1-1-2014

Predicting Adolescents' Academic Achievement: The Contribution of Attention and Working Memory

Diane Elizabeth Napier
University of South Florida, dnapier5@tampabay.rr.com

Predicting Adolescents' Academic Achievement:

The Contribution of Attention and Working Memory.

by

Diane E. Napier

A dissertation submitted in partial fulfillment
of the requirements for the degree of
Doctor of Philosophy
in Curriculum and Instruction
Psychological and Social Foundations
College of Education
University of South Florida

Major Professor: Darlene DeMarie, Ph.D.
James King, Ed.D.
Jeffrey Kromney, Ph.D.
Barbara Shircliffe, Ph.D.

Date of Approval:
November 10th, 2014.

Keywords: reading achievement, math achievement, written expression

Acknowledgments

I would like to thank my Chair, Dr. Darlene DeMarie, for her patience in guiding me through this process. Your high expectations and high standards encouraged me to continue working to complete the finished product. This finished product is proof of your abilities as a wonderful dissertation chair.

I also thank my committee members, Dr. James King, Dr. Jeffrey Kromrey, and Dr. Barbara Shircliffe for their expertise and patience with me throughout the writing of this dissertation. I also thank retired committee members Dr. Mary Lou Morton, and Dr. Nancy Williams for their guidance and instruction in the early development of this work.

All of you made the writing of the dissertation a very valuable experience

Table of Contents

List of Tables

List of Figures

Abstract

The present study examined the direction and strength of the relation between three different areas academic achievement and working memory with adolescent students. The data analyzed included ratings for inattention, a diagnosis of ADHD (or not), and demographic information for race/ethnicity. Fifty children aged 11 to16 years of age participated in the study. Participants were recruited from several middle schools, homeschooling networks, and churches from a southeastern state of the United States. Each participant completed a standardized achievement test, a behavioral rating scale, and visual and verbal working memory tests. The research questions investigated: 1) the relation between visual and verbal working memory with each of three areas of academic achievement; 2) whether the relation between visual and verbal working memory was strengthened or moderated by inattention.

Results found that verbal-auditory working memory ($p= <.01$) and visual-spatial working memory ($p=<.01$) each predicted both math and reading achievement. However, only verbal-auditory working memory predicted written expression achievement ($p=.01$). There was a positive relation between the working memory scores and academic achievement, with higher working memory scores predicting higher academic achievement. Due to significant differences with the standardized testing scores between Caucasians and non-Caucasians, the analysis was controlled for ethnicity. The measure of inattention problems did not add significantly to or moderate the prediction of academic achievement by visual or verbal working memory after controlling for ethnicity. Future recommendations included research to support students with low working memory skills and to examine the cultural sensitivity of the working memory batteries.

Chapter One:

Introduction

Considerable research has documented a strong correlation between intelligence quotients and academic achievement (Greven, Harlaar, Kovas, Chamorro-Premuzie, & Plomin, 2009). Intelligence (i.e., individual general cognitive ability) is widely considered the single most important predictor of academic performance (Deary, Strand, Smith, & Fernandez, 2007; Rhode & Thompson, 2007; Sattler, 2001). Traditionally this general cognitive ability has been measured with intelligence tests such as the Stanford Binet Intelligence Scale, which is now in its fifth edition. Currently there are several other full scale intelligence tests which include, but which are not limited to: The Wechsler Intelligence Scale for Children (Wechsler, 1949), and the Universal Nonverbal Intelligence Tests (Riverside Publishing). Each test has a unique target population, and each test also provides information about different aspects of cognitive functioning. The intelligence quotient obtained on traditional assessments like these compares scores obtained on a ratio based on the child's biological age to their mental development. Normative samples provided the bases for normal trends at different ages and stages of development.

Background of the Problem

There are criticisms of the use of intelligence tests as predictors of future academic achievement due to factors outside of the individual's control that are situated in their environment. Bronfenbrenner's (Bronfenbrenner, 1994; Bronfenbrenner & Ceci, 1993) Bio-Ecological Systems Theory describes several layers of ecological and environmental conditions which directly influence the development of the individual (Swick & Williams, 2006), and which interact with one another. These include the microsystem (e.g., the child's family or classroom), the mesosystem, (i.e., how two microsystems, such as home and school, interact), the exosystem (i.e., external environments that influence an individual's development, such as where the parents work), the macrosystem (i.e., larger socio-cultural contexts special to communities, different cultural groups, and countries), and the chronosystem (i.e., the time frame in which children and their environment are situated). These moderate the relation between intelligence and academic performance (Hart & Risley, 1995; Hoff & Tian, 2005; Nisbett, Aronson, Blair, Dickens, Flynn, Halpern & Turkheimer, 2012).

In the past 20 years, memory research led to the development of working memory assessments that also predicted academic performance. Working memory became a term which represented the short storage and manipulation of information actively being used by the individual to help process incoming task demands and outgoing responses. The working memory assessments measured the unique visual and verbal working memory skills of individuals. This approach has been an important departure from traditional IQ testing, because research has found the prediction of academic achievement by working memory appears to be independent of influences from external environmental factors such as maternal mother's education or age of leaving school (Alloway & Alloway, 2011).

Statement of the Problem

Working memory is described as the part of brain behavior which holds and processes incoming information; manipulating the information as needed for actions, or processing it for long term storage. It is defined as a component which is responsible for storage (capacity of information held in short term memory at a given time) and processing (manipulation and/or reflection of information in short term memory prior to retelling or any other actions) of incoming information. Working memory is involved in a range of regulatory functions which include retrieval from long-term (previously learned) memory (Baddeley, 2000).

Currently, the most widely used model in education is Baddeley's (2000) model. Baddeley's model of memory focused on the working memory, which added to an earlier theoretical construct called short term memory. Baddeley's model (2000) of working memory defined separate processing routes for each of verbal and visual working memory. He also identified directional flows of information within the memory systems. His model suggested that incoming sensory information went through an executive control area which then sent it to either of two slave processing systems: one for visual and one for verbal processing (see Figure 1).

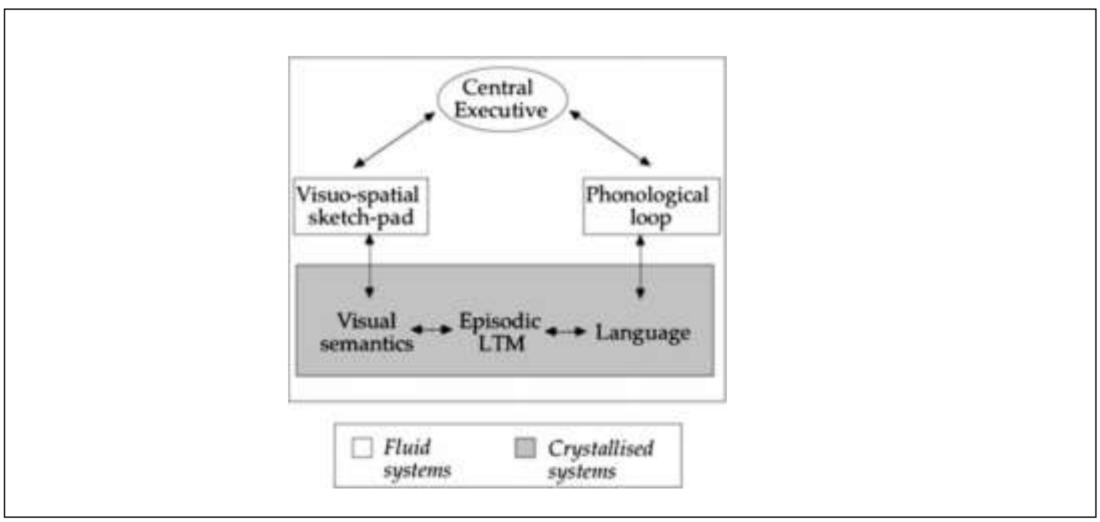

***Figure 1*:** Baddeley's Model of Working Memory (2011),
Reproduced with permission by Baddeley 06/25/13

Research has supported Baddeley's theoretical model and supported the existence of separate visual and verbal processing routes (Baddeley, 2000). The visual memory processing route is referred to as the visual sketchpad in Baddeley's (2000) model. This can be described as the eyes perceiving incoming sensory information, which is then processed in the visual sketchpad working memory storage area. Incoming sounds heard through the ears are processed in the auditory-verbal memory system which is also called a Phonological Loop. Working memory includes processing as well, as a person can hold and manipulate information simultaneously. The Central Executive in Baddeley's model directs an individual's attention to first focus on the stimulus and then to use one of these processing routes.

Memory research supports differences in people's understanding, processing, and memory for visual images, which can be based on the interaction between incoming sensory information and long term stored knowledge. A classic example of differences in individuals' memory is the interaction between different processing components evident in eyewitness testimony (Loftus, 1980; Tuckey, Rae, & Brewer, 2003). Studies found that witnesses cannot only make different statements about same events, but witnesses can also make errors in correctly identifying faces seen previously. Prior learning or biases can influence remembered events when people are questioned about them. However, not only is prior learning different among individuals, but the processing abilities for incoming verbal and visual information also differ among people.

Baddeley describes a phonological loop within his working memory model which corresponds with auditory and verbal processing routes. Examples of auditory verbal processing include a scenario such as the following: an individual is presented with auditory stimuli (e.g.,the 7 to 10 digits for a phone number). Then the individual rehearses (either silently or aloud) what he or she has heard until he or she can recall the number correctly. The individual then uses the information to make a call. Other research suggests people internalize oral language into inner speech (Vygotsky, 1978), and this enables both learning and language development (Landry, Miller-Loncar, Smith, & Swank, 2002).

Individual differences in working memory have been shown to predict academic performance. These differences are also a significant factor associated with children's ability to learn (Alloway, Gathercole, Willis & Adams, 2004). Alloway et al. (2004) reported that children's ability to store and to manipulate information in short-term memory was closely associated with academic achievement. Other researchers have reported that this is especially true in reading (De Jong, 1998; Swanson, 1994), mathematics (e.g., Bull & Scerif, 2001; Mayringer & Wimmer, 2000), and language comprehension (Seigneuric, Ehrlich, Oakhill, & Yuill, 2000).

The problem with working memory research is that not only does it not explain a substantial amount of the variance in the prediction of academic performance. There are differences between young children and older adolescents in the strength of the prediction of their working memory scores for their academic achievements. Therefore, current research examines other factors that may explain some of the variance in the prediction of academic achievement, or which may moderate the relation between working memory and academic achievement.

Some studies with students who have a diagnosis of Attention Deficit Hyperactive Disorder (ADHD) have examined whether working memory performance can be improved with training (Melby-Levag & Hume, 2012), or whether psycho-stimulant medications affect the relation between working memory and academic achievement (Kibby & Cohen, 2008). Other studies have examined attention (Alloway, Elliott, & Place, 2010), inattention (Rogers, Hwang, Toplak, Weiss, & Tannock, 2012), and the maturational age of the participant (Gathercole, Brown, & Pickering, 2003) as variables which may add significantly to the prediction of academic achievement by working memory.

A second problem with models of working memory is that some researchers place attention within a central position situated within all aspects of memory (Cowan, 2011), while others describe executive functioning processes (which can include attention) as a separate processing component (Baddeley, 2000). There also is interest in the impact that attention has within the memory model, and how it relates to the prediction of academic achievement (St. Clair-Thompson & Gathercole, 2007).

A third problem is that attention is a concept which is currently measured in different ways within different branches of psychological research. Cognitive psychologists measure attention as part of the executive functions (i.e., as brain-based behaviors which organize and direct behavior). Executive functioning brain behaviors are often associated with the frontal lobe area of the brain. Components of executive functioning activities include planning, attention, shifting attention, and organizational skills (Gioia, Isquith, Guy, & Kenworthy, 2000).

Educational researchers have examined the constructs of attention and/or inattention as they relate to behaviors commonly seen in the school setting; specifically, the lack of attention to a task and difficulty attending to details in academic work. This is most frequently measured with rating scales (Connors, 2012; Reynolds & Kamphaus, 2002). For teacher or parent rating scales, the perception of a child's behavior is rated across different categories which can include attention, inattention, school problems, or other observable behaviors. A limitation of this is that the ratings are socially constructed, so a child may present different behaviors across different situations, or the same behaviors may be perceived differently by different raters. For this reason, validity indices are often built into the assessments (Reynolds & Kamhaus, 2004), which help assess the reliability and consistency of the scores reported by the rater. These validity indices also examine the construct from different raters (i.e., teachers, parents, or self-reports).

Baddeley's model reports two different executive function components: the central executive and the episodic buffer. These two components share the functions of directing attention to processing needs, manipulating information, actively recalling, or focusing on rehearsal needs. The central executive is a part of the working memory model which directs attention and memory processes and regulates the acquisition of information for cognitive processing (St. Clair-Thompson and Gathercole, 2007). The episodic buffer is reported to be responsible for integrating information from both the short term and the long term memory (Baddeley, 2000). Senn, Espy, and Kaufman (2004) have found individual differences in children's working memory within the organization and development of their executive functions.

Clinical and medical psychiatric research studies of students with attention deficit hyperactivity disorder (Alloway, Elliott, & Place, 2010; Willcutt, Doyle, Nigg, Faraone, & Pennington, 2005) have focused on the relations between attention problems, working memory, and academic achievement. In these studies attention has been measured with social and behavioral rating scales sensitive to detect clinical levels of behaviors directly related to Attention Deficit Hyperactivity Disorder (ADHD). Although the research found that students with ADHD tended to underachieve academically (Marshall, Hynd, Handwerk, & Hall, 1997), questions remain whether the verbal and visual components of working memory are separately influenced by inattention (Rogers et al., 2012). The present study therefore examined if inattention moderated the relation between working memory and academic achievement. Assessments for both the verbal and visual components of the working memory model were included to allow for examination of separate trends for each component.

The present also addressed a fourth problem within current working memory research, which is the lack of research on written expression. There are many different outcome measures used throughout the literature with different maturational ages of participants, and currently there is limited research which reports how the different components of Baddeley's (2000) working memory model relate to the prediction of three different areas of academic achievement with adolescent students. The present study examined each of three academic areas (reading, writing, and math) by each of the two components from the working memory. Previous research has found that subcomponents of working memory predict math and reading performance differently (Alloway, Gathercole, Holmes, Place & Hilton, 2009; Rogers et al., 2012).

In the present study, attention was assessed by the score achieved on a rating scale construct for problems with attention and inattention. The relation of the inattention score, the working memory scores, and the prediction of academic achievement were then examined for trends.

Purpose of the Study

The purpose of the present study was to examine the role of attention/inattention as a moderator of the relation between working memory and academic achievement. A study by Rogers, Hwang, Toplak, Weiss, and Tannock (2012) investigated the relations between academic achievement and working memory with adolescent students. However, every student in their participant pool had a clinical diagnosis of ADHD, and their control group had other or comorbid mental health conditions. The proposed study examined the relation between attention problems and working memory with a population of students which could typically be found in a classroom (i.e., students with a diagnosis of ADHD and other students with no diagnosis of ADHD combined in one instructional setting). Broad behavior rating scales were used to measure perceived inattention problems, because rating scales have been found to be able to distinguish different impairments in the classroom which can affect learning outcomes (Alloway, Gathercole, Holmes, Place & Hilton, 2009).

The first purpose of the present study was to examine the relation between both visual and auditory working memory scores and three areas of academic achievement: reading, math, and written expression. There has been limited information in prior research documenting the prediction of written expression by working memory assessments.

The second purpose of this research was to examine the power of self-report of attention as a variable which may moderate the relation between working memory and academic achievement. This is important because teachers may assume there is a relation between a display of attention problems by some students and their poor academic achievement. If the present study found that inattention problems were found to be a significant moderator of the relation between working memory and academic achievement, the results could suggest that interventions to address inattention may result in higher academic gains.

Proposed Study

The present study specifically built on the research of Rogers et al. (2012) which examined the contribution of attention when achievement was predicted by working memory. Attention problems were measured as moderators in the prediction of achievement because research has found that students with Attention Deficit Hyperactive Disorder have lower achievement results than typically developing students (Rogers et al., 2012). Rogers et al. (2012) examined ‘inattention’, through an index score on the teacher form of the Strengths and Weaknesses of ADHD-symptoms and Normal Behavior Scale (SWAN: Swanson, Schuck, Mann, Carlson, Hartman, & Sergeant, 2005). The Behavior Assessment of School Children, BASC (Reynolds & Kamphaus, 2004) rating scale was used in the present study because it represents a broadband behavior rating scale which does not specifically screen for Attention Deficit Hyperactive Disorder. The Behavior Assessment of School Children rating scale contains an ‘inattention’ index. The SWAN (2005) and the BASC (2004) rating scales both consider the constructs of attention and inattention to be linear. This linear representation of the construct enabled a quantitative analysis of the data set.

The present study also examined written expression as a third academic area to be predicted by working memory. This was selected because the literature examining the prediction of academic achievement by working memory and attention has primarily focused on math and reading comprehension, but it has not also tested for written expression skills. As the Rogers et al. (2012) study only used reading and math scores for their outcome measures, the present study was built on the literature in the field by also examining the prediction of written expression.

Overview of the Research Method and Design Appropriateness

The research method was quantitative, and standardized scores were obtained by testing students who volunteered, had parent consent to participate in the study, and who met the selection criteria. The design was similar to the design by Rogers et al. (2012), so the results could be added to the knowledge of working memory, attention problems, and academic achievement with adolescent students as participants. Rogers et al. (2012) used a path analysis method to answer their questions. The present study used a hierarchical regression method for the statistical analysis. This enabled the researcher to control for working memory when examining the contribution of attention to academic outcomes.

The assumptions for the present study were that quantitative data provide the best resource to examine trends between variables and to statistically analyze predictions about students' academic achievement. Scores obtained from testing were both normed and linear in value. The researcher recruited participants from a variety of demographic sources to enable a diverse population of participants. These sources included two public middle schools from socio-economically diverse neighborhoods, two different home-schooling networks which covered a fifty square mile radius, and four different church communities with active student programs.

Research Questions

Verbal working memory questions:

Question 1a. What is the direction and strength of the relation between reading achievement and verbal-auditory working memory?

Question 1b. Do attention problems add significantly to the prediction of reading achievement after controlling for verbal-auditory working memory?

Question 1c. Do attention problems moderate the relation between verbal-auditory working memory and reading achievement?

Question 2a. What is the direction and strength of the relation between math achievement and verbal-auditory working memory?

Question 2b Do attention problems add significantly to the prediction of math achievement after controlling for verbal-auditory working memory?

Question 2c. Do attention problems moderate the relation between verbal-auditory working memory and math achievement?

Question 3a. What is the direction and strength of the relation between written expression achievement and verbal-auditory working memory?

Question 3b. Do attention problems add significantly to the prediction of written expression achievement after controlling for verbal-auditory working memory?

Question3c. Do attention problems moderate the relation between verbal-auditory working memory and written expression?

Visual working memory questions:

Question 4a. What is the direction and strength of the relation between reading achievement and visual-spatial working memory?

Question 4b. Do attention problems add significantly to the prediction of reading achievement after controlling for visual-spatial working memory?

Question 4c. Do attention problems moderate the relation between visual-spatial working memory and reading achievement?

Question 5a What is the direction and strength of the relation between math achievement and visual-spatial working memory?

Question 5b. Do attention problems add significantly to the prediction of math achievement after controlling for visual-spatial working memory?

Question 5c Do attention problems moderate the relation between visual-spatial working memory and math achievement?

Question 6a. What is the direction and strength of the relation between written expression achievement and visual-spatial working memory?

Question 6b. Do attention problems add significantly to the prediction of written expression achievement after controlling for visual-spatial working memory?

Question 6c. Do attention problems moderate the relation between visual-spatial working memory and written expression?

