond by pressing a left or right button depending on whether an arrow in the center of a visual display points left or right, respectively. On some trials, "flankers" are shown on both sides of the target arrow that are congruent (pointing in the same direction as the central arrow), incongruent (pointing in the opposite direction), or neutral (no arrows, just lines). Average reaction time and accuracy summary scores are produced for each of the three congruence types including neutral, congruent, and incongruent.

Stop Signal Task.

The Stop Signal Task was used as a measure of attention, specifically sustained attention. The stop-signal task is a well-established measure of response inhibition (Logan, Cowan, & Davis, 1984). On each trial, subjects perform a choice response time task, in which they respond whether an arrow is pointing left or right with spatially compatible buttons on a box. They are instructed to respond as quickly as possible, except on trials where they hear an auditory beep, in which case they are to withhold their response. Stop signals are presented on 30% of trials; the delay at which the stop signal is presented is determined adaptively using a tracking paradigm, which ensures that (on average) subjects will be successful at withholding their response on half of the stop trials. The tracking paradigm also allows the estimation of a stop-signal reaction time (SSRT), which is the amount of time needed to inhibit a response after presentation of the stop signal. This estimation is based on a well-established model that proposes a race between stop and go processes (Band, van der Molen, & Logan, 2003). The percentage accuracy of correct "Go" trial responses will serve as a measure of sustained attention.

Working memory.

Spatial Sternberg task.

The Spatial Sternberg task was used as a measure of working memory (Glahn et al., 2003). This spatial version of the Sternberg item recognition task (Sternberg, 1969; Jonides et al., 1993) requires maintenance of a set of spatial locations over a delay. Subjects see a target array of 1, 3, 5, or 7 circles positioned around a central fixation. After a fixed delay, subjects are shown a single circle and required to indicate whether that circle was in the same position as one of the targets. Trial events include a 2 second target-array presentation, a 3 second delay period, and a 3 second fixed response interval. A central fixation was visible throughout each of the 36 trials (12 per memory set size) over two blocks of 7 minutes each (Snodgrass & Corwin, 1988). Items are scored by block and by number of targets in each stimulus presentation. Summary scores include average reaction time and percent accuracy. Specifically, SDRT load 5 circles and load 7 circles served as a measure of visual-spatial working memory.

WISC-IV (Weschler Intelligence Scale for Children – Fourth Edition) Digit Span, Spatial Span, Letter-Number Sequencing.

Digit span, spatial span, and letter-number sequencing were all used as measures of working memory (Weschler, 2004). Digit span is a core working memory subtest of the WISC-IV and requires that the child repeat a series of up to eight digits forward for digit span forward, and a series of up to eight digits backward for digit span backward. There are two trials for each digit count series. Digit span measures auditory-verbal working memory, concentration and numerical ability. Reliability of digit span forward (r_{xx} = .87) with a range between r = .81 and r = .92.

The Letter-Number Sequencing subtest of the WISC-IV requires that children arrange a series of numbers and letters into alphanumeric order. Letter-number sequencing is also a test of auditory-verbal working memory and, like digit span backward, requires the manipulation of information to produce a desired result. Letter-number sequencing is also a reliable task (r = .90) ranging between .85 and .92 and correlated the most with the arithmetic subtest of the WISC-IV (r = .51).

Finally, the spatial span subtest of the WISC-IV Integrated requires that the child watch an experimenter touch a series of blocks and must replicate the pattern in the same order with an increasing number of blocks included in each trial (spatial span forward). In spatial span backward, the child must reverse the order of the touched blocks. The maximum trial number is eight and is discontinued if children score 0 on both items of a single set. Spatial span backward will serve as another measure of visual-spatial working memory.

Academic achievement.

GORT-4 (Gray Oral Reading Test, 4th Edition).

The Gray Oral Reading Test 4th Edition (GORT-4) is an assessment of oral reading rate, accuracy and fluency and reading comprehension (Wiederholt, & Bryant, 2001). In this task, children are asked to read a series of up to 14 passages aloud as quickly and accurately as they can while the experimenter marks errors in oral reading performance. The child then answers comprehension questions based on the passage read aloud. In order to discontinue the task, the child must reach a ceiling on both oral reading fluency and reading comprehension. The GORT-4 has excellent reliability (Wiederholt, & Bryant, 2001).

WRAT (Wide Range Achievement Test, 4th Edition) Math Computation and Spelling.

The Wide Range Achievement Test (WRAT-4) measures academic skills in spelling, math computation, reading, and sentence comprehension (Wilkinson & Robertson, 2006). For the purpose of this study, math computation was used as a measure of general mathematical academic skills. The math computation subtest of the WRAT-4 is a 15-minute task in which the individual completes a series of paper and pencil math problems of increasing difficulty. Children ages 7 and under first complete a measure of simple oral math computation to assess the child's ability to count, identify numbers, and solve simple oral math questions. The WRAT-4 spelling subtest was used as a measure of achievement in spelling. In this task, an experimenter says words aloud, followed by the word within the context of a sentence and the child must spell each word on a piece of lined paper. The WRAT-4 has been shown to be highly reliable and valid with standard scores based on a nationally representative sample of 3,000 individuals, ages 5 to 94 years old.

Data Analysis

For the purpose of these analyses, the samples from all three treatment arms were combined in order to assess a full range of ADHD and anxiety symptom levels. Structural equation modeling (SEM) was used to test the relationship between the latent constructs of attention, working memory, and academic achievement. SEM allows one to test both the magnitude and significance of relationships between dependent variables and independent variables to determine if a model (or theory) is consistent with the data from a confirmatory approach (Byrne, 1994). The model was estimated using EQS (Bentler, 2006). Of the 502 cases, 118 had missing data for at least one variable and there were 39 patterns of missing data. Given appropriate robust methodology in EQS software that provides accurate statistics for pairwise deletion, pairwise deletion procedures were used to handle missing data (Bentler, 2006). Pairwise analysis is an alternative to listwise deletion procedures and allows use of all univariate and bivariate in order to compute summary statistics. Missing data in this sample were missing completely at random and therefore pairwise deletion gives consistent estimates of population parameters (Brown, 1983).

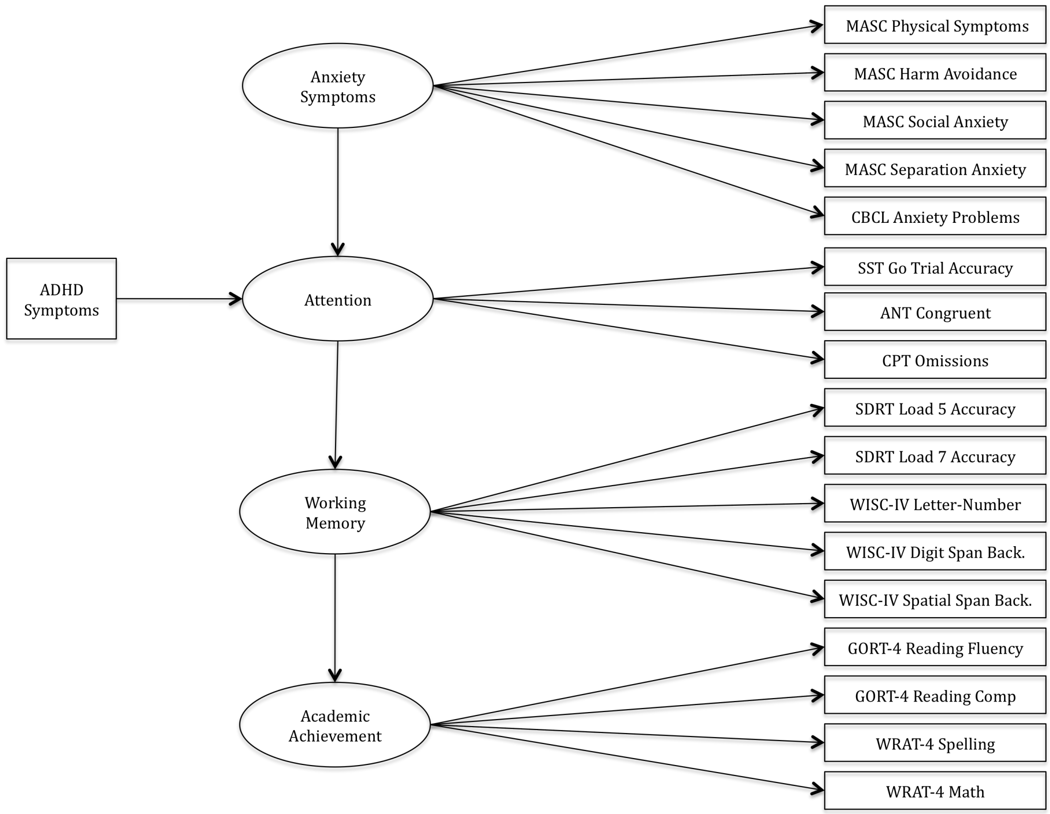

Figure 2. A priori model of the relationship between symptoms of ADHD, symptoms of anxiety, attention, working memory, and academic achievement according to Logan's Instance Theory

Results

Model Specification

A priori models.

All intercorrelations, means, and standard deviations of independent and dependent variables in the model are included in Table 1. Figures 1 and 2 illustrate the two *a priori* models that were initially tested. The first model tested was the measurement model to assess not only how the data reproduced Logan's instance theory specifically, but also how well the measures of the same construct loaded onto a similar latent factor. Adequacy of model fit will be assessed using the comparative fit index (CFI), root mean square error of approximation (RMSEA), chi-square statistic, and average standardized residuals (Bentler, 1990; Bentler, 2007). First, the smaller measurement model (Figure 1) was assessed with the attention latent factor predicting the working memory latent factor, which predicted the academic achievement factor. The data was not normally distributed as it exceeded a Mardia's coefficient normalized estimate of 4 to 5 (Mardia's coefficient normalized estimate = 12.5) and therefore robust statistics, specifically the Satorra-Bentler scaled chi-square statistic, will be reported for all models (Bentler, 2006). The overall model fit was poor, χ^2 (78, N = 502) = 329.50, $p < .001$ (CFI = 0.84, RMSEA = 0.103). There were also several standardized residuals that were indicative of a poor model fit (average absolute standardized residual = 0.067), including one standardized residual over .300, two over .200 and many over .100.

The second *a priori* model run was the larger hypothesized model depicted in Figure 2 that included ADHD symptoms and anxiety symptoms as predictors of attention in the measurement model. Again, the overall model fit was poor, χ^2 (129, N = 502) = 503.43, $p < .001$ (CFI = 0.85, RMSEA = 0.076). There were also several standardized residuals that were indicative of a poor model fit (average absolute standardized residual = 0.058). Examining the residuals, it appeared that the model misspecification was due to two primary causes. The first was that it appeared that ADHD symptoms were in fact related directly to all of the factors in the model as opposed to just the attention factor, and secondly that there was a relationship between measured variables of factors representing different constructs.

Table 1

Standard Deviations, Mean, and Intercorrelations Among Modeled Variables

Var	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	1																	
2	.198†	1																
3	-.166†	.188†	1															
4	.168†	.572†	.305†	1														
5	.126†	.456†	.356†	.514†	1													
6	.241†	.318†	.068	.271†	.241†	1												
7	-.140†	.046	.009	-.023	-.118*	-.054	1											
8	.248†	.041	-.054	.045	.106*	.065	.348†	1										
9	-.196†	-.017	-.090	-.092*	-.166†	-.049	.515†	-.519†	1									
10	-.275†	-.084	-.001	-.085	-.142†	-.040	.380†	-.401†	.515†	1								
11	-.269†	-.030	.003	-.081	-.119†	-.079	.331†	-.367†	.423†	.631†	1							
12	-.167†	-.034	.095*	-.022	-.052	-.123†	.244†	-.193†	.221†	.234†	.199†	1						
13	-.208†	.027	.146†	-.053	-.002	-.108*	.303†	-.244†	.259†	.284†	.318†	.365†	1					
14	-.225†	-.034	.050	-.051	-.068	-.186†	.161†	-.188†	.153†	.220†	.198†	.378†	.354†	1				
15	-.235†	.010	.111*	-.061	-.029	-.093*	.230†	-.157†	.179†	.242†	.270†	.424†	.342†	.390†	1			
16	-.103†	.007	.111*	-.054	-.011	-.010	.214†	-.156†	.166†	.202†	.241†	.321†	.285†	.229†	.450†	1		
17	-.236†	.017	.100*	-.081	-.035	-.144†	.223†	-.186†	.181†	.242†	.277†	.418†	.316†	.415†	.747†	.415†	1	
18	-.227†	-.030	.136†	-.049	-.091*	-.101*	.268†	-.264†	.272†	.309†	.295†	.540†	.414†	.380†	.499†	.402†	.546†	1
N	497	488	488	488	488	490	477	470	474	486	486	492	488	486	488	485	491	491
M	9.29	9.00	17.42	11.76	9.06	2.32	.906	37.48	.857	.657	.631	9.68	10.03	9.58	9.42	10.03	106.92	104.5
SD	6.00	5.99	4.50	6.49	5.04	2.33	.142	30.85	.136	.149	.143	3.08	2.96	3.02	3.86	3.35	15.56	15.01