Theoretical Framework

The theoretical framework for the present study built upon previous working memory research (Baddeley, 2000), which found support for different components (i.e., auditory and visual-spatial) of working memory in individuals. Specifically, the verbal-auditory processing component and visual-spatial components in working memory can be measured independently of each other, and each may provide a unique contribution to the prediction of academic achievement. The research also assumed the factor analysis of constructs for attention and attention problems in the rating scales measured a separate construct to working memory.

It should be noted this study built on the findings of other research (e.g., Rogers et al. 2012; Alloway, Gathercole, Willis, & Adams, 2004), which examined the impact of inattention on the relation between working memory and academic achievement. The Rogers et al. (2012) study examined the relation between inattention, working memory, and academic achievement in adolescent students referred for attention deficit/hyperactivity disorder. The Alloway et al. (2004) study examined the relation between working memory and cognitive skills in young children aged between 4 and 6 years old. These studies found support for a relation between verbal working memory and academic achievement in older students (Rogers et al., 2012), and a relation between verbal working memory and phonological processing in younger students (Alloway et al., 2004).

Assumptions

The assumptions for this research included the belief that the tests, assessments, and rating scales actually measured the constructs being researched: attention, working memory, and academic performance. For each of these constructs, dedicated scales were selected. The technical manuals were consulted to confirm the factor analysis for each construct, and values reported for reliability and validity data. These details will be shared in chapter 3.

The researcher assumed that when attention/attention problems were measured with behavioral rating scales that attention and inattention and attention problems shared the same construct. The attention problems index measured the attention problems the individual reported when reflecting on the school environment. The self-report rating scale for adolescents is normed to determine the level of problems typical for each age and grade level. Validity scores in the technical manual confirmed the test and retest accuracy of this assessment for the constructs measured, and also the comparative value when comparing scores achieved with other tests (Reynolds & Kamphaus, 2005).

The present study used the self-report rating scales from the Behavior Assessment of School Children to capture student perception of their attention because the population of students who participated in the research came from different sources, and not all participants had teachers in a school environment who could complete teacher rating scales (e.g., students with virtual learning or homeschooling situations), and some parents tutored their own children. For this reason a teacher rating scale and dedicated parent rating scale could not have been used with the entire population, as in some instances parents were also the students' teachers.

Another reason for selecting this measure was because previous research (Rogers et al., 2012) found that inattention measured with teacher and parent rating scales did not significantly mediate the prediction of every area of academic achievement by working memory. The researcher wished to gather data from an alternate source (i.e., a self-report scale) to determine if a different perspective could provide a different relation with the prediction of academic achievement. Theoretically, this was possible because self-report, teacher and parent rating scales all have high item and test validity with the construct, but the correlations between the parent, teacher and self-report forms are relatively weak (.03-.39). Achenbach et al. (1987) found that self-reports had a mean correlation of .20 with teacher ratings and .25 with parent ratings.

A second assumption in the present study was that the inattention problems measured in this study were separate behaviors from working memory skills. The research built on the Baddeley (2011) working memory model which suggested that attention may be a separate component in working memory, situated within the executive function and perhaps linked with the episodic buffer. For this reason, the research examined the contribution of attention as an independent moderating variable in the prediction of achievement by working memory.

The working memory battery of assessments measured the number and accuracy of items individuals remembered or manipulated using visual processing or auditory verbal processing skills. These tests were short and did not require sustained attention to task over time, and therefore, the construct of memory being measured was considered different to the information measured with the behavior rating scales. The behavior rating scales captured the construct of attention problems. Further details and sample questions for each of the assessments used is provided in chapter three.

Scope and Limitations

Limitations of this research include: the lack of control the researcher had over the time when the testing could occur, lack of control over the curriculum the participants had been exposed to, and no way of confirming if the manner of testing achievement matched the instructional experience of the student. Testing was limited to after school and on weekends, because permission was not provided by the local school authority to test during the school day. Therefore, as testing was on weekends or after school, the examiner had no control over fatigue level before testing, when the student had eaten, or any other personal condition which have affected a student’s test performance on that day. Although the research was conducted at sites which provided permission for the researcher to work with students, this time was limited to office hours. Therefore, most of the testing occurred on weekends, when the students may have given up some other preferred activity (i.e., a football or other sporting practice).

A second research design limitation was that although the Woodcock-Johnson assessment is standardized, the researcher was not able to discuss the syllabus content and delivery of the curriculum the students had received prior to testing as a factor which may have influenced the achievement results obtained on the test date.

Furthermore, the Woodcock-Johnson Tests of Achievement provided standardized measures which enabled comparison of scores between participants and groups. Each category of academics had unique limitations (e.g., in the reading comprehension portion, the passages required specific answers to obtain a full score). A limitation of determining the score for reading skills from this kind of formal test is that other assessment methods (e.g., participants could have talked about a subject with a teacher) could have offered a different kind of opportunity to discuss the content and to demonstrate comprehension. Gee (1996) considers reading comprehension a socially constructed exercise, with different meanings between the text, different readers, and the author. He suggested that literacy is broader than traditional reading books and lexile levels or standardized scores. Gee discussed literacy as a multi-modal conception within a new literacy framework. In this model (Gee,1996) discussed how new literacies are more than words read correctly or traditional text-based literacy. He suggests the social and cultural practices of each person are included economic, historical and political references. For this reason, traditional assessments may not provide sufficient opportunities to measure an individual's comprehension of literacy, and the results may be considered limited by the construct of the assessment perspective. Different assessment methods, with different constructs, have populated the literature on working memory. This has resulted in difficulty of interpreting and generalizing the results across ages and or subject areas.

The researcher selected the Woodcock-Johnson for measurement of reading comprehension, despite these limitations. One reason was because it is widely used in research. Second, it was selected because of the rigor of the standardizations for scores achieved, which provided normative comparisons by age, grade, and/or percentile for each measure of academic achievement.

Deliminations

Students with severe disabilities (e.g., autism, intellectual disability, or limited English proficiency) were not included in this participant pool because they did not have the same access to the same academic curriculum as typically-developing peers. Parents were provided with a self-report check list which required them to report if their child had a diagnosis of ADHD, a learning disability, or enrollment in a self-contained setting in school. Students were not delimitated if they had a current diagnosis of ADHD – as a typical population of adolescent students in general education would include those with and without any medical diagnosis for attention disorders.

The strength of the participant pool for the present study was that both students with ADHD and those without ADHD were included in the study. In the public school system, teachers are not able to require students with ADHD or suspected ADHD to take any form of medication. Therefore, random samples of middle school classes will find a mix of students with no diagnosis and no medicines, as well as students who have a diagnosis of ADHD and have either run out of medications, or have chosen not to take the medicine. The participant pool selected therefore enabled the researcher to examine the research questions with a sample of students which resembled a typical middle school group of students.

Chapter Two

Review of the Literature

This chapter contains a review of the research that is relevant to the prediction of academic achievement. For many years intelligence tests have been used to identify individual differences within students, and the scores obtained were then used to predict students' future academic achievement. Results of recent educational research have reported there is also a relation between individual students' working memory and academic achievement (St. Clair, Thompson, & Gathercole, 2007). Working memory refers to the amount of information that an individual can process, manipulate, and store when attending to a task. There are several different models of working memory, but the Baddeley model (Baddeley, 2000) is the one that is the most widely used in educational research.

The present chapter will provide an overview of Baddeley's model and will also explain the research to date that supports it. Currently, there is significant support for the relation between two of the components in Baddeley's model, e.g., the verbal-auditory memory (phonological loop), the visual-spatial memory (visual sketchpad), and academic achievement.

The literature on working memory now includes new models which consider the role that attention may contribute to the working memory processes (Cowan, 2011). Cowan's concept of the relation between attention and working memory is for one integrated process. He describes attention as central in the acquisition of sensory information through the verbal and/or visual routes.

This study built on past research and examined the prediction of academic achievement by working memory, while also examining the contribution that attention made as a potential moderator of that relation. Finally, the limitations of working memory research and the methodology used in the present study will be reviewed.

A Historical Perspective

American social and educational policy has been shaped by underlying assumptions that successful academic performance is related to individual differences in children. One of the most prominent of these individual differences is the construct of intelligence (Kranzler, 1997). The following section will review the historical use of intelligence (IQ) tests, with their strengths and weaknesses, when the IQ score obtained is used as predictors of academic achievement. Currently, the research in academic achievement is examining working memory as a better predictor variable, and the evidence for this new development requires an understanding of how working memory is defined. Three main models of working memory will be reviewed to enable a discussion about how perspective and definitions of the term affect the research in the literature.

The Prediction of Ability and Academic Achievement

Intelligence tests. Intelligence tests measure broad cognitive functioning (Nisbett, Aronson, Blair, Dickens, Flynn, Halpern, & Turkheimer, 2010). They have been used to help determine which children are low performers and which children have more serious cognitive or learning disabilities (Nisbet et al., 2012). Support for the use of psychometric measurement of intelligence as a strong predictor of school achievement is documented by many researchers (Parker & Benedict, 2002; Naglieri & Bornstein, 2003; Yen, Konold, & McDermott, 2004). Strong correlations have been found between intelligence test scores and academic achievement test scores, which have led to the discussion of causality. Specifically, there have been discussions of whether the relation between intelligence and achievement is reciprocal or causal (Watkins & Canivez, 2006).

In a study with a test and retest 2.8 years later, IQ and achievement scores from Time 1 were compared with results obtained at Time 2. It was found that IQ and achievement were significantly correlated at Time 1 (r^2=0.47), and also at Time 2. However the results also found differences in the relations between the variables at Time 1 and Time 2. This suggested unexplained factors may have account for some of the unique variance. Findings also have found IQ to be a protective factor in scholastic achievement. Those students identified with learning disabilities who have higher IQ scores make more gains over time than students identified with learning disabilities who have lower IQ scores (Swanson, 2001; Shaywitz, Shaywitz, Fulbright, Skudlarski, Menci & Constable, 2003).

There are concerns that IQ test scores may be influenced by factors and variables that are not related to individual differences within students (Nisbett et al., 2012). For example, studies with adopted children have found that environment and social class can significantly affect IQ scores, as the adoption of poor children by higher socio-economic families can raise their performance by up to 12 points (Locurto, 1990). Also, the stability of the intelligence test score over time may vary as children grow, leading to their use as a long term predictor of academic performance unjustified (Kranzler, 1997). Research also has identified a “Flynn effect” with intelligence scores (Flynn, 1987, 2010), in which groups over time can make large IQ gains from generation to generation. Poorer and developing nations that are in the process of modernization show the greatest gains in IQ scores over time. For example, children in urban Brazil, between 1930 and 2002 have gained at a rate of approximately 3 points per decade (Nisbett et al., 2012).

Group differences between males and females have also been found in visual-spatial abilities. Males as young as 3 months old have been found to perform better than females with visual spatial tasks requiring mental rotations (Quin & Liben, 2008). Intelligence score results are associated with factors outside of an individual's control such as nutrition, environment, socio-economic, psychological factors, cultural differences, and gender (Nisbett et al., 2012).

More recently, research has turned to examining the different factors within intelligence tests to determine their individual contribution and association with memory and learned facts (Engle, 2002). These include the measurement of fluid intelligence (reasoning and figuring out how to perform a task) and crystalized intelligence (long term memory and learned facts). Working memory (which refers to capacity and processing of new information) seems to be highly related to the construct of fluid intelligence (Engle, 2002). The relation between working memory and the general factor in intelligence is reported to range between 0.72 (Kane, Hambrick, & Conway, 2005) and 1.0 (Gustafsson, 1984; Suss, Oberauer, Wittman, Wilhelm, & Schulze, 2002). The precise correlation remains in dispute, as different studies define and assess working memory in different ways (DeMarie & Lopez, 2014; Nisbett et al., 2012). The next section reviews the contribution of working memory as a predictor of academic achievement.

Working Memory

Working memory is a term which has grown out of memory research and refers to the active processing system that manipulates information, explains our ability to remember information, and often occurs despite distracting or competing information which we have to ignore (Alloway & Alloway, 2010; Engle, 2002). For example, when students copy a sentence onto paper, they not only have to hold the sentence in their mind, they also need to retrieve the spelling of words and write each letter. Those students who have poor working memory skills will most likely forget their place in the sentence, or forget the sentence they want to write by the time they have retrieved the spelling of a word. The definition of working memory depends upon the perspective from which the model of working memory is derived. Three models of working memory are reviewed in the following section, which help the reader appreciate the differences in the research. These three models come from different branches of psychology: developmental, cognitive/neuropsychological, and cognitive/educational.

Three different perspectives of working memory. Different theoretical models of memory, and now working memory, have been presented over time. The range of explanations for working memory processes in individuals has come from many different perspectives which include cognitive psychologists (Cowan, 2011; Baddeley, 2000), developmental psychologists (Pascual-Leone, 1970), clinical psychologists (Rogers et al., 2012), and neuropsychologists (Vitay & Hampker, 2007). In the educational research literature, which examines student performance (e.g., Gathercole & Alloway, 2008) the Baddeley (2000) model of working memory processes is the most widely used reference for the theoretical structure of working memory. Cowan (2011) describes the biological mechanics of brain based learning in his description and model of the attributes of the working memory. Each perspective provides a unique contribution to the understanding of how learning occurs. In this section an overview of each model with reference to how it pertained to the present study is provided. In the next section, each of the models is reviewed in greater detail.

Pascual-Leone (1970) described the developmental attributes of capacity within the working memory model. His model is less widely referred to in the educational literature, but it relates to the current study, because a specific age range of students were targeted for this research. The Pascual-Leone (1970) theory suggested that as students mature and age, their working memory capacity and ability to hold and manipulate information changed. Pascual-Leone used an equation to determine the amount of capacity change as students matured. This study selected participants within one age range, which enabled a discussion of the trends found within only this adolescent age group. The study did not test the Pascual-Leone model by comparing the working memory capacity and manipulation across different developmental ages in the prediction of academic performance.

The Cowan (2011) model is selected for review because his model represents attention as a biological trace within all brain neural networks. Cowan (2011) did not measure attention separately as a unique component of the brain. This concept is important as this study examined the relation of attention as a unique predictor or moderator of the prediction of academic achievement by working memory. Cowan's model is important in this research, because it suggests that attention is not a stand–alone variable, and his model would provide support to the null hypothesis: that inattention does not moderate or add to the significance of the prediction of achievement by working memory. He did not consider inattention to be a separate construct within working memory in his model.

The Baddeley (2000) theoretical model was selected for review because, not only is it the most widely referenced model of working memory in the current literature, but it also provides the basis of examining the visual-spatial and verbal-auditory working memory processes separately in the prediction of academic achievement. All three models will be explained in more detail in the following sections.

A developmental model of working memory: The Pascual-Leone model. The Pascual-Leone model of working memory originates from a developmental perspective and explains how children's memory and processing develop over time as their brains mature **(**Pascual-Leone, 1970; Pascual-Leone & Baillargeon, 1994). Cognitive growth changes in performance were attributed to maturation of the intellect of the individuals, suggesting children have different cognitive abilities until the brain matures, and that growth in skill can be aligned with developmental stages (Kemps, De Rammelaere, & Desmet, 2000). This theory was able to predict working memory performance over time with young children through adults using precise formulae, which expressed the ‘maximum-capacity’ increasing by one informational unit every other year from age one to fifteen. This accounted for individual differences in the number of units a child could hold and could manipulate at any given age ranging from 1 unit to 7 units. Seven units are usually average for adult capacity (Kemps et al., 2000). The research explained not only maturational growth, but also other skills which were developmentally loaded such as reasoning and motor performance.

The Pascual-Leone model uses an equation to calculate developmental progression and abilities, and it has not been used widely in educational research. This model is different from the Cowan and Baddeley model, because Pascual-Leone examined developmental trends in the growth and development of cognitive and working memory abilities over time. Pascual-Leone reported (2000) that his model was very different to Baddeley’s model because Baddeley’s model was based on independent structural components of the phonological loop, the visual-sketchpad, and the central executive, whereas his model was based on activation of prior learning. Pascual-Leone considered working memory to be conceptually different because he considered working memory to be the activation of different sets of schemas. Schemas are content knowledge, experiential learning, emotions, and situational conditions that are activated when the individual interacts with a “field of focus” (2000).

Maturation trends were found to be predictable with regard to some working memory skills, such as amount held in capacity and being able to be processed and recalled accurately. Pascual-Leone reported that there were differences in the 'Peanut versus Corsi' task (Pascual-Leone, 2000) between 8 and 9 year olds, which was consistent with the measured growth in the capacity of their cognitive thinking. This model of working memory is significant within the research on developmental psychology, but the equations created to determine capacity have not been researched widely with regard to the prediction of future academic achievement, so this model has fewer citations in the literature.

There is support for the Pascual-Leone claim for differences in the capacity of working memory by age of student (Kemps, Rammelaere, & Desmet, 2000). With the Pascual-Leone model, chunking of similar stimuli by a similar order or hierarchical nature enables memory of more information. However, although the Pascual-Leone model explains the amount the student can learn, it does not explain the processes or biological changes in brain structure which may occur with learning.

In the following section, a different model of working memory will be reviewed. The Cohen (2011) model places attention at the core of the working memory by describing biological processes and trace elements that occur when the brain is actively processing information.

A neuropsychological model of working memory: The Cowan model. The Cowan model of working memory, which originated from individual difference and neuropsychological research, attempted to explain attention and consciousness (Cowan, 2011). Cowan examined evidence of the multi-item capacity limit and traces of brain activity that would decay over extended time periods. He created a theoretical model of working memory that placed attention at the center of the processing of stimuli (Cowan, 1988, 2011). He also found support for a focus of attention being associated with the amount of capacity and/or storage in each individual's working memory (Xu & Chun, 2006; Cowan, 2011).

Cowan's concept of attention came from a different neuropsychological perspective where the biological mechanics of brain neural networks were explained. Cowan's contribution with attention and trace theory suggested that when a person attended to a task, a biological neural trace was created in the brain, and repeated attending, repeated learning created stronger levels of traces which are more durable. With this model of working memory, an individual only processed information stored in traces before the trace decayed and the thoughts were no longer held in working memory. With this perspective, the trace element (or strengthening of neural networks by neural sheath enhancement) was integrated within the working memory process, and it was also evident in every other aspect of brain processing. Within Cowan's model of working memory, attention and focus combined as neurological chemical traces, and were stored on the neural sheaths of neural networks throughout all brain neural networks. The strength or thickness (due to repeated trace elements) led to thicker and more durable networks, which facilitated stronger memory traces. Stronger memory traces enabled faster manipulation of information during storage and retrieval.

Memory research in individual differences and neuropsychological psychology have mainly been limited to single–item focus of attention studies, (McElree & Dosher, 1989), capacity-limited focus studies (Cowan, 2011; Hamidi, Slagter, Tononi, & Posle, 2009), and capacity limits studies (Awh, Barton, & Vogel, 2007; Cowan, 2011). These aspects of attention related to the number of items a participant attended to with accuracy while distractors were present. This line of attention and cognition research is very different from educational research which measures academic achievement with standardized academic tests. Academic skills differ from the learning in attention and cognition research for several reasons. First, academic learning is a combination of processing incoming information (i.e, understanding the question and determining what is required) and second, academic learning also accesses long term memory for facts and procedures.

An example of single-focus attention is the number of digits in a number sequence, or words in a phrase that a participant can correctly recall or recount when prompted after a lapse of time. Distractors include verbal or visual stimuli, which are presented either simultaneously, or after the presented stimulus (e.g., alternate words, directions which include instructions to manipulate the information into a specified order, or an extended time delay between prompt and recount). Capacity limit is associated with the number of correct responses a participant provides when asked to respond. According to Cowan's model (2011) lack of attending, or attention problems, may result in students not creating sufficient traces in their brain to enable the processing of incoming information for working memory tasks.