Note. 1 = ADHD symptoms, 2 = Physical Symptoms, 3 = Harm Avoidance, 4 = Social Anxiety, 5 = Separation Anxiety, 6 = CBCL Anxiety Problems, 7 = ANT Congruent % Correct, 8 = CPT Total Omissions, 9 = SST Go Trial % Correct, 10 = SDRT Load 5 % Accuracy, 11 = SDRT Load 7 % Accuracy, 12 = WISC-IV Letter-Number Sequencing Standard Score, 13 = WISC-IV Spatial Span Standard Score, 14 = WISC-IV Digit Span Standard Score, 15 = GORT4 Reading Fluency Standard Score, 16 = GORT4 Reading Comprehension Standard Score, 17 = WRAT-4 Spelling Standard Score, 18 = WRAT-4 Math Computation Standard Score

* $p < .05$, † $p < .001$

Post-hoc model modification.

To further assess unspecified and non-hypothesized relationships, Lagrange Multiplier (LM) tests were conducted to determine which measured variables, latent factors, and errors should be freed in order to improve model fit (Bentler, 1986). Due to the exploratory nature of the LM test and the relative small size of this sample, the statistical theory associated with the LM test may be compromised and probability levels must be interpreted with caution. To confirm any findings in this analysis, the results should be cross-validated in another sample (MacCallum, Browne, & Sugawara, 1996).

As indicated by the LM tests, relationships between variables and factors were added to the model in order to improve model fit (see Figure 3). Only relationships between variables that were supported by theory were added to the model. Direct relationships were added between ADHD and anxiety, working memory, and academic achievement. These additions to the model are congruent with the literature as children with ADHD show higher rates of anxiety disorders, deficits in working memory, and deficits in academic achievement. Evidently, a direct effect is necessary between ADHD and all factors in this model as opposed to an indirect effect alone. In addition, attention was added as a direct predictor of academic achievement to supplement the predicted indirect relationship. Several correlated errors were also added and are listed in the description of Figure 3.

After the post-hoc addition of paths to the model, the model fit improved substantially. The sample data still appeared to be non-normal (Mardia's coefficient normalized estimate = 11.4), and therefore robust statistics will continue to be reported and interpreted. Under robust estimates, χ^2 (115, N = 502) = 240.88, $p < .001$ (CFI = 0.95, RMSEA = 0.047), the model yielded adequate fit. The standardized residuals on average were much lower (average absolute standardized residual = 0.0409) compared to the original model, however a few moderately large residuals remained. The largest residuals existed between the SST go trial percent correct and SDRT load 5 percent accuracy (0.146), SST go trial percent correct and

WISC-IV digit span (-.139), MASC harm avoidance and WISC-IV spatial span (.137), and MASC harm avoidance and ADHD symptoms (-.132). Direct relationships between measure of attention (SST) and a measure of working memory (SDRT, digit span), and only one subscale of the anxiety factor (harm avoidance) and a measure of working memory and ADHD symptoms were not expected and therefore, no paths were added.

The final model is presented in Figure 3. The modified model also accounted for a large portion of the variance in academic achievement (R^2 = 1.00), and some of the variance in attention (R^2 = .077) and working memory (R^2 = .716). The strength of factor loadings will be reported first, followed by a report of the relationships between variables and the significance of those relationships.

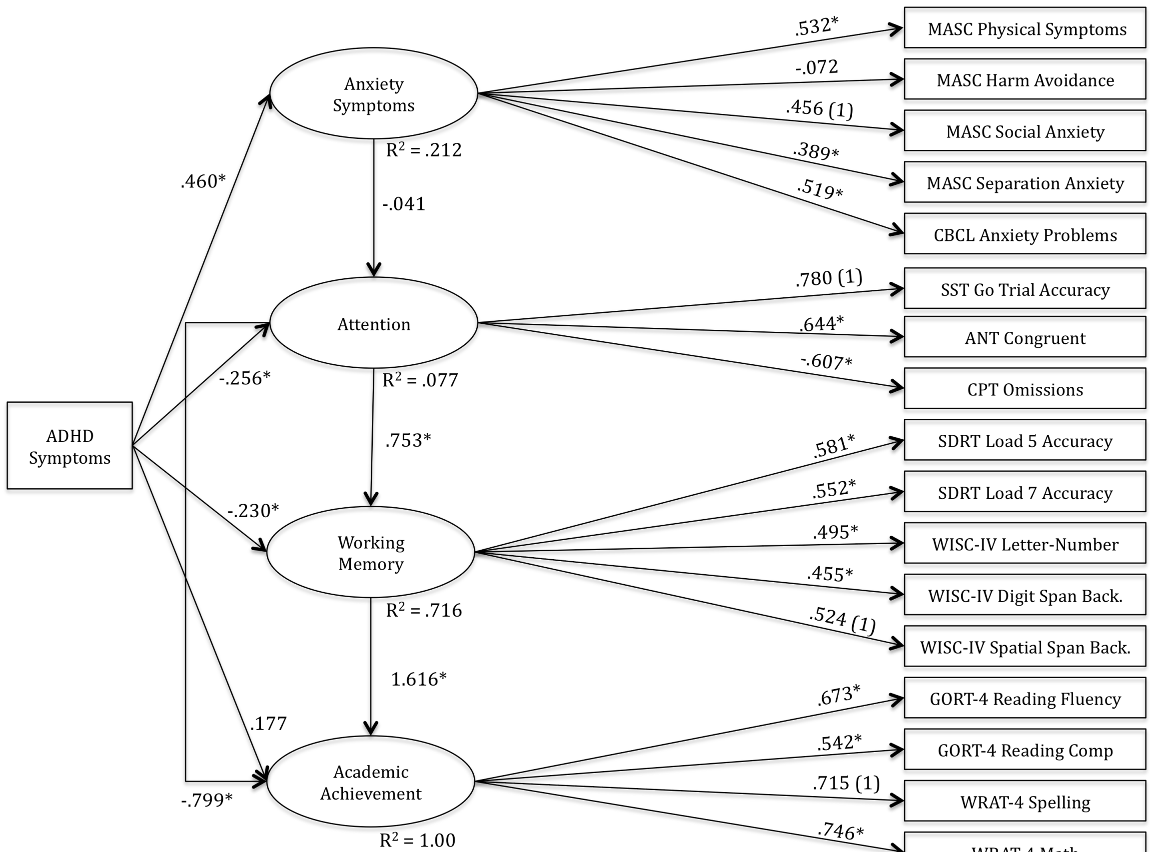

Figure 3. Standardized coefficients for the model of ADHD symptoms, anxiety symptoms, attention, and working memory effects on academic achievement. All significant values noted by "*" and significant at $p < .05$. All standardized coefficients noted, and paths with a "(1)" were fixed in the model. All dependent variables had error terms (not included in diagram), and the following errors were correlated: all MASC subscales; all WISC-IV subtests; GORT-4 Reading Fluency, WRAT-4 Spelling; WRAT-4 Math Computation, WISC-IV Letter-Number Sequencing; GORT-4 Reading Fluency, GORT-4 Reading Comprehension.

Post-hoc Model Results

Factors.

In order to examine the relationship between ADHD, anxiety, attention, working memory, and academic achievement, latent variables were created with measured variable indicators that were measured by either computer-based tests or paper and pencil tests. All standardized and unstandardized factor loadings are reported in Table 2. The MASC is a well-validated and consistent measure of anxiety symptoms, however in the context of this model the factor loadings of the MASC subscale indicators are highly variable. Standardized parameter estimates for social anxiety (β = .456, $p<.05$), separation anxiety (β = .389, $p<.05$), and physical symptoms (β = .532, $p<.05$) all load reasonably well, however harm avoidance does not load well (β = -.072, $p>.05$).

The indicators of the remaining factors, attention, working memory, and academic achievement, all loaded well (see Table 2). Standardized parameter estimates of the factor loadings for academic achievement ranged from β = .542, $p<.05$ for WRAT-4 spelling to β = .746, $p<.05$ for WRAT-4 math. The indicators of the attention factor also loaded well, with ANT congruent percent correct (β = .644, $p<.05$) and SST go trial percent correct (β = .780, $p<.05$) both positively loaded and CPT total omissions (β = -.607, $p<.05$) negatively loaded, as greater number of omissions is indicative of poorer task performance. Finally, working memory was also a strong factor with both paper and pencil measures and computer-based measures standardized parameter estimates ranging from β = .455, $p<.05$ for WISC-IV digit span backward to β = .581, $p<.05$ for SDRT load 5 circles percent correct.

Table 2

Unstandardized and Standardized Factor Loadings for the Final Model

		Factor Loadings	
Model Latent Factors	Model Measured Variables	Unstandardized	Standardized
Attention	ANT congruent % correct	.863*	.644*
	CPT total omissions	-177.31*	-.607*
	SST go trial % correct	(1)	.780
Working Memory	SDRT Load 5 % correct	.056*	.581*
	SDRT Load 7 % correct	.051*	.552*
	WISC-IV letter-number seq.	.975*	.495*
	WISC-IV digit span backward	.884*	.455*
	WISC-IV spatial span backward	(1)	.524*
Anxiety	MASC Harm Avoidance raw	-.110	-.072
	MASC Separation Anxiety raw	.663*	.389*
	MASC Social Anxiety raw	(1)	.456
	MASC Physical Symptom raw	1.077*	.532*
	CBCL Anxiety Problems raw	.408*	.519
Academic Achievement	GORT-4 Reading Fluency	.233*	.673*
	GORT-4 Reading Comprehension	.163*	.542*
	WRAT-4 Math Computation	.998*	.746*
	WRAT-4 Spelling	(1)	.715

Note. Significant (p < .05) parameter estimates in the unstandardized solution noted with a "*". Fixed paths noted with a (1).

ADHD and Anxiety.

Overall, more ADHD symptoms predicted greater anxiety (β = .460, p<.05). More symptoms of ADHD were predictive of higher ratings of physical symptoms (β = .253, p<.05), social anxiety (β = .210, p<.05), separation anxiety (β = .179, p<.05), and parent reported anxiety symptoms (β = .239, p<.05). Harm avoidance was the only subscale unrelated to ADHD symptoms within the structural model (β = -.033, p>.05). The relationship between harm avoidance and ADHD symptoms is inconsistent with the other indicators of the anxiety factor. Harm avoidance is negatively correlated (r = -.166, p<.01) with ADHD symptoms, meaning as ADHD symptoms increase, the number of child-reported harm avoidance symptoms decreases. The remaining anxiety subscales were positively correlated with ADHD symptoms. Harm avoidance is also the only anxiety self-report measure significantly correlated with measures of academic achievement. As the number of reported harm avoidance symptoms increase, performance on tests of academic achievement also increases.

Table 3

Anxiety Factor Means, Standard Deviations, and Correlations with ADHD

Model Latent Factor	Model Measured Variables	Mean	S.D.	S.E.	*r* with ADHD
Anxiety	MASC Harm Avoidance	17.42	4.504	.204	-.166**
	MASC Separation Anxiety	9.06	5.037	.228	.126**
	MASC Social Anxiety	11.76	6.490	.294	.168**
	MASC Physical Symptom	9.00	5.991	.271	.198**
	CBCL Anxiety Problems	2.32	2.327	.105	.241**

Note. * $p < .05$, ** $p < .001$

Attention.