Cowan's model did not disassociate various compartments of memory, but instead it explains their relation with attention. This means that if Cowan were to explain the relation between attention and the components of the visual sketchpad and the phonological loop, part of the Baddeley model (2000), he would suggest there were biological trace elements in the processing routes for each of these two components. Attention becomes a measure of the strength of the trace, and therefore it would be present within each of the components of Baddeley's (2000) working memory model, rather than a separate processing component.

Cowan's (2011) model has received support from Oberauer (2002) and Engle (2002) in explaining how traces of information can be lost from the working memory system. Cowan reports that differences between participants found in their individual memories are based on how many representations were held at the same time. A limited capacity model is supported, but more importantly the quality of the memory traces that were within the focus of attention, as compared to the quality of traces from occurrences outside of the focus of attention, were found to be different. Differences were found in the lengths of retrieval when subjects were timed. The focus of attention was considered a protection against interference and memory loss, although it had a limited store of only 3-5 chunks of information (Cowan, 2011). The focus of attention also has been researched as a storage device, able to specialize in different processes, and developmental changes over time in memory storage and loss.

A cognitive model of working memory: The Baddeley model. Baddeley and Hitch (1974; see also Baddeley, 2000) described the processing and rehearsal of incoming information as the "working memory." Their model referred to a limited capacity system which allowed temporary manipulation and storage (Baddeley, 2000). (Please see Figure 2 below).

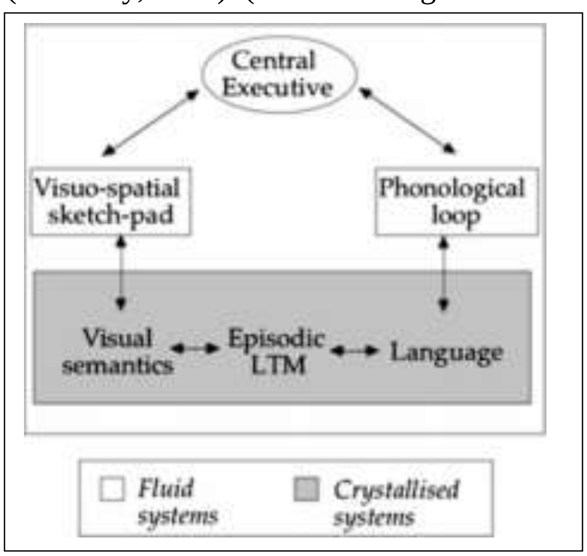

Figure 2**:** Baddeley's Model of Working Memory (2011),
Reproduced with permission by Baddeley 06/25/13

The structure of this model (Baddeley, 2011) is as follows: a central executive directs attention to two supporting slave systems, the phonological loop and the visuo-spatial sketchpad.

The episodic buffer links working memory with long term memory. Each of these components will be explained in more detail in the following sections.

The phonological loop refers to sensory information that enters the brain through participants' auditory channels (ears), and is processed or rehearsed (e.g., self-talk) in the verbal memory areas of the brain. The visual-sketchpad refers to the sensory input information which enters the brain via the eyes and becomes processed by the visual centers of the brain (e.g., remembering the color of an item seen). The central executive relates to the directing of attention to the task or cognitive process required at any time. The episodic buffer refers to the link between working memory and long term memory that enables visual or verbal recognition, faster processing, and comprehension of incoming stimuli. This model of working memory is now supported in research from many areas of cognitive science: cognitive psychology (Holmes, Gathercole, Place, Dunning, Hilton, & Elliott, 2010), neuropsychology (Alloway, Elliott, & Place, 2010), neuroimaging (Suchan, Linnewerth, Koster, Daum, & Schmid, 2006), developmental psychology (Bull & Scerif, 2000), and computational modeling (Baddeley, 2000; Garforth, McHale, & Meehan, 2006). Each component of Baddeley's model will be described in the sections that follow.

The phonological loop. The phonological loop is one of the most researched components of the working memory composite. It explains the storage of temporary auditory traces, which decay over a period of seconds if they are not sufficiently rehearsed (Baddeley, 2000). An example of a temporary trace which can decay and be lost could include the following examples: a person verbally tells another person a 10 digit telephone number, and the person told cannot remember the last 3 digits of the number. Another example would be teachers give a class of students a 4 step instruction which requires them to: get their text books, open to page 67, and then work on examples A-D, then bring completed work to her desk. A student may hear an instruction to get his textbook, but then not remember to which page his textbook should be opened.

The phonological loop is associated with speech perception and production and sub-vocal rehearsal (Kemps et al., 2000).This loop has a high association with the retention of sequential information, and it is often tested with memory span tests such as Digit Span. Digit Span refers to a cognitive assessment where a series of numbers are articulated, and the numbers must be generated back to the examiner by the participant. When the numbers are repeated back in the same order, it is called 'frontwards span.' When the numbers generated back in the reverse order, it is called 'backward processing.' DeMarie and Ferron (2003) found that frontward digit span and forward letter span measures loaded onto the same "capacity" factor. This was equally true for children aged 5 to 8 and for children aged 8 to 10.

The phonological loop provides explanation for the phonological similarity effect (words that sound the same are better remembered), the word length effect (shorter words require less capacity to remember), articulatory suppression effects (not allowing the participant to vocalize or repeat instruction or word aloud causes fewer items to be recalled in memory tasks), and also the transfer of information from the visual sketchpad to the articulatory loop (transfer of sensory codes to facilitate memory). Evidence supporting these aspects of working memory has been from research with participants who have different physical disabilities (e.g., patients who have problems with phonological short-term memory store). For example, aphasic patients with dyspraxia who are unable to repeat words are an example of individuals with impaired phonological memory stores (Baddeley, 2000).

The visuo-sketchpad. The visuo-sketchpad refers to visual memory. Researchers have examined both spatial and visual aspects of this memory store in children separately (Hamilton, Coates, & Hefferman, 2003). Methods of assessing this include: mazes, which involve children remembering, and tracing sequential visual routes (DeMarie & Lopez, 2013).

The central executive. The central executive is described as the main attentional system that directs the person's attention to the task and processing required when using other components (e.g., phonological loop, visual-sketchpad). These other two components of the working memory model (phonological loop and visual-sketchpad) are considered secondary components which then allow visual and/or verbal-auditory incoming information to be processed (Baddeley, 2000).

Baddeley (2011) described four main functions of the central executive. These include to: to focus attention, to divide attention between two or more separate streams of information, to switch between tasks, and to interface with long term memory. This central executive has not been widely researched in educational research, but aspects of participants' executive function skills (e.g., attention and/or inattention) have been researched in conjunction with the Baddeley model with clinical populations of students with attention deficit hyperactivity disorder (Rogers, Hwang, Toplak, Weiss, & Tannock, 2012).

The episodic buffer. More recently the model has been developed to include what is termed an "episodic buffer," which provides an exchange role between long-term memory and the sub-processing systems of the phonological loop and visuo-sketchpad (Baddeley, 2003). The episodic buffer is reported not only to provide ongoing processing with long-term memory, but also to behave as a director for processing (Baddeley, 2000). Baddeley considers the episodic buffer part of the role of the Central Executive, attributed it to linking cognitive stores (e.g., long term memory) during the working memory processes (Baddeley, 2011).

Baddeley's model (Baddeley & Hitch, 2000) has become very widely researched. His research was primarily based on adult participants, but it led to further research by others who examined the relation with working memory and school academic achievement with children (e.g., St. Clair, Thompson, & Gathercole, 2007). Work in neuropsychological fields with neuro-radiological imaging techniques has also found evidence to support Baddeley's model by identifying ways that different anatomical regions of the brain are used for different working memory processes (Smith & Jonides, 1999). These neuroimaging techniques have found evidence for distinctly separate visual and auditory working memory components. Specifically, left frontal areas more active for auditory working memory processes, and larger posterior areas were seen active for visual working memory processing (Ruchkin, Berndt, Johnson, Ritter, Grafman & Canoune, 1997; Suchan, Linnewerth, Koster, Daum, & Schmid, 2012). Research using Magnetic Resonance Imaging (MRI) scans found higher activations in the posterior parietal cortex occurred during visual stimuli, while the left dorsolateral prefrontal cortex were more active during auditory stimuli (Crottaz-Herbetter et al., 2004).

Working Memory as a Predictor of Academic Achievement

Currently, when examining working memory as a predictor of academic achievement, Baddeley's model has become the most widely used and referenced model within educational research. The following section provides key examples of the use of Baddeley's model in studies with students, ranging from children from as young as 5 years of age through adolescence, and also with clinical populations (e.g., students with attention deficit hyperactivity disorder).

Working memory research with children aged 4 to 10 years. Alloway et al. (2004) reported that working memory can be tested reliably with participants as young as 4 years old, and that performance on this construct can vary widely due to individual differences. Performance in working memory has been found to predict reading achievement (Swanson & Beebe-Frankenberger, 2004), math word problems (Swanson & Sachse-Lee, 2001), and computational skills (Bull & Scerif, 2001). Research also suggests that the working memory capacity has a significant relation with various learning disabilities including reading and language disorders with children aged 4 to 6 years old (Alloway, Gathercole, Willis & Adams, 2004), and with mathematics for children aged 6 to 8 years old (Bull & Scerif, 2001).

Alloway and Alloway (2010) reported a study of the predictive roles of working memory and intelligence on academic achievement. The participants were 98 children with a mean of 4.3 to 5.7 years of age who attended kindergarten full time. The design was a test and retest model, with the retest occurring 6 years later when the children were 10.0 to 11.3 years of age. Verbal short term memory and working memory tests from the Automated Working Memory Assessment (Alloway, 2007a), and also the Working Memory Test Battery for Children (Pickering & Gathercole, 2001) were administered in both time frames. IQ tests scores were obtained using subtests from the Wechsler Preschool and Primary Scale of Intelligence (Wechsler, 1990). Academic achievement was measured with standardized tests from the Wechsler Objective Reading Dimensions (Wechsler, 1993) and the Wechsler Objective Numerical Dimensions (Wechsler, 1996).

The results found that learning outcomes were more closely associated with working memory predictors than they were with intelligence scores as predictors. Regression analysis found that working memory at Time 1 accounted for the highest proportion of variance in numeracy (21%), while intelligence only contributed a further 6% to the explanation. Also, verbal working memory with the children at 5 years of age accounted for the most variance in both literacy and also numeracy skills six years later.

This research found support that working memory was an independent factor from intelligence when predicting academic achievement. Research where participants' intelligence scores were statistically controlled also found support that working memory was highly correlated with learning outcomes (Alloway, 2007b; Alloway et al., 2004; Alloway & Alloway, 2010). Another interesting finding from Alloway and Alloway (2010) was that neither the mother's educational level, nor the age at which she left school was significantly correlated with students' working memory scores at either Time 1 or Time 2. This finding provided support that working memory is a robust construct that is not adversely affected by environmental conditions, mother's educational level, early preschool attendance, or economic conditions.

Working memory research with children aged 7 to14 years old. Gathercole and Pickering (2000) found a direct relation between working memory skills and performance on the British National Curriculum Assessments. They found that students who performed poorly on the curriculum assessments, especially those who failed to reach expected levels of competence in English and Math, also performed poorly on central executive tasks involving both processing and storage of verbal information. They found a combination of the central executive and the phonological loop measures were very accurate in predicting which students would have poor academic performance.

Gathercole, Pickering, Knight, and Stegmann (2004) examined the relation between working memory skills and performance on standardized national assessments in more detail. They found close associations at ages 7 and 14 for working memory and academic performance, but there were differences between the two age groups. At 7 years of age, students who had high English and Math skills performed better on working memory tasks, but this was less evident at 14 years of age. At age 14, working memory scores were less correlated with English skills, but highly correlated with Math and Science results.

The fact that the correlations between working memory and academic achievement changed over the years was partly explained by the differences in tasks demanded of the students in the academic assessment. Tasks asked of 7 year olds involved considerably less processing. Thus, the correlations with working memory and achievement at age 14 may be measuring changes in the types of evaluation occurring academically. Gathercole, Pickering, Knight, and Stegmann (2004) reported the study provided little support that working memory is a good predictor of higher level conceptual and analytic ability, but they found support that working memory was a good predictor of mental arithmetic skills at both age groups. Overall, the working memory prediction worked well for the younger students across English and Math outcomes, but worked best for the older students when predicting science and math results.

One criticism of this research was that the selection of participants included two different samples of students for each of the groups aged 7 and aged 14. Another criticism was the nature of academic tasks and evaluation used at these different developmental levels tapped different cognitive requirements. At age 7 there was a significant effect of both the English and Math ability groups on working memory performance, but with the older students, there significant effects of ability group on working memory were only found in mathematics and science. This suggested the relation between fluid cognitive ability measured by working memory and crystalized knowledge measured by achievement tasks is not a simple linear trend (Alloway et al., 2004). One explanation is that younger students are still learning to read, therefore the correlations with their working memory scores may be higher than those of older students who read with more automaticity, and whose tests may be measuring more comprehension, knowledge, and strategies stored in long term memory.

New Trends in the Literature on Working Memory

The research on working memory in educational and cognitive psychology is now evolving to include other influences to explain the variance in academic achievement results predicted by working memory. Researchers have examined whether individual working memory deficits can be overcome by training the participants (Holmes, Gathercole, Place, Dunning, Hilton, & Elliott, 2010). Specifically, working memory research is examining the relation between different individual differences, such as long-term memory (previously learned facts which are stored in the brain, and are associated with crystallized intelligence), attention, inattention, and working memory. These will be briefly reported in the following section.

Long-term memory. Was (2010) looked at the relation between long-term memory and working memory in performance and suggested that activating prior learning impacts the prediction of reading skills. He suggested that prior learning is an important component in complex tasks requiring language processing, as prior learned units of memory are being manipulated for the understanding of current task demands.

Working memory, executive functions, and inhibition. There has been a lot of interest in the factors that may influence performance in students' academic achievement. Some of these relate to factors within executive functions. Executive functions are activities associated with the frontal lobes which help direct attention, sustain attention, and direct appropriate verbal, visual, and or physical responses. Executive functions also refer to brain behaviors which organize and direct the individual to engage in learning, participate in social activities, and attend to a task or instruction as needed. For example, studies have investigated behavioral inhibition (Alderso, Rapport, Hudec, Sarver & Kofler, 2010), working memory deficits (Alloway, Gathercole, Holmes, Place, Elliott, & Hilton, 2009), accuracy and error rate within automaticity tasks (Best & Miller, 2010), and focus of attention (Van Gerven, Meijer, Prickaerts, & Van der Veen, 2008).

St. Clair, Thompson, and Gathercole (2007) examined the relation between three executive functions of the brain and school achievement in students aged 11 and 12 years old. The three brain-based executive functions examined were shifting, updating, and inhibition. Shifting refers to the process of changing from doing one task to another task, requiring a change in direction for the mind and behaviors exhibited. Updating refers to the conscious monitoring of the incoming stimuli and coding of information to appropriately revise and review what responses are required. Inhibition refers to the ability of the individual to consciously inhibit, ignore, or refuse to engage in any automatic responses which may interfere with the desired goal driven behavior or thinking process.

One of their findings was that there was an association between the executive function components of working memory and academic achievement. Specifically, inhibition was significantly associated with attainment in English, Math, and Science. Conversely, when controlling for inhibition, working memory was found to be strongly associated with each academic area (Jarvis & Gathercole, 2003). Domain specific correlations were significant for verbal-auditory working memory and achievement in English, while visual-spatial working memory was significant for achievement in English, Math, and Science. The conclusions drawn from the research included support for executive functioning in working memory and also that inhibition was a contributing factor in academic performance in children.

Attention and working memory. Taylor (2007) reports on the role of attention in cognitive processing and cognitive architecture. Taylor's approach to explaining cognition uses a framework which features attentional control as a key component of cognitive processing. Taylor discusses the role of attention with regard to conscious reasoning and decision making, and unconscious actions where reasoning does not interfere with cognitive processes. Neuro-imaging research has contributed to our understanding of how conscious attending varies by the demand of the task (Suchan et al., 2006).

Baddeley's most recent paper (2011) also discusses attention as part of the central executive. Baddeley (2011) reports that the central executive is the most 'complex component' of the working memory, and provides four functions: to focus attention, to divide attention between different stimuli, and to enable the switching between tasks.

Inattention problems. There is considerable research with students who have attention deficit hyperactivity disorder to investigate how problems in attention, such as inattention, affect their academic performance (Rogers et al., 2012). Currently, the movement in this field is examining how problems with attention, academic achievement, and psychometric medications, interact with working memory components (Holmes, Gathercole, Place, Dunning, Hilton, & Elliott, 2010; Kibby & Cohen, 2008; Nigg, 2005). Both training programs and the use of stimulant medications have been found to remediate some working memory deficits in students with attention deficit hyperactivity disorder (Holmes et al., 2010). The working memory trainings and stimulant medication interventions have been found to be most effective with deficits initially caused by a participant's inattention. Holmes et al. (2010) reported that working memory trainings were effective across both types of working memory components (verbal-auditory and also the visual-spatial), while psycho-trophic medications tended to only improve performance with visual-spatial tasks.

The following section reviews key literature of how working memory (either individual or combined components of verbal-auditory and visual-spatial processing) is found to be specifically correlated with academic achievement. The construct of attention in educational working memory research refers to behavioral attention in a classroom. This construct for attention includes: active listening, passive attention to instruction being provided visually (interactive computer programs) or verbally (traditional teacher explanations), and attending to the requirements of a task by preparing the materials that are required for participation (books, pens, paper, homework, organizer binder). In this research working memory is measured with active participation and recall or processing of information, and is scored by the accuracy of the response to very specific standardized administrations of information presented verbally or visually in the standardized assessments provided.

Working Memory, Inattention, and Clinical Populations

A good example of research on working memory integrating several aspects of executive functions with the prediction of academic achievement is work by Rogers et al. (2012). They examined the predictive power of working memory, inattention and academic achievement. Inattention was measured by teacher rating scales of the ADHD-symptoms and Normal Behavior Scale (SWAN; J. Swanson et al., 2005). Inattention and working memory were selected as predictor variables on underachievement due to previous research in the field which documents the academic underachievement of students with a medical diagnosis of attention deficit disorder (Dally, 2006; Du Paul, Volpe, Jitendra, Lutz, Lorah, & Gruber, 2004). Students with attention difficulties were found to be likely to underachieve in reading (Warner-Rogers, Taylor, Taylor, & Sandberg, 2000; Wilcutt & Pennigton, 2000) and math (Rogers et al., 2012).

Rogers et al. (2012) summarized how research has demonstrated a correlation between students diagnosed with attention deficit hyperactivity disorder and low working memory scores (Martinussen, Hayden, Hogg-Johnson, & Tannock, 2005). More recently, students with subclinical levels of inattention have been identified with low working memory deficits (Alloway, Elliot, & Place, 2010). The low working memory deficits were found to be related to both temporary capacity and the processing or manipulation of memory (Baddeley and Hitch, 1974; Baddeley, 2003). Working memory deficits have been found to correlate with both standardized academic assessments (Marx, et al., 2010), and also with parent and teacher rating scales for attention (Toplak, Bucciarelli, Jain, & Tannock, 2009). Rogers et al. (2012) further explained there was significant correlation between deficits in the verbal-auditory working memory system and low academic performance.

Rogers et al. (2012). Rogers et al. (2012) reviewed the association between inattention and working memory as a predictor of academic achievement because students with attention deficit hyperactivity disorder often have lower academic performance than students who do not have an attention deficit problem. Specifically, Rogers et al. (2012) examined the prediction of academic achievement with adolescent students by each of the verbal-auditory and the visual-spatial working memory components. The relation of inattentiveness to the outcome achievement score was also entered into the path analysis model. Specifically their research examined the relation between working memory, inattention, and academic achievement in reading and mathematics. Their focus was to determine if the two aspects of working memory differentially predict reading and math while examining the relation between classroom inattention and academic achievement in students who had ADHD.