ADHD symptoms were predictive of poorer performance on the unmeasured latent variable representing attention, and every measured variable of attention (β = -.256, p<.05). Anxiety symptoms, holding constant symptoms of ADHD, were not predictive of attention (β = -.041, p>.05). In addition, only 7.7% of variance in attention was explained by ADHD and anxiety.

Working memory.

ADHD symptoms, attention, and anxiety symptoms explained 72% of the variance in working memory. More ADHD symptoms were both directly and indirectly predictive of poorer working memory (β_{direct} = -.230, p<.05; $\beta_{indirect}$ = -.207, p<.05). ADHD indirectly predicted working memory through attention. Anxiety symptoms were not predictive of working memory (β = -.017, p>.05). Better performance on measures of attention was also highly predictive of better performance on measures of working memory (β = .753, p<.05).

Academic achievement.

Overall, a significant portion of the variance of the academic achievement latent variable was explained by ADHD symptoms, anxiety symptoms, working memory, and attention (R^2 = 1.00). In the context of this structural model, ADHD symptoms were not directly predictive of high or low levels of academic achievement. However, there was a significant positive indirect effect of ADHD on academic achievement (β = -.487, p < .05). Recalling that higher ADHD symptom scores reflect the presence of more ADHD symptoms, more ADHD symptoms were predictive of lower academic achievement. Therefore, ADHD was only predictive of academic achievement indirectly through attention and working memory. Anxiety symptoms were not predictive of academic achievement ($\beta = -.017$, $p>.05$) in this model. Standardized parameter estimates of total effect of ADHD symptoms on oral reading fluency ($\beta = -.209$, $p<.05$), reading comprehension ($\beta = -.168$, $p<.05$), spelling ($\beta = -.222$, $p<.05$), and math computation ($\beta = -.232$, $p<.05$) were all significant and negative. More symptoms of ADHD predict poorer performance on every measure of academic achievement. Although differences in prediction of ADHD symptoms between measures of academic achievement were minor, ADHD symptoms were most highly predictive of poorer performance on the measure of math computation.

Higher scores on measures of working memory, controlling for attention, were also associated with better performance on measures of academic achievement ($\beta = 1.616$, $p<.05$). Although it appears that there is a negative relationship between attention and academic achievement ($\beta = -.799$, $p<.05$) meaning that better performance on measures of attention predicts lower scores on academic achievement, there is in fact a negative suppression effect in this model (Maassen & Bakker, 2001). The correlation between attention and academic achievement is significant and high (.47), and the sign switches when the regression coefficient is calculated. Negative suppression often occurs in a mediation model when $r_{(v1,v2)}$ and $r_{(v2,v3)}$ both exceed the correlation between variable 1 and variable 3 ($r_{(v1,v3)}$). In this model, the correlation between attention and academic achievement is not high enough to warrant the expected positive direct effect, resulting in a negative regression coefficient. However, the total effect of attention on working memory was strong and positive ($\beta = .418$, $p<.05$) and will be interpreted as such.

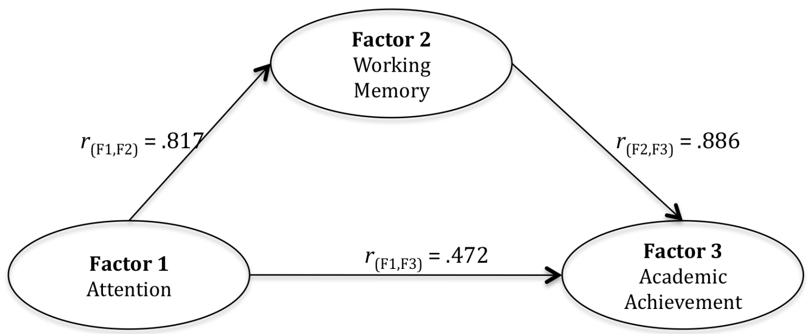

Figure 4. Correlations between factors to explain negative suppression effect in structural model.

Discussion

This study aimed to test how attention, working memory, and academic achievement were affected by symptoms of ADHD and anxiety. While previous studies have reviewed working memory and attention in children with ADHD, none have assessed the relative importance of attention and working memory to academic achievement. Moreover, few studies have examined how symptoms of both ADHD and anxiety on effect academic achievement through attention and working memory. Using structural equation modeling, this study uniquely examined a fuller picture of the phenomenology of academic achievement. Structural equation modeling allowed the simultaneous analysis of multiple measures of two constructs, attention and working memory, that are fundamental to the development of school success. There were three main findings as a result of these analyses. First, there was significant sequential prediction between attention, working memory, and academic achievement. Better performance on measures of attention and working memory predicted higher academic achievement, as relative weaknesses in academic achievement seen in children and adolescents with ADHD can be explained largely by deficits in attention and working memory. Second, anxiety symptoms were unrelated to attention, working memory, and academic achievement, when controlling for ADHD. Finally, the way in which we measure attention and working memory in children and adolescents are consistent within each domain.

ADHD, Anxiety, and Logan's Instance Theory

In Logan's Instance theory, attention affects working memory, which in turn affects academic achievement. While this theory was possibly first conceived to explain the factors affecting the encoding of memory in purely cross-sectional moments, the purpose here was to test the theory in the context of general measurement of current abilities in attention, working memory and academic achievement in children and adolescents. Results suggest that not only is there significant sequential prediction between each factor, but the model created to replicate a theory of automaticity fit the data well. Decreased attention and working memory in children with ADHD and anxiety are associated with decreased academic achievement. In the literature, a strong direct relationship has been established between symptoms of ADHD and academic achievement. However, in the presence of the factors representing attention and working memory, the direct relationship between ADHD and academic achievement was insignificant. This model suggests that the relative weaknesses in academic achievement seen in children with ADHD can be explained largely by deficits in attention and working memory. Therefore, poorer academic performance observed in children with ADHD is directly related to their relative strength or weakness in attentional and working memory domains.