Rogers et al. (2012) reported that behavioral inattention significantly predicted both visual-spatial working memory and verbal-auditory working memory. With regard to academic performance, visual-spatial memory was associated with achievement in math, but not reading. However, verbal-auditory working memory was significantly correlated with both reading and math achievement. In their research, the path from behavioral inattention to reading achievement was not found to be significant; suggesting the association between behavioral inattention and reading is mediated by verbal-auditory working memory (Rogers et al., 2012). Results of analysis found the path from behavioral inattention to reading was significantly mediated by verbal working memory variables, but the path from inattention to math was significantly related to both verbal and visual working memory.

Although the Rogers et al. (2012) research is important because of the contribution it made to understanding inattention and working memory in adolescents, there were methodological limitations in the design of the study. First, all the participants were students diagnosed with ADHD, so there was not a separate group of students without ADHD. This means that the research did not include students that were considered typically developing with either attention skills or academic performance. Thus, the results obtained in their research may only be generalized to adolescent students with ADHD.

Another limitation was that they only reported reading and math scores for academic achievement, and they did not include written expression scores in the research design. Therefore the results cannot generalize to discussions on the relation between inattention, working memory and written expression in adolescents.

Limitations within Working Memory Research

Limitations in the research on working memory and its explanatory power to predict future academic achievement include many different assessments to measure both working memory and also academic achievement. When varied tests are taken for research (i.e., different working memory batteries or alternate academic assessments) it becomes difficult to compare research findings within and between different studies in the literature because results may be unique to each study.

The following section will review in more detail some other limitations which include: different ages of the participants (St. Clair –Thompson & Gathercole, 2012; Melby-Lervag & Hulme, 2012), the types of assessments used to measure achievement (Alloway & Alloway, 2010; Rogers et al., 2012), and different statistical analysis. The problems of generalizing working memory research to school student populations extends to discussions about the meaning of correlational relations among the data and conditions (DeMarie & Lopez, 2013). These include, but are not limited to the fact that a high correlation between two variables may suggest a relation between them, but it may not support a statement which suggests one variable causes a change in a condition (e.g., high or low verbal-auditory working memory may cause differences in academic achievement or there may be other factors that could also predict the outcome measure which were not included in the analysis. Therefore a third, undisclosed, omitted variable may influence the results with both working memory and also academic achievement performance, but this may not be identified at the time of analysis.

Participants. There are recognized differences in cognition and performance skills between children 4 to 5 years of age and those who are 7 to 11 years of age (Alloway et al., 2004; Gathercole et al., 2004). These not only affect performance within academic and cognitive skills, but they also may affect symptoms of attention deficit hyperactivity disorder (Biederman, Mick, & Faraone, 2000). Baddeley's working memory model was originally tested on adults, and it has only been in recent years that it was tested on children (Baddeley, 2003; Gathercole et al., 2004). When either the age or the health of the participant is used as a variable, the results may not generalize to diverse populations of people who were not included in the research sample.

Outcome measures. The academic assessments are as broad as national standardized assessments (Gathercole et al., 2004) to laboratory analogues of class performances (Gathercole et al, 2008), to traditional standardized assessments such as the Woodcock Johnson Tests of Achievement, which is used worldwide (DuPaul et al., 2004). Gathercole et al. (2004) provided a good explanation of how results from studies vary as a function of the task expected. When different outcome measures are used throughout the literature, it may not be possible to compare the results with any degree of certainty. The following section will review some limitations in the methodology used when the prediction of academic achievement is examined.

Prediction tests. There are limitations of all methodological designs, and in this section some limitations of methods which use single predictor tests and moderator variables are examined. These two examples have been chosen because they directly relate to the present study and the statistical analysis that will be used.

S*ingle predictor tests.* Ghisielli (1956, 1960a, 1960b) examined the efficacy of testing individuals with one predictor measure. He reported that the use of a single test as a predictor for an outcome measure test later in time can be valid for one individual. However, there is variation within prediction from a single measure of an outcome score between participants. This variation means the relation between the predictor test and outcome score may be interpreted differently for different individuals. Some individuals with similar standard scores obtained from the predictive assessment may demonstrate wider variation with their dependent variable scores. These differences may suggest alternate predictability tests could provide additional information to provide more accurate confidence intervals around the score achieved (Sackett, Laczo, & Lippe, 2003).

Moderator variables. Moderator variables are variables which influence the strength or relation between the predictor and the outcome measure (Baron & Kenny, 1986). These could include variables such as gender, race, health condition, intervention provided, or other. In the present study, attention is examined as a moderator variable.

A moderator variable is different from a mediator variable. A mediator variable explains the strength and relation between the predictor and outcome measure (Baron & Kenny, 1986). Zedeck (1971) suggested that the differences in findings between different prediction methodologies could be the results of difficulties comparing quantitative and qualitative techniques, and the way in which the data obtained for the variables is analyzed.

In moderated regression analysis, the moderator variable is treated as a quantitative variable (Sackett, Laczo, & Lippe, 2003). In the present study, linearity is considered important in determining the relation between the variables, so attention will be measured with a standardized assessment which will provide quantitative scores which are from a continuous scale.

Conceptual differences in the regression analysis used are important to discuss when examining issues relating to the assessment of a test. In addition, there are empirical concerns which address how results from statistical analysis can give mathematically correct results, but misleading answers when limitations of the research design are not sufficiently accounted for

(Sackett, Laczo, & Lippe, 2003). Empirical concerns which affect the mathematical analysis will be discussed in the following section.

Omitted variables. Regression models are not only subject to conceptual differences, but also have empirical problems. These problems include the consequences from omission of relevant variables in the regression equation. The concept of an ‘omitted variable’ is important because it refers to missing variables, which may affect the interpretation of the results. Just because a difference in slopes or intercept values can be determined using a regression analysis does not mean that the results can truly explain bias, if it is found. This empirical problem occurs because statistical regression analysis share the variance obtained between variables. A poorly fitting model with a larger error term is created when an omitted variable is correlated with the criterion variable, but not with the predictor variable (Johnson, Carter, Davison, & Oliver, 2001). In these circumstances, the regression coefficients for the predictor variable are not biased by the omission of the variable. However, if the omitted variable is correlated with both the criterion and the predictor variables, the coefficients for the predictor variable could be biased (Johnson, Carter, Davison, & Oliver, 2001).

To give an example of this problem: if only two variables, for instance effort and gender, were entered into a regression equation examining the prediction of achievement, the variance of scores proportioned for each factor would be given in the R^2. If when comparing the R^2 no differences were found in slope or intercept, a regression line for effort and achievement, and also gender and achievement could be reported with no bias determined. However, if there was really a variable omitted, such as socioeconomic class, which correlated highly with the criterion measure of achievement and also a predictor variable of effort, the regression equation may not be able to attribute any variance to this variable, because it was omitted. In this example, variance caused by socio-economic class could be included in the R^2 for the variable of effort because of their high correlation with each other. Now, if the regression analyses were run with three variables (e.g., effort, gender, and socio-economic class) variances which werr previously shared, could now be attributed to the third variable. It is important to understand how the statistical analyses selected for an analysis can affect the outcome results. There are many different statistical analysis methods that can help interpret the data in a meaningful manner, however, the researcher needs to be aware of how missing variables can affect the final results.

In the present study, the data included a wide range of variables. There were two different working memory assessments, three different achievement measures, and an attention variable. Of these, attention was selected as the moderator variable. The study has some known 'omitted variables' which include: socio-economic level of the participant, and maternal mother's highest educational level. Each of these two predictors has previously been demonstrated to be highly correlated with academic achievement (Alloway & Alloway, 2011). However the principal investigator is not asking volunteers to verify personal information (e.g., socio-economic status with free and reduced lunch) due to respect for privacy of disclosure and inability to verify information on these data even if they were provided. Other 'missing or omitted variables' may exist, but these will be discussed in the final chapter after review of results.

Bias is a sensitive issue, and in the following section, the importance of bias will be discussed as it relates to the present study. Bias refers to deliberate preferences or choices made by the researcher. Possible biases in the present study included the locations used to recruit participants, the statistical analysis method, and the assessments used with students.

Bias in Testing

Test bias will be discussed in more detail in the following sections because the principal researcher has chosen a method for the statistical analysis based on considerations such as appropriateness of the method to explain the results from the research questions. Bias refers to a disproportionate selection or favoring of any criterion (e.g., weight, height, socio-economic, ethnicity, academic assessment measure, or other) when comparing results gathered from the data. The following section explains how bias can affect assumptions, explanations of results, as well as choices of tests, and/or analysis methods, and the examples are forms of bias that could relate to the present study.

Criterion bias. Flaugher (1978) identified criterion bias as a feature possible in tests. He reported that when using predictor tests and outcome criterion tests, reliability between the two tests is usually based on the mean differences between them, for instance, minority and majority groups. However, when discussing results - the mean difference, interpreted as bias, is usually awarded to the predictor test - when really it could be assigned to either or both the predictor and outcome criterion test because the difference is shared between both of them. The following sections will provide a review of how construct measurement, conformational bias, and measurement bias can affect the outcomes reported in studies. This is to acknowledge the socially situated aspect of all research and respect the cultural and perspective differences which will always be present in any research study.

Construct Bias. Reynolds and Suzuki (1990) also discussed socially situated norms of majority cultures' acceptance in the measurement of different constructs (e.g., an intelligence test taken by an ethnic minority). They suggested examiners could only measure the degree to which they have adopted the majority culture, because differences between norms in a group may in part be due to the cultural differences between groups. They may not represent the true ability measured by each group. Intelligence tests have a history of being reported as unfair and biased for some minority populations (Nisbett, Aronson, Blair, Dickens, Flynn, Halpern, & Turkheimer, 2012). The subtests used in this research are selected from intelligence tests, but they will provide an independent analysis, which previously research reported was less biased by environmental and cultural influences (Alloway & Alloway, 2011).

Confirmational bias. Confirmational bias includes the tendency for people to favor information which confirms their beliefs or hypothesis (Plaus, 1993). Factors that contribute towards bias continue to be important to educators today, because this directly impacts special education placements, federal dollars for funding, as well as the children who will have a 'label' during their formative years. The present study will include participants from a diverse population and will report trends between the variables found which are statistically significant to enable future research to examine interventions which can support students with deficit skills to close achievement gaps. The researcher is striving to examine links between ways of learning and academic achievement which can generalize to a population of middle school students. There is no bias to try to 'label' students on any individual level for special educational placement.

Methodological measurement bias. Measurement of test bias takes different forms. Apart from item bias which has been discussed, there is also methodological statistical analysis bias. While item bias refers to analysis of the individual question content, methodological statistical analysis refers to bias by errors in over or under predicting the result. When a regression analysis examines scores for trends and differences, a slope is generated. The results for the predictive validity calculated by the regression determine the trend line of a given set of scores (e.g., in a scatter plot).

There are different kinds of regressions that can be performed on data, and each has unique qualities. A simple linear regression examines the relation between one variable and one criterion. A hierarchical regression examines the unique contribution each variable makes in a given order, so that variance can be attributed proportionately to each variable. In a multiple regression, the variables are entered into the equation in a sequential order. This sequential order is an important feature not only because additional variance can be explained at additional levels, but also because the regression controls for the effect of the previous levels. Therefore, if a researcher wishes to control for any variable (e.g., gender, ethnicity) the sequence can provide for this.

This study uses a regression model because it has the ability to examine trends between the data with several different analyses for each academic subject, and each area of working memory. The analysis method is robust for producing correlations which can be judged with effect sizes to help consider the contribution of the results for educational application.

Error Bias. The choice to use a regression model will affect the proportion of Type 1 (rejecting a true null hypothesis) and Type II (failing to reject a false null hypothesis) errors made, as well as the significance factor of the results. If a regression analysis reveals different slopes for different groups, and a significant difference is found between the differences, a measure is considered potentially biased. However, as discussed in differential prediction, results of regressions can be misleading if there are omitted variables that are affecting the results. For this reason, if any form of difference is found by a statistical analysis, it is important to examine the evidence further to determine which factors present or not present may be influencing the results, and then to include these in the discussion when the findings are reported.

The Present Study

The present study builds on the literature of working memory, and specifically the research by Rogers et al. (2012) in three ways. First, the study examined if attention significantly added to the prediction of academic achievement by working memory. Rogers et al. (2012) measured inattention in a population of students who all had ADHD, but the present study recruited a participant pool with typically developing students so that results obtained could be generalized to a wider population of children. The participants were recruited from varied sources (e.g., schools, churches, home-schooling networks) where a range of typically developing students could be recruited. Students who had ADHD were not excluded from participation in the study, because this is a commonly diagnosed condition in childhood. Demographic statistics described the numbers of students who have, and who do not have ADHD. Both typically developing and students diagnosed with ADHD were included to ensure a typical range of scores for attentional problems. Rogers et al. (2011) did not find attention added significantly to the prediction of academic achievement; however the effects of ADHD could not be ruled out, therefore their study was replicated with a more typical population.

Second, the present study examined whether attention problems moderated the relation between academic achievement and working memory. This contributed to the field because the research examined the effect of attention as a moderator with typically developing students. Third, the present study added written expression to the academic achievement measures, because this has not been previously reported in the literature.

The purpose of the present study was to examine the relations among attention problems, working memory, and academic achievement. If there was support that attention was a significant moderator of the relation between working memory and achievement, there would be support for attention problems to be discussed as a separate component within Baddeley's (2000) working memory model. In the following section the participants, measures, and methodology that Rogers et al. (2012) used are reviewed, and then these are compared to those that were used in the present study.

Comparison of Rogers et al. (2012) and the present study.

Participants. The Rogers et al. (2012) research included 145 adolescents aged 13 to 18 who were referred for attention deficit hyperactivity disorder (ADHD), and who also were at high risk for educational problems. Their participants' mean age was 15 years, and all participants had a medical diagnosis of ADHD.

Although Rogers et al. (2012) included students up to 18 years of age, adolescents between 12 and 16 years old were selected for the present study. This is because the Weschler Intelligence Scales for Children (WISC-IV) is normed for children aged 6-16, and the Behavior Assessment of School Children -2nd Edition (BASC-2) provides ratings by age range of 12 – 21. The researcher did not want to jeopardize the validity of the standardized score results by including students who were younger, older, or different to the normed sample reported in the technical manuals for each assessment.

Rogers et al. (2012) included 145 participants in his study, but the number of participants to generate sufficient power to support the statistical analysis for the present study was calculated by power analysis. Utilizing an effect size of .15, the probability level of statistical significance of .05, the statistical power of .80, as well as the number of predictor variables, the calculated minimum number of participants required was 43 (Erdfelder, Faul, & Buchner, 1996; Erdfelder, Faul, & Buchner, 2005). The researcher recruited 50 participants to allow for some attrition, so that even if some participants dropped out or failed to provide all the data required for a full analysis, sufficient data would have been obtained to answer the research inquiries.

Diagnostic Measures. Many of the assessments that Rogers et al. used in their study have been held constant in the proposed study. However, the changes are explained in the following sections.

Verification of diagnosis for ADHD. Rogers et al. (2012) used a clinical interview: The Schedule for Affective Disorders and Schizophrenia for School-Aged Children – Present and Lifetime Version (K-SADS-PL; Kaufman, J., Birmaher, B., Brent, D., Rao, U0., Flynn, C., Moreci, P.., & Ryan, N., 1997). The present study recruited typically developing students and did not limit the research to students who had a medical diagnosis of ADHD. A self-disclosure questionnaire check list was given to volunteers and their parents to complete. They were asked to check a box if their child had a diagnosis of either attention deficit hyperactivity disorder (ADHD) or attention deficit disorder (ADD). There was no checklist of medications students were taking or were prescribed and were not taking, as these students were all identified as general education students, and not requiring any special treatment for medical reasons.

The present study also examined whether attention problems were moderators of the relation between working memory and academic achievement in a group of typical students (with and without ADHD). The purpose of this was to obtain a range of scores which represented students without attention problems as well as those with attention problems, so trends in the relations between the data could be examined.

Teacher Interview. Rogers et al. (2012) used The Teacher Telephone Interview –IVth Ed. (Tannock, Hum, Masellis, Humphries, & Schachar, 2000) to confirm the presence or lack of ADHD characteristics in students included in the research. However, this study did not gather data from teachers. Parents were asked to complete a checklist with their child which reported and disclosed any conditions which could adversely affect the validity of their participation in the research. The checklist served as a method of determining if any child had a condition which would match for criteria for their delimitation from the study. This checklist also provided opportunity for the parent and student to write or speak to the principal examiner about any other concerns or conditions, and it was the basis of a structured interview (if conducted in person), or a written disclosure (if the participant wanted the information sent by mail to review and complete at home). A copy of the self-disclosed check list is attached in Appendix 1.

Rating scales. Rogers et al. (2012) used The Strengths and Difficulties Questionnaire (SDQ: Goodman, 1997), which rates the amount of 'Inattention' evident with the students with ADHD. This rating scale is a dedicated scale designed to measure and progress monitor the symptoms of ADHD over time. As all their participants had ADHD, this rating scale was an appropriate choice; however, in the present study a broad band behavior rating scale was selected because the range of participants included typically developing students, and some of them did not have a diagnosis or any perceived problems with attention or inattention. The Behavior Assessment for School Children 2nd Ed. (BASC-2.) rating scales were selected for their Inattention Index for several reasons. First, they are a broad band rating scale, so students without a prior diagnosis of ADHD would not receive a score for inattention based from a dedicated ADHD rating scale. Secondly, they have a high internal consistency, with a median for reliabilities on individual scales near .80. The composites were based on two types of factor analyses: covariance structure analysis (confirmatory factor analysis), and a principal axis analysis which examines fit of the scale to the intercorrelation data. The attention and inattention composite on the child and adolescent scales had moderate to high loadings on the Internalizing Problems factor (*r*=.85),suggesting a good construct validity. Correlations of the BASC-2 self-report scale with other self report assessments have moderate to high correlations. The correlations between the BASC-2 Internalizing composite and the Achenbach System of Empirically Based Assessment (ASEBA: Achenbach & Rescorla, 2001) Total Problems composite are high (*r*=.80), while correlations with the Conners-Wells self-report (Conners, 2008) are in the moderate range (r=.59). This suggests the different assessments do not measure the same aspects of inattention.

There is currently no information available to determine the correlation between the SWAN teacher rating scale used by Rogers et al. (2012) and the BASC-2 self-report scale used in the present study. However, this is not considered a limitation as past research (DiStefano, Kamphaus, Home, & Winsot, 2003) has documented a low correlation between teacher and self-raters, suggesting different aspects of inattention are measured (*r*= .20 to *r*=.25) by different raters.

The present study asked student participants to complete the Behavior Assessment for School Children (BASC-2nd Ed.) Self-Rating scale to determine their feelings about school and obtain a standardized score for their feelings about their perceived attention problems. The Rogers et al. (2012) study found that inattention measured with teacher rating scales did not significantly moderate the relation between working memory and academic achievement. Due to the fact that previous research (DiStefano, Kamphaus, Home, & Winsot,2003) found weak correlations between the scores achieved for inattention between teacher rating scales and self-rating scales, it has been suggested this is because different aspects of the construct are being measured. Reynolds and Kamphaus (2005) found weak correlations (r = .27 for inattention scale) between the Self-report and the Teacher report rating scales of the BASC-2, which suggest that an alternate aspect of inattention is being measured with the self-report scale. The reliability estimates for the emotional symptoms index for the self-report rating scale used in the present study was high (r =.85), with individual scale ranges having a median value of r =.70 (Reynolds and Kamphause, 2005). This suggests the self-rating scale is a robust measure, which may capture a different aspect of the inattention construct for the present study. As the Rogers et al. (2012) study did not find any significant effect with the teacher rating scales used to measure the inattention index, the present study used self-rating scales to examine if measuring a different aspect of the construct of inattention could produce a different result. This is not considered a methodological limitation because previous research (Rogers et al., 2012) has not found a significant effect with inattention as a moderator of this relation using teacher rating scales. If the present study had found that inattention moderated the relation between working memory and achievement using self-rating scales, it could have suggested that future research examine the differences between the rating scales used to determine the inattention factor when examining the relations between these variables.

Secondly, teacher ratings were not used, as homeschooled students may use online computer instructional programs and obtain support from their parents, so there may have been no independent teachers who could have provided the rating. Some homeschooled students are exclusively taught by their parents, not all have tutors. Additionally, the local school district did not provide research consent for the principal investigator to approach any teachers in the public school system and ask them to complete rating scales. Private tutors were not used for teacher ratings because they typically teach one student at a time and would not be able to generalize the behaviors observed to how the student performed compared to the rest of the class. It would not have been possible to obtain teacher rating scales for this study because the population selected came from different environments (home and public school) with different provisions and regulations surrounding interactions between teachers and students. Homeschooled students were included in the study to help provide a heterogenous participant pool of adolescent students. In the current climate many students have a period of time with virtual learning, or homeschooling at some point during their educational career, and the researcher felt that the data gathered would therefore represent a wide sample of current adolescent abilities.

The parent rating scale was not used because those students who were home-schooled may have had a parent providing instruction, and the role between teacher and parent would be different to those students who were taught by a teacher in a school setting who was not their parent. This could have created a threat to the internal validity of the results of the parent rating scale, as the relationships between the students and the parents of home-schooled students may be different to those students who were enrolled in a public school and taught by a teacher who was not a parent.

Verbal-auditory Working Memory. Rogers et al. (2012) used the Digit Span & Letter Number sequencing subtests of the WISC-IV (Wechsler, 2003). The present study used this same assessment, so the results can be directly compared.

Visual-Spatial Working Memory. Rogers et al. (2012) used the Spatial Span subtest from the Wechsler Intelligence Scale for Children- 3rd Edition (Wechsler, 1991). The present study used the Spatial Memory and Object Memory subtest from the Universal Nonverbal Intelligence Test (Bracken& McCallum, 1998), because it was normed and published more recently (1998).

The use of the most recent norms available is important due to the Flynn effect (Flynn 1987, 2010). The Flynn effect describes how groups gain in IQ scores over time from generation to generation. This is most pronounced in developing nations where, for example, in urban Brazil between 1930 and 2003 scores gained at the rate of approximately 3 points per decade (Nisbett et al., 2012).

Academic achievement. Rogers et al. (2012) used the Woodcock-Johnson III Tests of Achievement: Broad Reading and Broad Math Cluster. The present study used the same assessments in both Reading and Math to measure academic achievement, but the present study also included Written Expression achievement. Written Expression was not measured or reported in the Rogers et al. (2012) study, and therefore this study provided unique information about the relations of working memory and attention to written expression achievement in adolescents.

The contribution to the field. The contribution of the present study to the field is to: provide information about how attention problems may moderate the relation of working memory and academic achievement, to build on the research in working memory using adolescent participants, and to examine the relation between working memory and written expression. Currently, a significant amount of research for working memory in cognitive psychology has been with adults, or with younger children. The literature in educational psychology tends to focus on children 14 years old or younger, and therefore the examination of trends with students between the ages of 12 and 16 contributes to the literature in a unique way.

The present study had three groups of research questions. The first group examines the direction and strength of the relation between academic achievement and working memory. A graph of hypothetical results to pictorially represent the results that may be obtained from the first group of research questions follows. Figure 3.1 which follows shows the hypothesized relation between working memory and academic achievement. As the working memory increases, academic achievement was expected to increase as well.

The second group of research questions examined whether attention problems significantly added to the prediction of academic achievement by working memory. The graph in Figure 3:2 shows the possibility of attention adding in a positive way. Those students who had higher levels of attention would be expected to have higher academic achievement, when working memory was controlled. Likewise, when attention was controlled, those with higher working memory would be expected to have higher academic achievement.

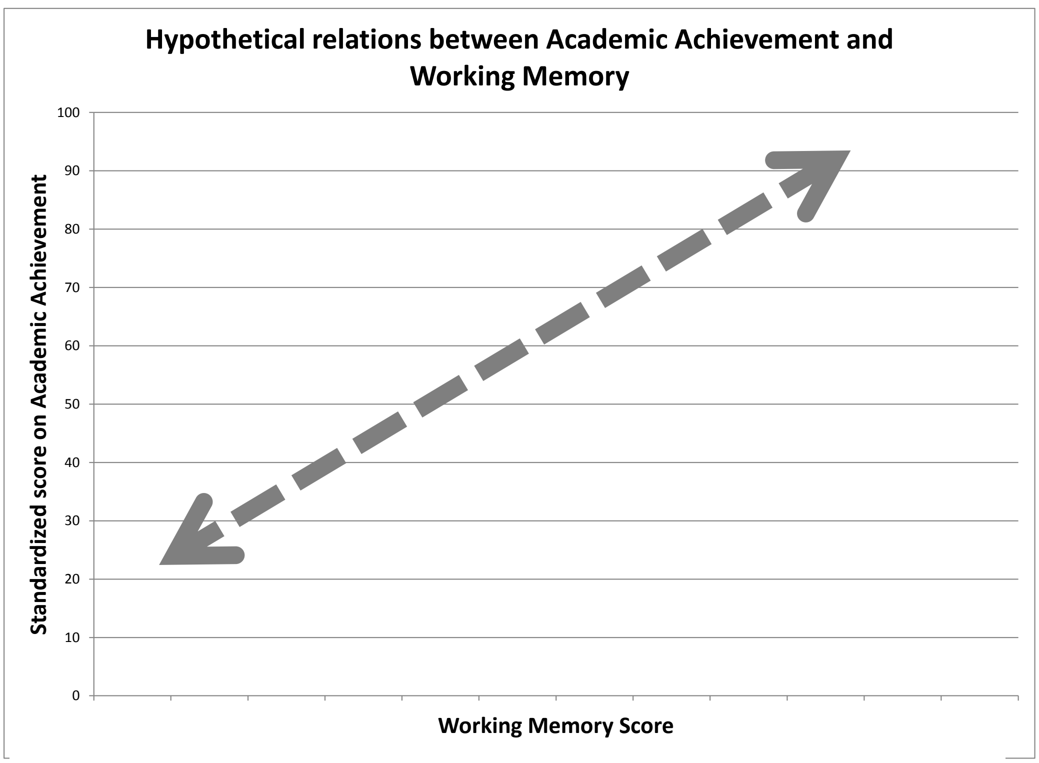

Figure 3.1: *A diagram representing a possible result for strength and direction of the relation between working memory and academic achievement.*

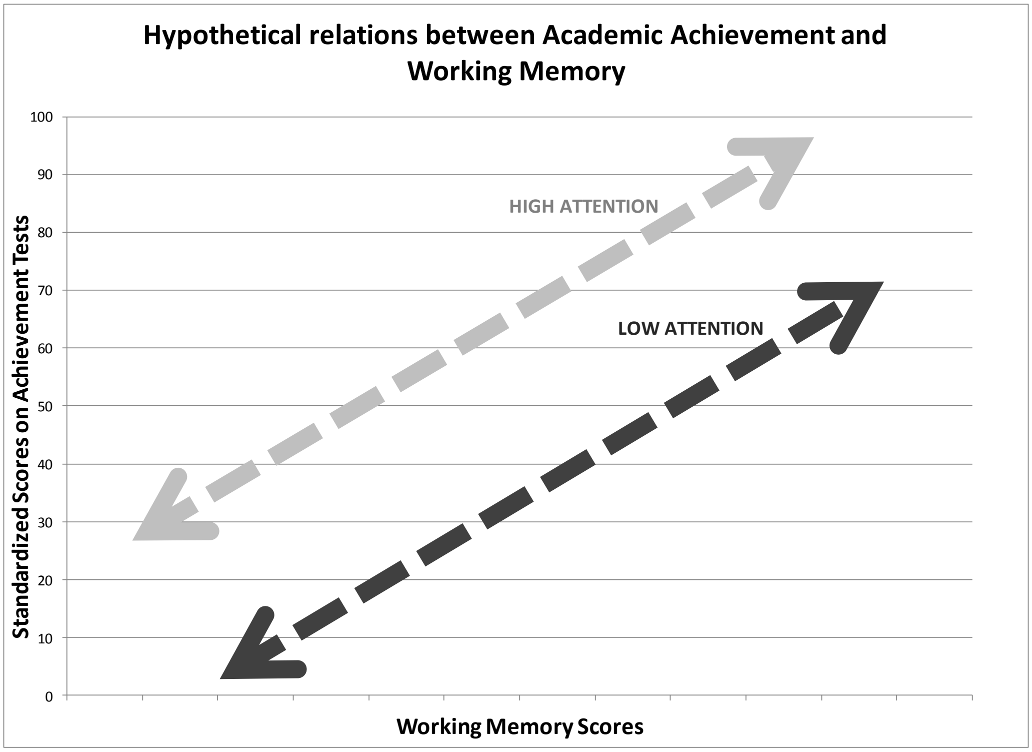

Figure 3.2: *Do attention problems add to the prediction of academic achievement by working memory?*

The third group of research questions examine whether attention moderates the relation between working memory and academic achievement. A possible result for this research question could be that there is little effect on the relation between working memory and academic achievement when there are attention problems, but when there are no attention problems there is a significant difference in the relation between attention and the prediction of academic achievement by working memory. (Please see Figure 3.3 below.)

The third research enquiry examined for trends between the relations of attention problems, working memory (verbal-auditory and visual-spatial) and academic achievement in reading, math, and written expression skills. Significant trends could help guide educational practice to develop interventions to address deficit skills.

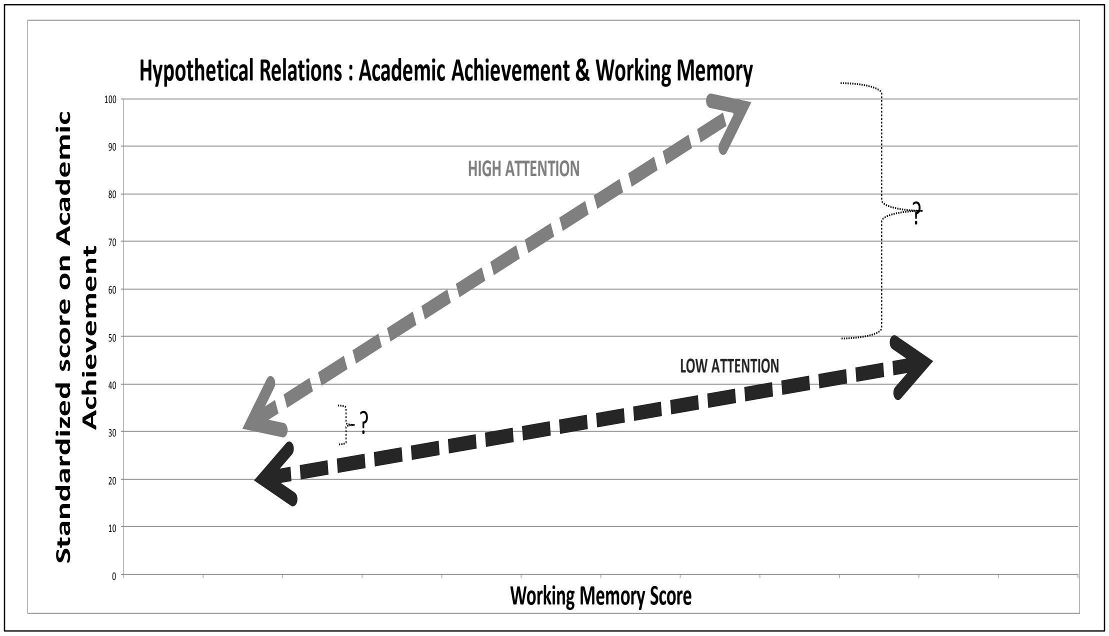

***Figure 3.3*:** *Is there evidence of moderation by attention problems in the relation between academic achievement and working memory.*

The focus of the enquiry was to examine if inattention moderated the relation between working memory and academic achievement. Specifically, the research may help guide interventions which address verbal-auditory learning routes (e.g., listening to tapes, explicitly repeated verbal instructions for the acquisition of new skills) for some academic subjects, while using interventions which use high visual-spatial skills (e.g., picture charts, examples which can be provided to students to keep on their desks) for other subjects (e.g., math). If attention problems were found to moderate the relation between academic achievement and working memory, interventions could be created to specifically address attention problems.

Chapter Three

Method

This chapter reviews the method that was used to collect the data and to determine trends among the variables. The present study examined the relation between working memory as a predictor of adolescent academic achievement. Inattention was also examined to determine if it added significantly to the prediction, or moderated the relation between working memory and academic achievement. This is important because currently there are limited studies on adolescent students, and students in middle school are at a critical period in their school life. They have completed their elementary and introductory school years, which have taught them the mechanics of reading and early math, but they are not yet advanced students (e.g., college students) who are able to work independently and to organize their study habits without support. By examining the prediction of academic success with working memory and attention factors, the researcher hopes to describe the prediction of which students are at risk more precisely. The findings also may lead to further research for interventions to help struggling learners. The chapter is organized into the four sections: research design, participants, procedures, and data analysis.

Research Method and Design

The rationale. The purpose of this study was to examine factors which predict and promote academic achievement. Current research in the field has examined the relation between working memory and reading and math, but there was limited information about the relation between working memory and written expression. Additionally, there was limited information about the relation between attention problems and working memory in the prediction of academic skills with typically developing adolescents. The theoretical framework for this study was based on Baddeley's model (2011) of working memory which suggested that visual-spatial and verbal-auditory working memory components process information separately, and that these differ from one another in terms of their prediction of academic achievement.

The research design. The research design was correlational and used a quantitative analysis. This research method was appropriate to address the research questions because we were looking to find a numerical correlation value attached to the relation among different variables. The quantitative correlational design was the most appropriate research design for this study because the objective of the study was to examine relations among three identified variables: working memory, attention problems, and academic achievement. The present study had two independent variables: working memory and attention problems, and one dependent variable, academic achievement. The working memory battery included separate assessments for each of the verbal-auditory and the visual-spatial processing components. The academic achievement composites include three distinct curriculum areas of: reading, math, and written expression.

The quantitative methodology provided an analysis through which correlations and relations among variables could be identified, measured, and deductively investigated (Neuman, 2006). This goal was enabled by selecting assessments which were administered that had standardized norms for children aged 12 to 16. Scores obtained were reported in either standard scores or T-scores because the data gathered enabled quantitative analysis. There were other methods of assessing attention problems, academic skills, and working memory, but the researcher wished the study to be replicable, and for this reason she selected standardized measures that are available world-wide. Each of the tests was shown to have acceptable reliability and validity data to ensure replicable measurement of constructs. The reliability and validity data will be reported with each measure separately in the section which reports on instrumentation.

Research Questions

Verbal working memory questions:

Question 1a. What is the direction and strength of the relation between reading achievement and verbal-auditory working memory?

Question 1b. Do attention problems add significantly to the prediction of reading achievement after controlling for verbal-auditory working memory?

Question 1c. Do attention problems moderate the relation between verbal-auditory working memory and reading achievement?

Question 2a. What is the direction and strength of the relation between math achievement and verbal-auditory working memory?

Question 2b. Do attention problems add significantly to the prediction of math achievement after controlling for verbal-auditory working memory?

Question 2c. Do attention problems moderate the relation between verbal-auditory working memory and math achievement?

Question 3a. What is the direction and strength of the relation between written expression achievement and verbal-auditory working memory?

Question 3b. Do attention problems add significantly to the prediction of written expression achievement after controlling for verbal-auditory working memory?

***Question3c*.** Do attention problems moderate the relation between verbal-auditory working memory and written expression?

Visual working memory questions:

Question 4a. What is the direction and strength of the relation between reading achievement and visual-spatial working memory?

***Question 4b*.** Do attention problems add significantly to the prediction of reading achievement after controlling for visual-spatial working memory?

Question 4c. Do attention problems moderate the relation between visual-spatial working memory and reading achievement?

Question 5a What is the direction and strength of the relation between math achievement and visual-spatial working memory?

Question 5b. Do attention problems add significantly to the prediction of math achievement after controlling for visual-spatial working memory?

Question 5c Do attention problems moderate the relation between visual-spatial working memory and math achievement?

Question 6a. What is the direction and strength of the relation between written expression achievement and visual-spatial working memory?

Question 6b. Do attention problems add significantly to the prediction of written expression achievement after controlling for visual-spatial working memory?

Question 6c. Do attention problems moderate the relation between visual-spatial working memory and written expression?

Participants

Participant selection. Participants were 50 adolescents from ages 12 to 16 years of age.

Recruitment for the study was shared between three public middle schools and a home-school network. Six students were enrolled in home-schooling and studied at home with their parents or a tutor, 2 students were learning with virtual programs, and 2 students were enrolled in private schools. The remaining students were enrolled in public middle schools and these had a mixture of face to face teaching in the school setting, support with tutors at home or at a tutoring center, and also online interactive classes for some programs (e.g. virtual math programs). The participants were considered a skewed sample because all the parents were interested in the research, brought their child to the examination room, and many reported that they used tutoring when needed to help boost their child's academic performance.

The participant pool had a total of 50 participants with 25 boys and 25 girls. The parents checked a box on the Self-Disclosure Demographic Checklist (see appendix) to indicate the race/ethnicity of their child. The choices were: "Caucasian," "African-American," "Hispanic," "Other," or "Do Not Wish to Disclose." No parents checked the "Do Not Wish to Disclose" box. The labels parents checked are the ones used for this study throughout the paper. There were 30 "Caucasian", 13 "African American", and 7 "Other" race/ethnicities reported. As no other group besides "Caucasians" had sufficient numbers of students for a separate analysis to be conducted, only two groups were included in the analyses: "Caucasian and Non-Caucasian."

There were 19 students (38% of the sample) who reported a medical diagnosis of Attention Deficit Hyperactive Disorder (ADHD) or Attention Deficit Disorder (ADD), however, the analysis did not separate these students because it was not possible to control for students who were on meds or off meds, and how efficiently their treatment plan was working. As students with no diagnosis of ADHD sometimes report attention problems, and some students with ADHD, but on medication have no problem with attending in school, the scores were not divided by diagnosis. By using the scores from the inattention index, the researcher could control for inattention if needed, and could examine trends with high and low attention within the data set. The Rogers (2012) study used a clinical population from a Mental Health providing clinic, so all the participants either had ADHD, some other mental health condition, or various medical treatment plans.

Participant delimitations. Children with developmental delays such as intellectual disability, autism, were not invited to participate, and they were deselected from the participant pool. Students with these limitations were deselected because their performance could not be compared to the normed sample for their age and grade level for the standardized tests provided. Only standardized scores obtained from typically developing students that matched the test normative sample were used, so the scores entered into the analysis could be considered valid. It is an assumption of standardized testing that the standardized norms to determine test scores results is based on a defined normative sample, and participants who fall out of this normative value may need special interpretation for their scores.

Deselection occurred at the point of parent enquiry and interview (in person or by telephone) about participation in the study. Parents who expressed interest were asked to confirm their child’s enrollment in a general education setting. Students enrolled in special education self-contained settings or hospital homebound settings were excluded because only students with disabilities which severely impede learning in a general education classroom are included in self-contained settings. Hospital homebound were deselected as the students within this group were not well enough to partipate in regular education classes. In addition only one child per family unit, (no siblings) was allowed in the recruitment pool. This helped protect independence of the observations for participants. Participants who were not eligible to participate were thanked for their enquiry, and the researcher explained the reasons they did not meet the selection criteria. When a parent had two children who wanted to participate, the parent chose which student would move forward with the study. Only two students were deselected from participation because they were siblings of participants who were accepted into the study.