We can also conclude from this study that although children with more symptoms of ADHD have more symptoms of anxiety, it is unclear that anxiety symptoms, while controlling for ADHD, have any effect on attention, working memory, or academic achievement. The structural model presented here yielded neither significant effects of anxiety on the broader domains, nor the individual indicators of attention, working memory, and academic achievement and will thus require further exploration. Children with anxiety do exhibit an attentional bias toward threat, and therefore tasks targeting severity of attentional bias may better explain differences in academic achievement. In contrast, more symptoms of ADHD were directly predictive of poorer performance on all measures of attention and working memory. ADHD symptoms were also indirectly associated with poorer performance on all measures of academic achievement.

The comorbidity between reading and ADHD has received much attention in the literature. Although there appeared to be minor differences between the effects of ADHD symptomotology on children's reading fluency, reading comprehension, spelling, and math computation, ADHD symptoms appeared to have the greatest affect on math computation. Thus, future studies should further study factors associated with math achievement in children with ADHD.

ADHD and Harm Avoidance

ADHD and anxiety frequently co-occur in pediatric populations, and all but one of the subscales measuring anxiety (harm avoidance) revealed that as ADHD symptoms increase, symptoms of anxiety do as well. Perfectionism symptoms (e.g. doing everything exactly right) and anxious coping symptoms (e.g. checking to make sure things are safe) are the two subscales that make up harm avoidance. In the context of the structural model, the harm avoidance subscale was the only anxiety subscale unrelated to symptoms of ADHD. However, when the relationship between ADHD and harm avoidance were examined alone, more ADHD symptoms were related to less harm avoidance. This is unsurprising due to reported impulsivity and risk-taking in children with ADHD. Meticulous attention to detail and greater influence of top-down self-regulatory control systems evidenced by strict rule following and obedience can be characteristic for children with an anxiety disorder, but the opposite is often true for children with ADHD. Features of ADHD including lack of attention to detail, impulsivity, and the frequent co-occurrence of oppositional defiant disorder stand in stark contrast to the features of the harm avoidance subscale. The harm avoidance subscale was also the only self-report anxiety subscale positively and significantly correlated with measures of academic achievement (see Table 1). Although dimensions of anxiety did not significantly predict attention, working memory, or academic achievement performance in the structural model, future research is necessary to investigate differences in relationships between ADHD and certain aspects of anxiety. This would be an important contribution, including possible differences in neurobiological etiology that may differentially affect anxiety disorders and can be illuminated by the comorbidity of ADHD.

Measurement and Latent Variables

A significant contribution of this study is confirmation of the consistency with which we measure important domains of executive functioning in a large sample of children with ADHD and anxiety. For the most part, the indicators of each factor loaded well, however there were some exceptions. After the LM tests, all latent variables remained unchanged from the a priori model. While typically post-hoc modifications based on characteristics of a specific sample are discouraged, one purpose of these analyses was to explore if tasks used to measure the same constructs were in fact doing exactly that. Through these analyses it appears that among the tests used in this study, there is surprising consistency in the way that working memory, attention, and achievement are measured. Despite heterogeneity in method of task administration, including computer-based measures and paper and pencil tasks, indicators of each factor remained loaded on the single factor to which their relationship had been hypothesized.

Revisiting the literature, both attention and working memory are divided into several domains. In this study, sustained attention was measured through three different computer-based measures. It comes as no surprise that the three measures of sustained attention were highly correlated and highly predictive of working memory and attention. The same is true of working memory, which can be divided into auditory-verbal and visuo-spatial working memory. It was expected that even though there is substantial distinction between the two areas of working memory, the measures of these categories would be highly related and load onto a single factor. This hypothesis was confirmed as each measure of working memory loaded significantly onto the latent construct.

The measured variables loaded well and distinctly onto factors without cross-loadings. However, the relatively weaker relationship between attention and academic achievement compared to working memory and academic achievement may bring to light important distinctions in methods of measurement used in this model. The dissimilarity in method of measurement between the attention factor (all computer-based) and the academic achievement factor (all paper and pencil) suggests that it may be relatively unclear if consistency in measurement style artificially inflates the relationship between factors, or if relationships between constructs can truly be equally measured using different methods. Further study of assessments used to measure the specific constructs included here are important to clarify this phenomenon.

In conclusion, impairment in reading and math achievement in children with ADHD can be explained by a concurrent weakness in attention and working memory. In this study, structural equation modeling revealed the complexity of the relationship between attention, working memory, and academic achievement that could not be uncovered using other analytic approaches.

Limitations and Future Directions

Unfortunately in these analyses we were not able to categorize the sample by diagnoses due to insufficient sample sizes of clinical levels of anxiety in the absence of ADHD. Instead, we used number of symptoms as a continuous predictor of attention, working memory, and academic achievement. Future research would be needed to compare the theoretical model in children with ADHD, ADHD and anxiety, and anxiety alone. Another valuable addition to the literature would be to compare this model in males and females to ensure consistency. It is also important to note that the intent of these analyses was not to establish a causal relationship between variables. Instead, complex relationships between variables were established within structural equation modeling, a procedure that can be used to reject implausible structural hypotheses.

There are several areas of this study that require further exploration. The measures of attention used in these analyses primarily tapped the domain of sustained attention. Including other aspects of attention including shifting, selective attention, and possibly even attentional bias toward threat in an anxiety sample may further elucidate the relationship between attention, working memory, and academic achievement. Higher residuals between the MASC harm avoidance subscale, ADHD symptoms, and the tasks of academic achievement suggest that it may be of value to explore the theoretical underpinnings of the relationship between harm avoidance, attention, and the role of ADHD in this relationship.

Despite these limitations, this study is one of the first to examine the effects of symptoms of ADHD and anxiety on the phenomenology of academic achievement, in addition to consistency in our measurement of important domains of executive functioning that are impaired in many childhood developmental disorders. From these findings, extensions may be made to other areas of school content that may be also impacted by deficits in attention and working memory associated with ADHD and anxiety. This study will produce findings that inform not only the theory of underlying deficits in children with ADHD and anxiety, but also intervention in the areas of oral reading fluency, comprehension, and mathematical computation. Findings regarding the source of deficits can inform practitioners and allow for better and more targeted intervention techniques in order to improve outcomes for children struggling to achieve and engage at school.

References

Achenbach, T. M. (1991). Manual for the Child Behavior Checklist/4-18 and 1991 Profile. Burlington, VT: University of Vermont, Department of Psychiatry.