Parents of successful applicants were required to complete the parent consent form, and their child was required to complete the child assent form. There was also a demographic checklist which gathered more personal information needed for the research. This included the student's date of birth (required for scoring of standardized assessments), and confirmation that the student had no delimiting conditions which could adversely affect the research. There was a voluntary check box available for racial/ethnic demographics, and the participants contact address or email address was requested for those parents who wanted the results of the achievement test mailed to them. A limitation the self-disclosure on the demographic check list is that social-economic status was not addressed. This was not addressed because the researcher had no way of verifying the information. The examiner observed that every participant was driven to the examination center with independent transport (i.e., their own family car). This suggests the population was skewed towards families who had sufficient income to support at least one vehicle instead of relying on public transportation.

With mixed marriages in families, and histories of mixed race families in the family past on either of a child's parents – it may not be possible to categorize an individual according to one ethnic type. The advantage of the checklist was that parents could select the race they wished to report – but the disadvantage is, there were no guidelines as to how to identify mixed race students, except from the "other" category. The information gathered about diagnosis of ADHD did not include date of diagnosis (i.e., how long this had been a problem), and any medical (e.g., psychotrophic mediation) or other (e.g., counselling) interventions the student was currently taking to address needs.

In the event that the parent completed a demographic checklist and reported no delimitating conditions, but the researcher had concerns that the student had a condition that could adversely affect the research – the researcher suggested that the parent complete the line marked “other” on the demographic form to provide more information about the problem, so the researcher could review this at a second stage of participant selection. This problem did not arise, and there were no secondary stages of participant selection needed. (Please see Appendix A for sample of adult consent form, child assent form, and demographic check list.)

Sample size

Three criteria are important when considering a sample size. The first criterion is the size of the desired effect. The Cohen effect size is a measurement of the strength in the relation between the variables. In terms of correlation analysis, the effect size is defined as small, medium, or large (Cohen, 1977). The second criterion is the alpha level. This is the probability of a Type I error, that is the probability of rejecting the null hypothesis given that that the null hypothesis is true. Usually alpha level is set to .05 or 95% confidence interval. The third criterion is the power of the study. The power represents the probability of being able to reject a false null hypothesis and conventionally a power of .80 is used for quantitative researches. The power analysis was completed using the G*Power. The G*Power analysis utilized an effect size of .15, probability level of statistical significance .05, and the statistical power of .80, as well as the number of predictor variables. (Erdfelder, Faul, & Buchner, 1996; Erdfelder, Faul, & Buchner, 2005). A Cohen medium effect size for the significance of the findings (0.15), power of 0.80, and the statistical significance level of 0.05 also indicated a minimum sample size of 43 would be required (Faul, Erdfelder, Lang & Buchner, 2009).

The calculations found the researcher needed a sample size of 43 based upon the power analysis, but the sample was increased to 50 to include for any possible mortality of participant data during the testing cycles. This was adhered to reach the necessary power of 80 percent in a quantitative analysis to be able to reject the null hypothesis in the statistical analysis.

Sampling Frame

Sampling method. To accommodate the small size of the target sample and the potential difficulty in identifying and recruitment of participants, a convenience sampling methodology was employed. The convenience sampling selected individuals who could be reached, surveyed, and tested through the convenience sampling method. This method is cost effective, convenient, and purposeful. A convenience sampling is a non-random method of sampling that can influence the generalizability of the study, thereby diminishing external validity because the sample may not represent the population accurately (Castillo, 2009). A convenience sample is appropriate for this study, because it is the most effective way to recruit and enlist individuals for this study.

Geographic location. The location of the participants in this study was a southeastern state in the United States. Students came from varied socioeconomic backgrounds and lived within three large urban school districts. The sources of recruitment were varied to enable recruitment from different socio-economic areas within the district, as well as to enable selection from a culturally diverse population. For this reason, recruitment sites were approximately 10-20 miles apart from each other to help obtain a varied sample.

Sampling sources. The participants were recruited from sources which had IRB consent for research. These included, but were not limited to two public schools where typically developing students were enrolled. The researcher attempted to recruit from the local YMCA's in several different locations, some church summer school programs, the information also was shared with a homeschooling network. The standardized testing used to measure academic achievement was valid with the homeschooling network, and is one of the assessments accepted by the local school districts to help measure academic growth over a school year for homeschooled students. All the homeschool parents wanted feedback from the academic achievement testing, as the information was important to them to help them with educational planning.

In order to approach students in public middle schools, a separate IRB application to the local school district was made. One local school district, and three principals in the same district, granted IRB consent for the researcher to provide leaflets to their students. In one school a morning announcement invited students to pick up leaflets if they were interested. By approaching multiple places it was hoped that a good selection of typically developing students aged 12-16 would volunteer to participate in the study.

Approximately 500 flyers were created to share between agreed locations. With a 10% response rate, there still would be 50 volunteer participants for the study. Digital versions of the flyer were provided by email to the homeschool networking groups.

Sampling procedures. In order to gain permission from these sources, the researcher visited the sites to request permission and provided them with a sample flyer. Post IRB approval, the researcher sent a mailshot to prospective email sites such as the homeschool network. The researcher offered to meet with any supervisor, manager, or church counselor to enable a person to person conference to address any questions. After IRB approval, the leaflets were left at the front desk of grade level offices in school, and emailed to home school networks. Students who were interested were instructed to share the flyer with their parents.

The sampling procedures were conducted in several stages. First the researcher had flyers available to parents to collect at a front desk. Second, the parents completed the self-disclosure demographic checklist and returned this to researcher with their signed consent and also the student signed assent. Third, the researcher reviewed the forms completed and selected participants who met the qualifying criteria.

Sampling Time frame. Once participants were recruited, there was only one time sampling for data for each student's testing administration. Parents chose when they wanted to bring their student for testing so that the time of day chosen was the most convenient to them. Testing opportunities included: after school or weekends, and the date and time was flexible. Of the 50 participants, 4 students were tested after school, and 46 were tested over 6 weekends with a maximum of 4 students per day. To standardize the order effect of testing, all students were provided the assessments in the same order, with the same amount of time reserved for breaks. As testing was provided over several weekends at different venues, this enabled similar testing conditions and procedures no matter which date or venue a participant attended.

Informed Consent

Informed assent were provided to all children participants and consent forms were provided to their parents (see Appendix A & B). Signed forms were collected prior to administration of the testing battery. The informed consent form provided the participants with information regarding the purpose of the study, information about informed consent, a brief description of the study's objective, the time commitment involved and information about anonymity and confidentiality. The contact information of the researcher was also provided.

The choice to withdraw at any time during the study was emphasized. A participant was able to withdraw at any point in time before, during or after completing the study. Withdrawal would entail removal of all data gathered from the sample.

Confidentiality

All personal identifier information was removed from the data. Demographic checklists (See Appendix C) which held personal identifying data were held until assessments were scored. After scoring of test data, personal identifying information was removed from data set to protect confidentiality. The consent form offered an opportunity for parents to receive feedback on the student's performance on the achievement test. The personal information kept until feedback was provided included the name, address, source of recommendation, and date of birth. After scoring of assessments, scores obtained were entered into an EXCEL spreadsheet, with no personal identifying information on the sheet. When results were reported in the finished study, no identifiers for cities or schools or any other details of personal identifying information were provided.

Assessment scores and all data details were entered into an EXCEL spreadsheet which could be entered into SPSS. The electronic files of the data were kept in password-protected files and they will be kept for 5 years on a flash drive which will be kept in a locked file at the researcher's office. All identifying information was removed prior to entering the data into SPSS, and shredded. Participants were identified through assigning numerical codes in replacement of their actual names throughout the course of recruitment and data gathering.

Procedure

Data collection procedure. The protocol for the research had several steps. These are described in the following section in detail. After IRB approval, a Pilot study was conducted to rehearse the procedures and to identify any areas that needed clarification before the main study was conducted. A flyer was produced which met IRB approval and was approximately 5.5 X 8.5 inches. A copy of this flyer is in Appendix D. It had the University logo on it to help identify the research as an approved study. The flyer identified the purpose of the study, the kinds of testing that would occur, and time the student would take to complete the assessments. It also provided the cell number of the researcher as a contact number for any interested person to call. The flyer was provided in digital format to email enquiries and paper format to approved sites.

The IRB approved several sites which were interested in supporting the research, but only to distribute flyers. Permission was not granted to interact with teachers or students in the school setting, observe students in class, or ask teachers to spend time completing any rating scales. These sites included local public middle schools and a local home school network. Leaflets were provided by email or by collecting at front desk from grade level offices. When the parents called and expressed interest in the study, the researcher explained that there were some prequalifying conditions which required students to be selected for participation. The researcher reviewed the delimitations with the parents, and if there were no disqualifying conditions, the consent form and demographic check list were provided for review and signatures. Several student testing sessions and locations were available, to enable parents to select a location that was most convenient to them. Students were provided with individual testing times to enable standardization of test administration.

The researcher has been trained in the administration, scoring, and interpretation of psychological and educational assessments and was the only person to score and interpret the data.. The raw data of the test instruments were summarized into an analyzable dataset in Microsoft Excel which included: gender, age of student, race, current diagnosis of ADHD, and results of standardized scores from: BASC-2, WISC-IV, UNIT, and Woodcock-Johnson Tests of Achievement. The data were then uploaded into the SPSS statistical software program for analysis.

Instrumentation

The battery of assessments that was used in this research included rating scales which measured attention problems (BASC-2 Self-Report Scales), working memory assessments (subtests from the WISC-IV and also the UNIT), and academic achievement tests (from the WJ-3 Tests of Achievement standard battery). All the assessments were completed by each student in one testing session. The following sections will provide details tests, administration, and the reliability and validity data.

Behavior Assessment System for Children–2ndEdition (BASC-2). The BASC-2 Self-Report form for Adolescents (SRP-A) had 5 composite indexes which include: school problems, internalizing problems, inattention/ hyperactivity, emotional symptoms, and personal adjustment. The self-report scale for adolescents (SRP-A) was completed by each participant to determine (their perception of) their difficulties attending in the school environment. The BASC-2 SRP-A required approximately a third grade reading level, and if the student had any difficulty, the examiner could have assisted with reading and explaining any words they found difficult. The first 69 questions required a 'True' or 'False' answer, the remaining questions were answered on a 4 part scale. Examples of inattention problems which could be reported could include: "People tell me I should pay more attention," " I have attention problems," " I have trouble paying attention to the teacher." Examples of responses possible included "Never," "Seldom," "Sometimes," and "Often." The responses were scored on a computer and a statistical analysis within the scoring program provided by the test makers provided standardized t-scores for each index.

Although only the attention problem index was used in this research, every question on the assessment was answered because the manufacturers built in validity indicator questions which were interspersed with the target questions. The validity indicators included “off topic” statements (e.g., ‘I ride an airplane every day to go shopping’), which the participant was required to respond to.. They helped determine the likelihood that participants read each question carefully, and did not randomly select a response without due thought. The test makers (Reynold & Kamphaus, 2005) permited a maximum of 2 unscorable items per scale. The technical manual recommends not scoring forms that have more than 10 missing answers (Reynold & Kamphaus, 2005).

The Attention Problems index reported scores for difficulties a student could have for attending, keeping on track, and feeling that other people comment on his or her lack of attention. Low to average scores (20-59) indicated typical levels of attention problems reported by students of this age group. High scores (60 or higher) indicated problematic levels of paying attention by the student (e.g., having a short attention span or forgetting things). The Attention Problem scale was designed to assist in diagnosing the presence or absence of symptoms commensurate with Attention Deficit Hyperactivity Disorder. The inattention scales measured an inability to maintain attention and the tendency to be easily distracted from tasks requiring attention. Research has previously demonstrated that inattention is more highly correlated with academic problems than hyperactivity (Hartley, 1999).

The BASC-2 also provided a Validity Index to help determine the likelihood of the respondents’ answers being ‘acceptable’ across 3 different indexes: Response Pattern, Consistency, and the F-Index which refers to an extreme negativity (e.g., always answering 'never'). T-scores had a mean of 50 and a standard deviation of 10. T-scores which were between 60 and 70 were described as being 'At Risk.' 'Clinically Significant' problem scores. would have required a score of 70 or higher. 'Average' scores had scores in the range of 41 to 59. Scores of 31 to 40 were reported as 'Low' and 30 and below are considered 'Very Low.' Students who obtained scores of 60 and below are described as having a score which is typical for their age and grade level. The BASC-2 scores were normalized with a linear transformation of raw scores that keeps the same raw-score distribution of results. A percentile score was also provided (e.g., a percentile of 96 means the individual is in the top 4 percent of the norm sample). The norms are based on a large national sample of over 13,000 cases that were representative of the entire USA. The norms are divided by age (Reynolds & Kamphaus, 2004).

Reliability of the BASC-2. The BASC-2 Self Report is a well-known rating scale, with item elections for each construct determined by a covariant structure analysis to ensure that reliability, distinctiveness, and interpretability of each scale represented the construct they belonged to. The self-report scale has a high internal consistency and test-retest reliability calculated from the normed sample which ranged between .71 and .94. The composite and internal-consistency reliabilities were measured by coefficient alpha. The scale of Attention Problems was used in the present study, the reliability coefficient was .78 for adolescents aged 12 to 14 and .79 for adolescents aged 15 to 18. The test and retest reliability for adolescents was .84 between the first and second administration of the scale. Attention was one of the scales with the highest levels of test and retest reliabilities. Other measures of validity include a Consistency Index and Response Pattern index which provide scores to determine an Acceptable through to Extreme Caution warning on answers provided by participants. All protocols scored in the present study were examined for the consistency index and also the response pattern index to determine if the results met the criteria for Acceptable on the validity indexes.

Validity of the BASC-2. The BASC-2 Self-Report Attention Problem subscales were highly correlated with the Hyperactivity scales (averaging about .70 across the teacher and parent rating scales when compared). Validity of the rating scales were tested using two types of factor analysis composites: covariance structure analysis, and principal axis analysis. These methods determined if there is a good fit to the scale with inter-correlation data. Correlations with other self-report measures included a comparison with the Achenbach System of Empirically Based Assessment Youth Self-Report. For adolescents the correlations for attention problems were around .70. There were no correlations available for a comparison with the teacher rating scale of the Strengths and Weaknesses of ADHD symptoms and Normal Behavior Scale (SWAN) which Rogers et al. (2012) used in their study.

Wechsler Intelligence Scale for children – 4th edition (WISC-IV). The WISC-IV measures intelligence with a four –index framework based on a factor-analytic analysis. The WISC-IV is an individual administered test of intelligence appropriate and normed for individuals ages 6 through 16. Only the factors which relate to the Working Memory Index were administered. These included the digit span and letter number sequencing subtests. Subtest scores were reported in scaled scores. Scaled scores had a mean of 10, with scores of 8 to11 representing an average performance. Standardized scores which had a mean of 100 are then calculated from norm tables based on age of the participant.

Digit span. Digit span was a test for which the examiner read a sequence of random numbers to each participant, and the participant was required to repeat the sequence back to the examiner. There were two parts to this assessment. The first part was a ‘digit span forwards’ test for which the participant repeated the sequence in the same order. For instance, if the examiner said: “5 4 3 2,” the participant had to repeat the digits in the same order “5 4 3 2” to score a correct response. The second part was “digit span backwards,” for which the participant needed to reverse the sequence heard when reporting the numbers back. For instance, if the examiner said: “9 4 8 2,” the participant must have said: “2 8 4 9” in order to score a correct response. The assessment began with short sequences of numbers and gradually increased the number of digits in the sequence until the participant was not able to continue. Scores from the digit span forwards and the digit span backwards were combined to form a composite score. Practice trials are built into the test design, and serve to ensure the participant understands the directions. All the participants coped with the basal requirements for the assessment, and no scores of 0 were recorded.

Letter-number sequencing. With letter-number sequencing the participant was instructed to say “first the letter/s, then the number/s. However, letters had to be presented in the correct alphabetical order, and numbers needed to begin with the lowest number first. The participant listened to the cue, and then manipulated the information to represent the correct answer. For instance, if the examiner said: “ 9 5 B 2 A,” the participant needed to provide the answer as follows: “A B 2 5 9” to score a correct response. The item numbers began with single numbers and digits and became increasingly difficult.

The composite scores from each of these two working memory subtests were added together, and the results were normed by the age of the participant to provide a standardized score for the working memory battery. This battery represents the verbal-auditory working memory assessment because words and digits which require vocalization are used, and these skills require the use of verbal and auditory processing skills.

Reliability of the WISC-IV. The Mental Measurement Yearbook 17 reported "the composite scores of WISC-IV appear to be highly-reliable. The WISC-IV reliability was based on an entire sample of 2,200 people. Internal consistency estimates using the split-half method with Spearman-Brown correction (test-retest reliability for speeded subtests [mean interval of 32 days]) was excellent for the FSIQ, with coefficients of .96 or .97 at every age. Average reliability coefficients for the core and supplemental subtests across age groups ranged from .79 to .90..

Test-retest reliability information was estimated using a sample of 243 children across several age groups with a retesting interval of 32 days (range = 13 to 63 days). At the composite level, the index reliabilities ranged from .84 to .95, whereas the FSIQ coefficient was .91 or higher for each age group. Although the coefficients ranged from .63 (Arithmetic, ages 8-9) to .95 (Vocabulary, ages 14 to 16), most were in the .70s to .80s (Wechsler, Kaplan, Fein, Kramer, Morris, Delis, & Maelender, 2004).

Validity of the WISC-IV. The general factor of the WISC-IV was analyzed using a confirmatory factor analysis with a sample of 355 students. The general intelligence factor was assessed in a hierarchical model, and produced the highest source of variance in the model- 48% for the total variance, and 75% of the common variance, and 77% of the common variance for pediatric neuropsychological profiles (Watkins, 2010).

Woodcock-Johnson 3rd Tests of Achievement (WJ3). The Woodcock-Johnson was selected because it has been used extensively in the literature, is a broad standardized assessment which is used commonly in student evaluations for academic skills, and also because the Rogers et al. (2012) research used this measure. The Woodcock-Johnson achievement tests for Broad Math, Broad Reading, and Broad Written Expression were used.

A limitation of this assessment is that scores are obtained for answers were either correct or wrong. There are many different theoretical perspectives to testing – and these correspond with different ways of assessing children's reading performance. The Woodcock-Johnson was chosen to provide standard scores for each of the academic skill areas in order to enable future replication of the study. The standard battery of theWJ-3 contains 9 subtests which cover three curricular areas: reading (letter-word identification, reading fluency, passage comprehension), math (calculation, math fluency, applied), and written expression skills (spelling, writing fluency, writing samples). Specifically, the combined subtest scores provided a standardized score for Broad Reading, Broad Math, and Broad Written Expression. The standardized scores have a mean of 100. Details of the subtests are as follows:

***Broad reading*.** Broad reading includes three subtests which are:

1) Letter–word identification. This subtest required a student to read letters and/or words presented on a sheet which are out of context. Students read until they reach a ceiling for errors allowed. The first words are short and decodable, however as the examinee moves through the subtests, the word become increasingly difficult and irregular.
2) Reading fluency. This subtest recorded the number of statements that were correctly answered in a timed 3.00 minute session. Examples include: "A cat can bark. Yes or No?"
3) Passage comprehension. This subtest required the respondent to read a short sentence and then to complete the sentence which had a missing word; there were cartoon drawings to illustrate most sentences. An example is: "The car is bigger than the ___________" (The cartoon drawing would show the picture of a dog.) The passage text became progressively more challenging, using longer words with more adult

abstract concepts, and no supporting illustrations. This required readers to understand the passage content to be able to generate a word that will fit in the missing space.

***Broad math*.** Broad math includes two subtests which are:

1) Math calculation skills. This subtest required a student to work independently with a math calculation that is presented in figures with the signs and symbols required to enable the calculation. (e..g., 12 ÷3 = ?).
2) Math reasoning. This subtest involved a student reading math word problems and looking at an illustration, and then figuring out the answer to the problem{e.g." When added together, how much money is this?" Or," If you had this much money (see picture) and you bought two balls (price in picture) how much change would you have left over?"}.

Broad written language. This composite included three subtests of:

1) Spelling. This subtest required the examinee to listen as the examiner read a target word aloud and then read a sentence containing the target word. Then the examinee was asked to spell the target word. (e.g. "dog" "The dog has a bone.")
2) Writing fluency. This subtest required a student to look at a picture which had three words written below it, and then make a good sentence using the three words to describe what they can see in the picture (e.g., a picture of a cup of coffee, with the words: my hot coffee) .
3) Writing samples. This subtest required the examinee to look at a picture or to read an introductory sentence, and then to follow the instructions provided by the examiner (e.g., "Look at the picture and write what could happen next," or "Complete the missing line in this paragraph.").

Reliability of the Woodcock-Johnson Tests of Achievement- 3rd Edition. Most of the individual WJ-3 tests showed strong reliability measures of 0.80 or higher and others were 0.90 or higher (The Riverside Publishing Company, 2006). In addition, the internal reliability for the subscale of Total Achievement was .98 which would be considered to be very high. The Inter-rater correlations for even the most subjective measures in the total battery (Writing Samples, Writing Fluency, and Handwriting from the Achievement Battery) were very high (upper .90s), Results of the test-retest reliability of scores over time intervals (e.g., less than 1 year, 1-2 years, and 3-10 years) yielded acceptable to high median reliabilities with a range of .70 and above. Thus the reliability characteristics of the WJ-3 suggested this was a good assessment to use in the present study.

Validity of the Woodcock-Johnson Tests of Achievement – 3rd Edition. The Woodcock Johnson Technical Manual reported the internal consistency reliability coefficients ranged from .90 to .94. This is a high correlation with the test and retest reliability towards measuring the constructs identified per subject area.

Universal Nonverbal Intelligence Test (UNIT). The Spatial Memory and Object Memory subtests of the UNIT were used to measure visual-spatial working memory skills with the participants.

The spatial memory subtest. This subtest measured a student's ability to replicate with manipulative counters an image which was viewed and then concealed from sight after a few seconds. The examinee viewed a pattern of green, black, or green and black dots on a grid for a few seconds. After the stimulus was removed, the examinee recreated the spatial pattern with the colored chips on a response grid. This measure was primarily a measure of short term visual memory for abstract shapes. Spatial memory consisted of 27 scored items, 5 demonstration items, and 5 sample items. Items 1 through 5 were checkpoint items. Responses were scored on categorical basis of either correct or not. The total number of responses provided a raw score which was then normed to a T-score after adjusting the response for age.

Symbolic memory. This was a memory test for visually presented information. The examinee was presented with a flip chart which presented drawings of a few objects. After viewing the drawings for a few seconds, the stimulus was removed. The examinee was then provided the opportunity to select counters with drawings of the objects seen and arrange them in the order seen. As the assessment increased in difficulty the number of presented stimuli increase. Responses were scored either correct or not and raw scores were adjusted with norm tables to provide scaled scores. The scaled scores from both indexes were then added and a standard score was calculated by referencing the norms for the student by age.

Reliability of the UNIT. The median of the average subtest reliability coefficients across different ages was .83 for each subtest. The reliability of the standard battery which included other subtests was .92. The UNIT approached or met the reliability standards for the population on the normative samples. The reliability scores for the UNIT were calculated using the Spearman-Brown formula which uses an analysis based on linear combinations (Bracken & McCallum,1998). The population of students selected matched the demographics of the normed sample enabling the scores achieved to be considered valid.

Validity of the UNIT. Verification of the validity of a test may occur when its correlations with other tests that have been validated over time are compared (Borghese & Gronau, 2005). Correlations between the UNIT Symbolic and Nonsymbolic Quotients and the WISC-III Full Scale IQ scores supported convergent and discriminant validity. The shared variance between the Symbolic Quotient and Verbal IQ score was a correlation of 0.71. The

UNIT's authors detailed the theoretical model that the test is based on, and provided detail about the content review study, which went beyond item content.

Order of Test Administration

The tests were administered in the same order to every participant to keep the testing conditions constant between students. The reason for this was to keep the order effect for conditions standard between participants. The limitation of this standard order was that fatigue may have occurred with all the final assessment subtests due to position at end of testing session. Table 1 below indicates the order of assessments and average time taken for testing. Breaks were taken between administrations when needed. The BASC-2 self-rating scale was administered first because it gave the students time to become comfortable in the testing environment, as the remaining tests required close work with the examiner. All of the students completed all of the required tests.

Table 1. *Order of Test Administration*

ORDER	**TEST**	**AVERAGE TIME**
1.	Behavior Assessment for School Children- 2nd Ed. (BASC-2)	15 min.
2.	Universal Nonverbal Intelligence Test (UNIT): Spatial Memory	12 min.
3.	Universal Nonverbal Intelligence Test (UNIT): Object Memory	12 min.
4.	Wechsler Intelligence Scales for Children-4th Ed (WISC-IV): Digit Span	12 min.
5.	Wechsler Intelligence Scales for Children-4th Ed (WISC-IV): Letter-Number Sequencing	12 min.
6.	Woodcock-Johnson Tests of Achievement- 3rd Ed. (WJ-3)	45 min
	TOTAL TIME for all tests:	**2 hours**

Internal Validity for the Present Study

Campbell and Stanley (1963) identified 8 factors that were related to determining the internal validity of a research study. These included the history, maturation, testing, instrumentation, statistical regression, differential selection, experimental mortality, and any selection-maturation interaction or diffusion of treatments.

History refers to events, apart from the research procedures which may influence the results. There were no unexpected events which threatened the validity of the study. Maturation refers to psychological changes that may occur within the participants over the course of the study. As the participants only met the researcher one time, maturation was not considered a threat to the internal validity of this study. Testing refers to any pretest or learning that would intervene to influence posttest results. As the participants did not have a pre and post-test, this was not considered a threat to the possible findings.

Selection issues included systematic differences in participant selection. A demographic check list provided the researcher with a method to obtain demographic information about the students who volunteered (and ensure they met the selection criteria) prior to the researcher confirming they would be able to participate in the study. The checklist itemized the delimitations, thereby ensuring systematic differences in selection were avoided.

Experimental mortality refers to participants not completing the battery of tests which they volunteered to complete. There were 50 students who completed the full battery of assessments required for this study. Selection and maturation interaction/ diffusion of treatments refers to some conditions influencing subjects in a separate testing condition. As the participants only met the researcher one time, and there are no prior conditions which varied between participants, this was not considered a relevant threat to the internal validity of the study. Because the testing was provided over different dates at different sites, this was not considered a threat to the study, as in each place, a private conference room or classroom was used.

Instrumentation can be considered a threat to validity when the assessments do not have good test and retest reliability, and there is insufficient documentation of the validity with which they measure their constructs. Tests with poor reliability may create scores that are inconsistent or misrepresent true performance, due to failures within the test product itself to ensure good reliability and validity on constructs they measure. In this study, only assessments with good reliability and reputations were used. Sometimes the analysis method itself can be a threat to the findings, as with statistical regressions there is a trend for scores that are very high or very low to migrate towards the mean during retesting. As no retesting occurred this was not considered a relevant threat to internal validity in the present study.

There may have been reliability and validity issues which applied to the instrumentation alone. The instruments in this study were selected because they were well documented in research with adolescents, and they were valued because they had good reliability and validity data for measuring the constructs that were relevant in the study.

Threats to the Validity of the Present Study

Threats to the validity of the study must be considered if there were any significant changes which affected the data collection, participants, or conditions under which the data were collected in any unforeseen way (Neuman, 2006). Measures were incorporated in the research design that protected it against potential internal threats to validity. These included administering the battery of assessments (e.g., working memory, attention and academic achievement) in the same order across the entire participating sample. The testing environment was also limited to a private conference room or classroom in each of the testing sites agreed with IRB. This enabled the researcher to control the level of distractions to a minimum by controlling the privacy for testing, lack of visual (e.g. pictures) and auditory (e.g. radio, television) distractions, and interruptions from siblings or pets. Also, the testing locations were booked for the time necessary to complete the testing, which supported the intended one-time-frame sample for data collection.

The confidential collection of data assisted in establishing trust with each research participant while enhancing the dependability of the data. This provided the means to maintain internal validity and establish credibility based upon integrity (Hopkins, 2010).

Data Analysis

The data analysis included several steps. These steps included computing descriptive statistics, correlational statistics, and also multiple hierarchical regressions to analyze the relations among the variables. The data included information generated from describing the participants and each of the three variables: working memory, attention problems and academic achievement.

Descriptive Statistics.

Participants. The demographic details included the total number of participants, ethnicity, gender, and mean age.

Variables. The following analysis was provided for each of the variables (working memory, attention problems and academic achievement): the mean score, standard deviation between scores, and distribution of the scores (skewness or kurtosis). This information described how closely the data approximated a normal distribution.

There were three cluster groups of variables - two independent variables (working memory and attention problem scores), and one dependent variable (the academic achievement score). The working memory had continuous scores for each of the verbal-auditory memory and also the visual-spatial memory. The attention problems had a continuum of scores which included high attention problems reported and low or no attention problems reported. The academic achievement variable had three areas of academic achievement (broad reading, broad math, and broad written expression), which were represented with standardized scores.

Analysis.

Correlational analysis: The Pearson Product-Moment Correlation Coefficient examined correlations among the variables to determine if there were any significant relationships. The purpose was to examine the data for multi-collinearity. Multi-collinearity occurs when there is a strong relationship between two or more predictors in a regression model. It can be a problem when perfect collinearity occurs because it would not be possible to determine which regression coefficients were unique to each variable (because there are infinite combinations of coefficients that would work equally well) (Field, 2005). Previous research in the literature (Rogers et al., 2012) did not report any problem with multi-collinearity.

Multiple regression analysis. A multiple regression analysis was used to look at the predictors of academic achievement. A multiple regression is a form of linear regression where the dependent variable is predicted by more than one independent variable. There are assumptions which need to be met for multiple regressions. These include making sure there are sufficient participants; the variables have a normally distributed population of scores; the variables are each linearly related to the dependent variable, and outliars have been considered for elimination, and no multicollinearity is evident (Dancy & Reidy, 2002). The following sections provide details of the equations, the order of entering the data, and how each research question was answered.

Equations. Please see Tables 2 to 4 below for explanations of the terms used for the regression equations that were used to answer questions 1-6.)

Table 2 ***Key for abbreviated terms in regression equation for questions for "Part a"***	
$Y\text{-hat} = a + b_1 * WM$	
This equation describes the relationship between achievement scores and working memory.	
Y-hat	Y-hat represents the dependent variable which is Achievement
a	"a" is the intercept (the expected value of Y when the regressor is equal to zero)
b_1	b_1 is the expected change in achievement given a one-point increase in working memory
WM	Working memory

Table 3 ***Key for abbreviated terms in regression equation for "Part b"***	
$Y\text{-hat} = a + b_1 * WM + b_2 * \text{attention}$	
This equation describes the relationship between achievement scores and both working memory and attention.	
Y-hat	'Y-hat' represents the dependent variable which is Achievement
a	'a' is the intercept (the expected value of Y when both regressors are equal to zero)
b_1	b1 is the expected change in achievement given a one-point increase in working memory, while holding attention constant.
b_2	b_2, is the expected change in achievement given a one-point increase in attention, while holding working memory constant.
WM	Working memory

Table 4 ***Key for abbreviated terms in regression equation for questions in "Part c."***	
$Y\text{-hat} = a + b_1 * WM + b_2 * \text{attention} + b_3 (WM * \text{attention})$.	
This equation controls examines the interaction of working memory and attention in their relation to the prediction of academic achievement.	
Y	'Y' represents the dependent variable which is Achievement
a	a is the intercept (the expected value of Y-hat when the regressor is equal to zero)
b_1	b_1 is the effect of WM on the achievement score when the value of the Attention score is = 0
b_2	b_2 is the effect of Attention on the achievement score when the value of the WM score is = 0
b_3	b_3 is the changing of the effect of WM on the achievement score when the Attention score increases by 1 point.
WM	Working memory

Procedures. The regression analysis involved several steps. The regressions were run with the following data:

1) *Ethnicity*. The ethnicities of the students were entered into the data base for the analysis using the same descriptors as the Demographic Check List. However, as there were 30 Caucasians and a smaller number for each of the remaining racial/ethnicity groups, a combined group was created which was named "Non-Caucasian." As there were significant differences between the Caucasians and Non-Caucasians with standard scores for the dependent variables of every area of academic achievement, the regressions were computed holding ethnicity constant.

2) *Academic achievement scores*. The dependent variable scores for broad reading, math and written expression were entered into the data set. Data of standardized scores from each academic area were provided from the scores obtained from the Woodcock-Johnson Tests of Academic Achievement- 3rd Edition. There were separate regressions run for each area of academic achievement (reading, math, and written expression).

3) *Working memory*. The independent variable scores for working memory were added into the hierarchical regression to determine their effect on the dependent variable of academic achievement. Working memory scores were analyzed with two regressions – one for visual spatial working memory and the second for verbal-auditory working memory. The results from the WISC-IV for verbal-auditory working memory index (two subtests of letter number sequence and digit span) provided one standardized score that was added to the model. Two subtests from the UNIT represented the visual-spatial working memory score.

4) *Attention Scores*. The independent variable of attention problems (scores for inattention) were added to the model to determine the effect it had on the prediction. Inattention was an independent variable which was added to the model to examine its relation with the main effect . The regression controlled for the individual impact of working memory when

calculating the additional influence of inattention. The inattention data was provided by the T-scores obtained from the BASC-2 rating scale.

This analysis determined the unique contribution in explanatory power that inattention provided in the prediction of achievement by working memory in typically developing adolescent students. The result of the analysis determined the individual effects of each factor of working memory and inattention to the dependent by examining the statistical significance of the change in the correlation coefficient R^2. A probability or alpha value of .05 was used in order to determine the statistical significance of relationships. If that parameter estimate was significant at the .05 significance level, the null hypothesis could be rejected. In the present study, this would imply a statistically significant relation of the independent variable to the dependent variable. In the statistical tool, the beta coefficient represents how strongly the independent variable is associated with the dependent variable. A two-tail t-tests p-value statistic was used to test the statistical significance of the parameter estimates.

An interaction statement. An interaction statement was used to explore the interaction between attention and working memory for predicting each of the academic variables. The additional variance explained by the inclusion of the interaction term (Working Memory X Attention Score) was assessed through the change in R^2 statistic and the associated effect size, as measured by Cohen's f^2. This analysis assessed the practical significance of the results, which was carried out separately for each academic achievement group (reading, written expression and math). This provided information which reported on the power of inattention as a moderating variable on the prediction of academic achievement by working memory.

Summary

This chapter provided the detailed methodological procedures of the present study. The purpose of this study was to examine the relation between each of the two components of working memory for the prediction of each of three academic skill areas: reading, math, and written expression. Second, research questions examined whether attention was a statistically significant predictor of academic achievement when controlling for working memory. Finally, the analysis examined if attention was a significant moderator of the relation between working memory and each area of academic achievement. Cohen’s effect size (for any significant finding) was calculated to help determine the importance of the find.

Chapter Four

Results

In this chapter, the findings for the research questions are presented. The three goals of the present study were: to examine the direction and strength of the relation between working memory and each of three academic achievement subjects (e.g., reading, math, and written expression), to examine whether attention problems added to the prediction of academic achievement when working memory was controlled, and to examine if attention problems moderated the relation between working memory and academic achievement. Two aspects of working memory were examined: visual-spatial and verbal auditory. Descriptive statistics for the sample are presented first. These are followed by results of the regression models which address each goal.

Descriptive Statistics

Population. Fifty participants aged from 12 to 16, and from a diverse range of ethnic backgrounds were represented in the sample, which reflects the cultural diversity present in the local area. 19 out of the 50 participants reported a diagnosis of ADHD. There were equal numbers of male and females in the study. The proportion of students with ADHD as compared to those without ADHD represents a typical selection of adolescent students in school (see Table 5, p. 94).

Attention Deficit Hyperactive Disorder. As Figure 4 (p.94) shows, parents from a subtotal of 30 Caucasian students (27% of all Caucasian students) reported their child had ADHD, while 9 out of 16 African Americans (69% of the African American) had a diagnosis of

ADHD. The ratio of this diagnosis for African Americans was nearly 3 times as much as each of the other two subgroups.   The ratio for the Hispanic students (2 out of 7 students) was 27%, which was close to the percentile reported by Caucasians. These ratios reflect trends previously reported in the literature, that African Americans have a higher rate of diagnosis of ADHD than Caucasians in the United States (Mash & Barkley, 2003).

Table 5 *Frequency Distribution: Age, Gender, ADHD & Ethnicity*

Variable	Category	Frequency	Percent
Age (Years)	12	16	32.0
	13	10	20.0
	14	16	32.0
	15	5	10.0
	16	3	6.0
Gender	Male	25	50.0
	Female	25	50.0
ADHD	No	31	62.0
	Yes	19	38.0
Ethnicity	Caucasian	30	60.0
	Black	13	26.0
	Hispanic	7	14.0

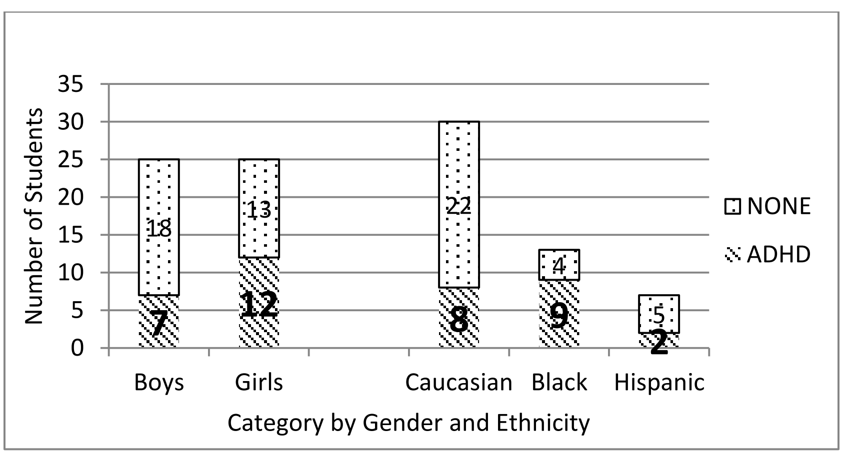

Figure 4
Frequencies of ADHD by Gender and Ethnicity

Table 6.

Frequency and percentage of diagnosis of ADHD by Gender and Ethnicity.

Subgroup	Diagnosis of ADHD out of group by same Ethnicity or Gender	Percentage of Subgroup by Ethnicity or Gender
Caucasian	8/30	27%
African American	9/13	69%
Hispanic	2/7	28%
Females	12/25	48%
Males	7/25	28%

Table 7

Mean Scores of Assessments by Gender

Assessment	Males (*n* = 25)	Females (*n* = 25)	Total (*n*=50)	*SD*	*F*	*p*
WJ Reading	95.0	96.6	95.80	17.40	0.10	.749
WJ Math	83.68	83.68	85.76	17.24	0.72	.399
WJ /WE	92.64	96.28	94.46	19.65	0.42	.518
Attention	56.36	56.80	56.58	10.40	0.02	.884
Verbal WM	88.48	93.76	91.12	15.38	1.48	.229
Visual WM	93.88	94.44	94.16	15.18	0.17	.898

WJ = Woodcock-Johnson Tests of Achievement 3rd Ed.
WM = Working Memory

Gender. Preliminary Analyses of Variance (ANOVA) were computed on each area of achievement with gender or race/ethnicity as between-subject factors. These were computed to see if either of these demographics could be eliminated from subsequent analyses. Table 6 shows the results of each analysis by gender. There were no significant differences between males and females for any academic achievement area. Therefore subsequent analyses combined males and females for the analysis (see Table 6, p.95).