American Psychiatric Association. (2000). *Diagnostic and Statistical Manual and Mental Disorders,* 4th edn, American Psychiatric Association.

Baddeley, A. D. (1990). *Human Memory: Theory and Practice.* Allyn & Bacon. Boston, MA.

Baddeley, A. D. & Hitch, G. (1974) in The Psychology of Learning and Motivation, ed. Bower, G. A. (Academic, New York), Vol. 8, pp. 47–89.

Band, G. P., van der Molen, M. W., & Logan, G. D. (2003). Horse-race model simulations of the stop-signal procedure. *Acta Psychologica, 112,* 105-142.

Bedard, A.C., & Tannock, R. (2008). Anxiety, methylphenidate response, and working memory in children with ADHD. *Journal of Attention Disorders, 11*(5), 546-557.

Bendetto-Nasho, E., & Tannock, R. (1999). Math computation, error patterns and stimulant effects in children with Attention Deficit Hyperactivity Disorder. *Journal of Attention Disorders, 3*(), 121-134.

Bentler, P. M. (2006). *EQS 6 structural equations program manual*. Encino, CA: Multivariate Software, Inc.

Bentler, P. M. (2007). On tests and indices for evaluating structural models. *Personality and Individual Differences, 42*, 825-829.

Bentler, P. M. (1990). Comparative fit indexes in structural models. *Psychological Bulletin*, *107*, 238-246.

Bentler, P. M. (1986). *Lagrange Multiplier and Wald tests for EQS and EQS/PC*. Los Angeles: BMDP Statistical Software.

Brown, C. H. (1983). Asymptotic comparison of missing data procedures for estimating factor loadings. *Psychometrika, 48*, 269-291.

Byrne, B. M. (1994). *Structural equation modeling with EQS and EQS/Windows: basic concepts, applications, and programming.* Thousand Oaks, CA: Sage Publications.

Carnoldi, C., Marzocchi, G. M., Belotti, M., Caroli, M. G., De Meo, T., & Braga, C. (2001). Working memory interference control deficit in children referred by teachers for ADHD symptoms. *Chld Neuropsychology, 7*(4), 230-240.

Conners, C. K. (1996, October). *Clinical use of the Continuous Performance Test: Diagnostic utility and drug sensitivity.* Paper presented at the 1996 Annual Meeting of the American Academy of Child and Adolescent Psychiatry, Philadelphia, PA.

Engle, R. W., Cantor, J., & Carullo, J. J. (1992). Individual differences in working memory and comprehension: a test of four hypotheses. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 18*(5), 972-992.

Eriksen, B. A., & Eriksen, C. W. (1974). Effects of noise letters upon the identification of a target letter in a nonsearch task. *Perception and Psychophysics, 16*(1), 143-149.

Eysenck, M. W., & Calvo, M. G. (1992). Anxiety and performance: the processing efficiency theory. *Cognition and Emotion, 6*, 409-434.

Gaze, G., Kepley, H. O., & Walkup, J. T. (2006). Co-occurring psychiatric disorders in children and adolescents with Tourette Syndrome. *Journal of Child Neurology, 21*(), 657- 664.

Glahn, D. C., Therman, S., Manninen, M., Huttunen, M., Kaprio, J., Lonnqvist, J. et al. (2003). Spatial working memory as an endophenotype for schizophrenia. *Biological Psychiatry, 53,* 624-626.

Goldston, D.B., Walsh, A., Arnold, E.M., Reboussin, B., Daniel, S.S., Erkanli, A., Nutter, D., Hickman, E., Palmes, G., Snider, E., & Wood, F.B. (2007). Reading problems, psychiatric disorders, and functional impairment from mid- to late adolescence. *Journal of the American Academy of Child and Adolescent Psychiatry, 46*(1), 25-32.

Halperin, J. (1996). Conceptualizing, describing, and measuring components of attention: a summary. Pp 119-136. In Attention, Memory, and Executive function, Lyon, G. R. & Krasnegor, N. A. (Eds.). Paul H Brookes Publishing Co: Baltimore, MD.

Hammerness, P., Geller, D., Petty, C., Lamb, A., Bristol, E., & Biederman, J. (2010). Does ADHD moderate the manifestation of anxiety disorders in children? *European Journal of Child and Adolescent Psychiatry, 19*(), 107-112. DOI 10.1007/s00787-009-0041-8.

Hudson, R. F., Pullen, P. C., Lane, H. B., & Torgesen, J. K. (2008). The complex nature of reading fluency: a multidimensional view. *Reading and Writing Quarterly, 25*(1), 4-32.

Ialongo, N., Edelsohn, G., Werthamer-Larsson, L., Crockett, L., & Kellam, S. (1994). The significance of self-reported anxious symptoms in first-grade children. *Journal of Abnormal Child Psychology, 22*(4), 441-455.

Jacobsen, L.A., Ryan, M., Martin, R.B., Ewen, J., Mostofsky, S.H., Denckla, M.B., & Mahone, E.M. (2011). Working memory influences processing speed and reading fluency in ADHD. *Child Neuropsychology, 17*(3), 209-224. DOI: 10.1080/09297049.2010.532204.

Jarrett, M.A., & Ollendick, T.H. (2008). A conceptual review of the comorbidity of attention-deficit/hyperactivity disorder and anxiety: implications for future research and practice. *Clinical Psychology Review, 28*(), 1266-1280.

Jensen, P. S., Hinshaw, S. P., Kraemer, H. C., Lenora, N., Newcorn, J. H., Abikoff, H. B., March, J. S., Arnold, E., Cantwell, D. P., Conners, C. K., Elliott, G. R., Greenhill, L. L., Hechtman, L., Hoza, B., Pelham, W. E., Severe, J. B., Swanson, J. M., Wells, K. C., Wigal, T., * Vitiello, B. (2001). ADHD comorbidity findings from the MTA study: comparing comorbid subgroups. *Journal of the American Academy of Child and Adolescent Psychiatry, 40*(2), 147-158.

Jonides, J., Smith, E. E., Koeppe, R. A., Awh, E., Minoshima, S., & Mintun, M. A. (1993). Spatial working memory in humans as revealed by PET. *Nature, 363*, 623-625.

Kaufman, J., Birmaher, B., Brent, D., Rao, U., Flynn, C., Moreci, P., Williamson, D., & Ryan, N. (1997). Schedule for affective disorders and schizophrenia for school aged children-present and Lifetime Version (K-SADSPL). *Journal of the American Academy of Child and Adolescent Psychiatry, 36*(7), 980-988.

Logan, G. (1997). Automaticity and reading: perspectives from the instance theory of automatization. *Reading and Writing Quarterly, 13*(2), 123-146.

Logan, G. D., Cowan, W. B., & Davis, K. A. (1984). On the ability to inhibit simple and choice reaction time responses: a model and a method. *Journal of Experimental Psychology: Human Perception and Performance, 10,* 276-291.

MacCallum, R. C., Browne, M. W., & Sugawara, H. M. (1996). Power analysis and determination of sample size for covariance structure modeling. *Psychological Methods, 1*(2), 130-149.

Martinussen, R., Hayden, J., Hogg-Johnson, S., & Tannock, R. (2005). A meta-analysis of working memory impairments in children with attention-deficit/hyperactivity disorder. *Journal of the American Academy of Child and Adolescent Psychiatry, 44*(4), 377-384.

March, J. S., Parker, J. D., Sullivan, K., Stallings, P., & Conners, C. K. (1997). The Multidimensional Anxiety Scale for Children (MASC): factor structure, reliability, and validity. *Journal of the American Academy of Child and Adolescent Psychiatry, 36*(4), 554-565.

Maassen, G. H., & Bakker, A. B. (2001). Suppressor variables in path models: definitions and interpretations. *Sociological Methods and Research, 30*(2), 241-270.

Mayes, S. D., Calhoun, S. L., Bixler, E. O., & Zimmerman, D. N. (2009). IQ and neuropsychological predictors of academic achievement. *Learning and Individual Differences, 19*(), 238-241.

Merikangas, K.R., He, J., Brody, D., Fisher, P.W., Bourdon, K., & Koretz, D.S. (2010). Prevalence and treatment of mental disorders among US children in the 2001-2004 NHANES. *Pediatrics, 125*(1), 75-81. doi:10.1542/peds.2008-2598.

Morris, L. W., Davis, M. A., & Hutchings, C. H. (1981). Cognitive and emotional components of anxiety: literature review and a revised worry-emotionality scale. *Journal of Educational Psychology, 73*(4), 541-555.

Morris, R. D. (1996). Relationships and distinctions among the concepts of attention, memory, and executive function. In Lyon, G. R., & Krasnegor, N. A (Eds.), *Attention, Memory, and Executive Function* (pp. 235-261). Paul H. Brooks Publishing Co., Inc: Baltimore, MD.

Owens, M., Steventson, J., Norgate, R., & Hadwin, J. A. (2008). Processing efficiency theory in children: working memory as a mediator between trait anxiety and academic performance. *Anxiety, Stress and Coping: An International Journal, 21*(4), 417-430.

Pennington, B. F., & Ozonoff, S. (1996). Executive functions and developmental psychopathology. *Journal of Child Psychology and Psychiatry, 37*(1), 51-87.

Polanczyk, G., Silva de Lima, M., Horta B. L., Biederman, J., & Rohde, L. A. (2007). The worldwide prevalence of ADHD: a systemic review and metaregression analysis. *American Journal of Psychiatry, 164*(), 942-948.

Schatschneider, C., Fletcher, J. M., Francis, D. J., Carlson, C. D., & Foorman, B. R. (2004). Kindergarten prediction of reading skills: A longitudinal comparative analysis. *Journal of Educational Psychology*, 96, 265–282.

Schulz, K. P., Newcorn, J. H., Fan, J., Tang, C. Y., & Halperin, J. M. (2005). Brain activation gradients in ventrolateral prefrontal cortex related to persistence of ADHD in adolescent boys. *Journal of the American Academy of Child and Adolescent Psychiatry, 44,* 47-54.

Snodgrass, J. G., & Corwin, J. (1988). Pragmatics of measuring recognition memory: applications to dementia and amnesia. *Journal of Experimental Psychology: General, 117*(1), 34-50.

Sternberg, S. (1969). Memory-scanning: mental processes revealed by reaction- time experiments. *American Scientist, 57,* 421-457.

Tannock, R., Ickowicz, A., & Schachar, R. (1995). Differential effects of methylphenidate on working memory in ADHD children with and without comorbid anxiety. *Journal of the American Academy of Child and Adolescent Psychiatry, 34*(7), 886-896.

van Zomeren, A. H., & Brouwer, W. H. (1994). Clinical Neuropsychology of Attention. U.S.A.: Oxford University Press.

Visu-Petra, L., Ciairano, S., & Miclea, M. (2006). Neurocognitive correlates of child anxiety: a review of working memory research. *Cognition, Brain, Behavior*, *10*(4), 517-541.

Vloet, T. D., Konrad, K., Herpertz-Dahlmann, B., Polier, G. G., & Günther, T. (2009). Impact of anxiety disorders on attentional functions in children with ADHD. *Journal of Affective Disorders, 124*(), 283-290.

Weschler, D. Weschler Intelligence Scale for Children, Integrated: Technical and Interpretive Manual IV Edition. San Antonio, TX: PsychCorp; 2004.

Weissman A.S., Chu, B.C., Reddy, L.A., & Mohlman, J. (2012). Attention mechanisms in children with anxiety disorders and in children with attention deficit hyperactivity disorder: implications for research and practice. *Journal of Clinical Child and Adoelscent Psychology, 41*(2), 117-126.

Wiederholt, J. L., & Bryant, B. R. (2001). GORT 4: Gray Oral Reading Tests examiner's manual. Austin, TX: PRO-ED.

Wigal, S.B., Maltas, S., Crinella, F., Stehli, A., Steinhoff, K., Lakes, K., & Schuck, S. (2012). Reading performance as a function of treatment with lisdexamfetamine dimesylate in elementary school children diagnosed with ADHD. *Journal of Attention Disorders, 16*(1), 23-33.

Wilkinson, G. S., & Robertson, G. J. (2006). *Wide Range Achievement Test: Fourth Edition.* Lutz, FL: Psychological Assessment Resources.