Table 8

Mean scores of Assessments by Ethnicity

Assessment	Caucasian (*n = 30)*	African American (*n = 13)*	Hispanic/ Other (*n = 7)*	*TOTAL*	*SD.*	*F*	*p*
WJ Reading	101.93	88.92	82.29	95.8	17.40	6.01	.005
WJ Math	90.67	81.67	72.43	85.76	17.24	4.16	.002
WJ Written Expression	102.40	83.15	81.43	94.46	19.65	7.86	.001
Attention Problems	55.93	59.08	54.71	56.58	10.48	0.53	.594
Visual WM	98.80	90.46	81.14	94.16	15.38	5.09	.01
Verbal WM	93.53	83.00	77.29	91.12	15.18	3.65	.034

WJ = Woodcock-Johnson Tests of Achievement 3rd Ed.
WM = Working Memory

Race/ Ethnicity. Table 8 (see above) shows mean scores by ethnicity. There were significant differences by ethnicity for all three areas of academic achievement and also for attention. In order to take these differences into consideration and yet determine the relation between attention and achievement in the analysis, the subsequent regressions controlled for ethnicity. However, because the numbers within the minority groups were small, the subgroups of "African Americans," "Hispanics," and "Other," were combined as 'Non-Caucasians' in the regression analysis. Thus, ethnicity only had two levels, Caucasian or Non-Caucasians in the regressions.

Distribution of Scores. The scores were examined for skewness and kurtosis to determine if any outliers could skew the results. If a noticeable outlier were evident in the data set, the researcher would need to consider whether running the regressions with the outlier would provide a fair representation of the relation between the variables. The skewness and kurtosis for all variables were within the values range of minus one through plus one. The lack of skewness or kurtosis in each of the variables, including the verbal and visual working memory scores, suggested the variables approximated a normal distribution**.** No outliers were observed in the data set. Table 9 (see below) provides the scores for this information.

Table 9
Mean Scores and Distribution of Scores per Variable

Assessment	Mean	Std. Error	Std. Deviation	Variance	Skewness	Kurtosis
Reading	95.80	2.46	17.40	302.81	-.59	.97
Math	85.76	2.44	17.24	297.17	-.71	-.25
Written	94.46	2.780	19.65	386.25	.02	.30
Verbal	91.12	2.18	15.38	236.68	.46	.30
Visual	94.16	2.15	15.18	230.50	.65	.13
Attention	56.58	1.48	10.48	109.84	.37	-.51

NB. Normal Distribution for Symmetry: Skewness value = -1.0 to 1.0; Kurtosis value = -0.5 to 0.5

Analysis

The Pearson Product-Moment Correlation. A Pearson 2-tailed correlational analysis was conducted to examine the relation between the variables to determine if there was sufficient independence to run the regression analysis. The analysis examined the Visual and Verbal Working Memory relations with each of the three academic subjects (i.e., Reading, Math, and Written Expression), gender, and attention (see Table 10, p.98).

Attention. It should be noted that attention problems were not significantly correlated with any other variable. On the following table, and in the analysis, lower scores on the attention index indicate fewer attention problems (see Table 10 below).

Table 10

BiVariate Intercorrelations between Study Variables Using Total Sample (N=50)

	Variable		1.	2.	3.	4.	5.	6.
1.	Attention	Pearson Correlation	—					
		Sig. (2-tailed)						
2.	Verbal	Pearson Correlation	-.26	—				
		Sig. (2-tailed)	.07					
3.	Visual	Pearson Correlation	-.22	.49	—			
		Sig. (2-tailed)	.13	<.01				
4.	READING	Pearson Correlation	-.13	.49	.49	—		
		Sig. (2-tailed)	.39	<.001	<.001			
5.	MATH	Pearson Correlation	-.20	.53	.44	.79	—	
		Sig. (2-tailed)	.17	<.001	.001	<.001		
6.	WRITTEN	Pearson Correlation	-.21	.41	.32	.67	.60	—
		Sig. (2-tailed)	.15	.003	.023	<.001	< .001	

NB: Lower scores indicted fewer attention problems.

Academic achievement and working memory. There were significant and positive correlations between each area of academic achievement (i.e., Reading, Math, and Written

Expression) and each aspect of working memory (verbal and visual working memory) (see Table 10).

Analysis of Variance (ANOVA) .

Gender. ANOVAs were computed on each area of Academic Achievement (i.e., Reading, Math, and Written Expression), Attention, and Verbal or Visual Working with gender as a between-subjects factor. There were no significant main effects of gender for any of the ANOVAs. Therefore, gender was eliminated from subsequent analysis (see Table 11 below).

Table 11

Univariate ANOVA: Between –Subjects Factors for Gender and Dependent Variables

Source	df	Mean Sq.	*R2*	*Adj R2*	*F*	*p*
Gender	1	2.42	.000	-.020	.022	.884
Verbal WM	1	348.48	.030	.010	1.49	.229
Visual WM	1	3.920	.000	-.020	.02	.898
Attention	1	2.42	.000	-.020	.022	.884
Reading	1	32	.002	-.019	.11	.749
Math	1	216.32	.015	-.006	.73	.399
Written Expression	1	390.850	.009	-.012	.42	.518

NB: WM = Working Memory

Regression Analysis

Regression analyses were computed to test the research questions. The results of these analyses are reported by each area of working memory and academic achievement. The results first report on trends with the prediction of academic achievement by working memory. Then, the analysis reported is the relation between academic achievement and working memory, with the addition of inattention to determine if adding this variable significantly adds to the prediction. The third analysis for each question group examined the interaction of inattention with working memory in the prediction of academic achievement to determine if inattention problems moderate the relation between working memory and academic achievement. All the regressions controlled for race/ethnicity because significant differences in mean scores by ethnicities had been found in the background variable analyses.

Verbal-auditory working memory and academic achievement. The results from the analysis for each of three areas of academic achievement predicted by verbal working memory will be reported separately. Each area of academic achievement was examined with three different questions. These questions examined the strength and direction of the relation between the area of academic achievement and working memory, whether attention added significantly to the prediction of academic achievement by working memory, and whether attention moderated the relation between working memory and academic achievement.

The prediction of reading achievement by verbal-auditory working memory. The statistical analysis for each research question is reported. The results are displayed in Table 12 (see p.103).

Question 1a. What is the direction and strength of the relation between reading achievement and verbal-auditory working memory?

This regression controlled for ethnicity because there was a significant difference in the means for reading achievement between the Caucasian students and the 'Non-Caucasian" group (p =.005). Caucasians performed better than the 'Non-Caucasian' group by approximately 16.33 points, p=.005 (please refer to Table 8, p.96). The results from this regression found significant difference between the groups of Caucasians and Non-Caucasian in the prediction of reading achievement by verbal working memory, t (47) = 2.98, $p < .005$. This suggests the intercepts for the prediction of the achievement differ by ethnicity (see Figure 5 below). After controlling for ethnicity, the present study found that as verbal working memory increased, the predicted score for reading achievement increased [t (47) =3.54, p=.001]. Verbal-auditory working memory uniquely explained only 42% of the variance. The Adjusted R^2 (.33) suggested that race/ethnicity and verbal working memory accounted for 33% of the variance in this model. The adjusted R^2 increased by 16% after verbal working memory was added to the model.

Cohen's Effect size was calculated to estimate the effect size for educational research for this prediction of reading by verbal working memory. The R^2 change correlation after working memory was added to the model (see Table 12, p.103) was calculated to have an effect size of .19, which is a small effect.

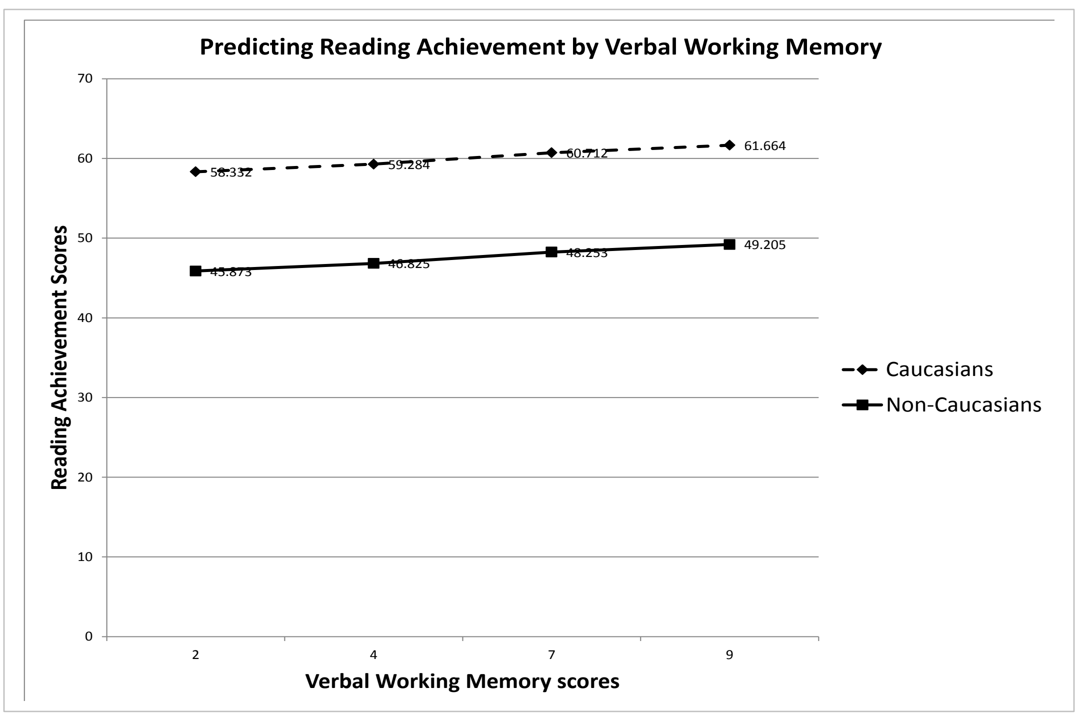

Figure 5
The Prediction of Reading Achievement by Verbal Working Memory

Question 1b. Do attention problems add significantly to the prediction of reading achievement after controlling for verbal-auditory memory and ethnicity? There was no significant contribution of attention adding to the prediction of reading achievement after controlling for ethnicity and verbal working memory, t (46) =.11, p = .917.

Question 1c. Do attention problems moderate the relation between verbal-auditory working memory and reading achievement? There was no significant interaction between attention and verbal-auditory working memory, t (45) = 1.11, p = .273. Therefore, there was not sufficient evidence that attention moderated the relation between verbal–auditory working memory and reading achievement.

The prediction of math achievement by verbal-auditory working memory. The next group of questions examined the variables of math achievement, attention and verbal-auditory memory. Summaries of the answer to each question are followed by full results in Table 13 (see p.105).

*Question 2a***.** What is the direction and strength of the relation between math achievement and verbal-auditory working memory?

The results from this regression found a significant difference in the prediction of math achievement by verbal working memory between the two groups of Caucasian and Non-Caucasians [t (47) = 2.15, p < .036]. (See Figure 6, p.104).The data analysis found the intercepts for the prediction of achievement differed by ethnicity. After controlling for ethnicity, the present study found that as verbal working memory increased, the predicted score for math achievement increased [t (47) = 4.02, p= <.001]. The Adjusted R^2 (.35) suggested that race/ethnicity and verbal working memory accounted for 35% of the variance in this model. The Adjusted R^2 increased by 20% after verbal working memory was added to the model.

Cohen's Effect size was calculated to estimate the effect size for educational research for this prediction of math by verbal working memory. The R^2 change of .20 after verbal working memory was added to the model was calculated to have an effect size of .25, which is a small to medium effect, and confirms the unique contribution of verbal working memory in the prediction of math achievement.

Table 12

Regression Analysis Results for Reading Achievement, Ethnicity,& Verbal Working

Model/Predictors	*b*	*β*	*F*	*t*	*p*	R^2	Adj R^2	R^2 Change
Race/Ethnicity	15.33	.44	11.27	3.36	.002	.19	.17	-
(1a) Strength and Relation of Verbal WM/Reading								
Reading/Verbal WM	44.92	-	13.27	3.54	<.001	.36	.33	.16
Cauc/ Non-Caucasian	12.46	.35		2.98	.005			
Verbal WM	0.48	.42		3.54	.001			
(1b) Does Attention Significantly Add to the Prediction of Verbal WM/Reading								
Reading /Verbal WM/Att	52.0	-	8.66	2.60	.013	.36	.33	-
Cauc./ Non-Caucasian	12.47	.36		2.95	.005			
Verbal WM	0.48	.42		3.42	.001			
Attention	0.02	.01		0.11	.917			
(1c) Does Attention Moderate the Relation between Verbal WM/Reading								
Reading/ Verbal WM / Att/ Att*Verbal WM			6.84			.38	.33	
Cauc/ Non-Caucasian	13.10	.37		3.08	.004			
Verbal WM	-0.19	-.17		-0.30	.764			
Attention	-1.06	-.64		-1.07	.293			
Attention*Verbal WM	0.01	.77		1.11	.27			

Note: Abbreviations: WM= Working Memory Cauc= Caucasian Att= Attention
* The F test correlation is associated with the R^2 in each analysis.

Question 2b Do attention problems add significantly to the prediction of math achievement after controlling for verbal-auditory memory and ethnicity? Attention was not a significant predictor of math achievement after controlling for ethnicity and verbal working memory [t (46) = -.454, p =.652].

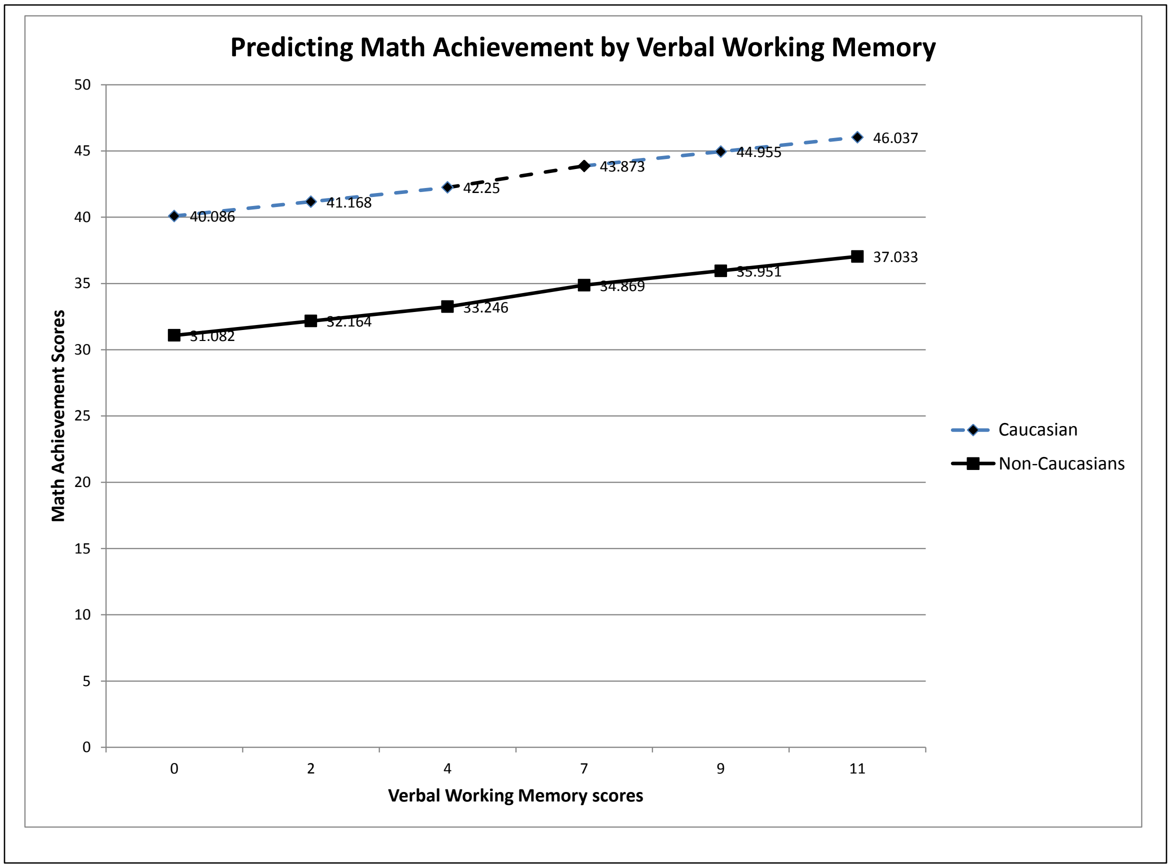

Figure 6
The Prediction of Math Achievement by Verbal Working Memory

Question 2c. Do attention problems moderate the relation between verbal-auditory working memory and math achievement? There was no significant interaction between attention and verbal–auditory working memory as a predictor of math achievement, suggesting that inattention problems do not moderate the relation between working memory and math achievement [*t* (45) = 0.81, *p* = .421].

Table 13

Regression Analysis Results for Math Achievement, Ethnicity,& Verbal Working Memory

Model/Predictors	*b*	*β*	*F*	*t*	*p*	R^2	Adj. *R*	R^2Change
Race/Ethnicity	12.27	.35	11.27	2.60	.012	.12	.11	-
(2a) Strength and Relation of Verbal WM/Math								
Math/Verbal WM	37.78	-	12.55	1.97	.014	.35	.31	.20
Caucasian/ Non-Caucasian	9.01	.26		2.15	.036			
Verbal WM	.54	.48		4.02	<.001			
(2b) Does Attention Significantly Add to the Prediction of Verbal WM/Math								
Math/ Verbal WM/ Att	37.78	-	8.30	1.97	.055	.35	.31	-
Caucasian/ Non-Caucasian	8.95	.26		2.12	.039			
Verbal WM	0.53	.47		3.74	.001			
Attention	-.09	-.06		-0.45	.652			
(2c) Does Attention Moderate the Relation between Verbal WM/Math								
Math/ Verbal WM/ Attention/ Attention*Verbal WM						.36	.31	
Caucasian/ Non-Caucasian	9.41	.27		2.20	.033			
Verbal WM	.034	.03		.054	.957			
Attention	-.889	-.54		.887	.380			
Attention*Verbal WM	.009	.57		.81	.421			

Note: Abbreviations*:* WM= Working Memory
* The F test correlation is associated with the R^2 in each analysis.

The prediction of written expression by verbal-auditory working memory. The next group of questions examined the relation among written expression achievement, attention and verbal-auditory memory. Summaries of these analyses for each question are followed by full results in Table 14 (see p.108).

*Question 3a***.** What is the direction and strength of the relation between written expression and verbal-auditory working memory?

As Figure 7 shows, results from this regression found a differences between the Caucasians and Others in the prediction of written expression by verbal working memory [t (.001) = 3.64, $p < .001$]. This suggested that the intercepts for the prediction of achievement differ by ethnicity.

After controlling for ethnicity, the present study found a positive relation with verbal working memory and math achievement. As verbal working memory increased, the predicted score for written expression score increased [t (47) =2.72, p=.009]. The Adjusted R^2 suggested that race/ethnicity and verbal working memory accounted for 32 % of the variance in the outcome measure of written expression in this model in this model. The adjusted R^2 increased by .09% after verbal working memory was added to the model.

Cohen's Effect size was calculated to estimate the effect size for educational research for this prediction of written expression by verbal working memory. The R^2 change of .09 after verbal working memory was added to the model was calculated to have an effect size of .09. This is a small effect when explaining the unique variance added by verbal working memory in the prediction of written expression.

Question 3b. Do attention problems add significantly to the prediction of written expression after controlling for verbal-auditory memory and ethnicity? Attention was not significant after controlling for ethnicity and verbal working memory [t (46) = -0.79, p = .436].

Question 3c. Do attention problems moderate the relation between verbal-auditory working memory and written expression? There was no significant interaction between attention and verbal working memory. Attention did not moderate the relation between verbal–auditory working memory and written expression [t (45) = -.334, p = .74].

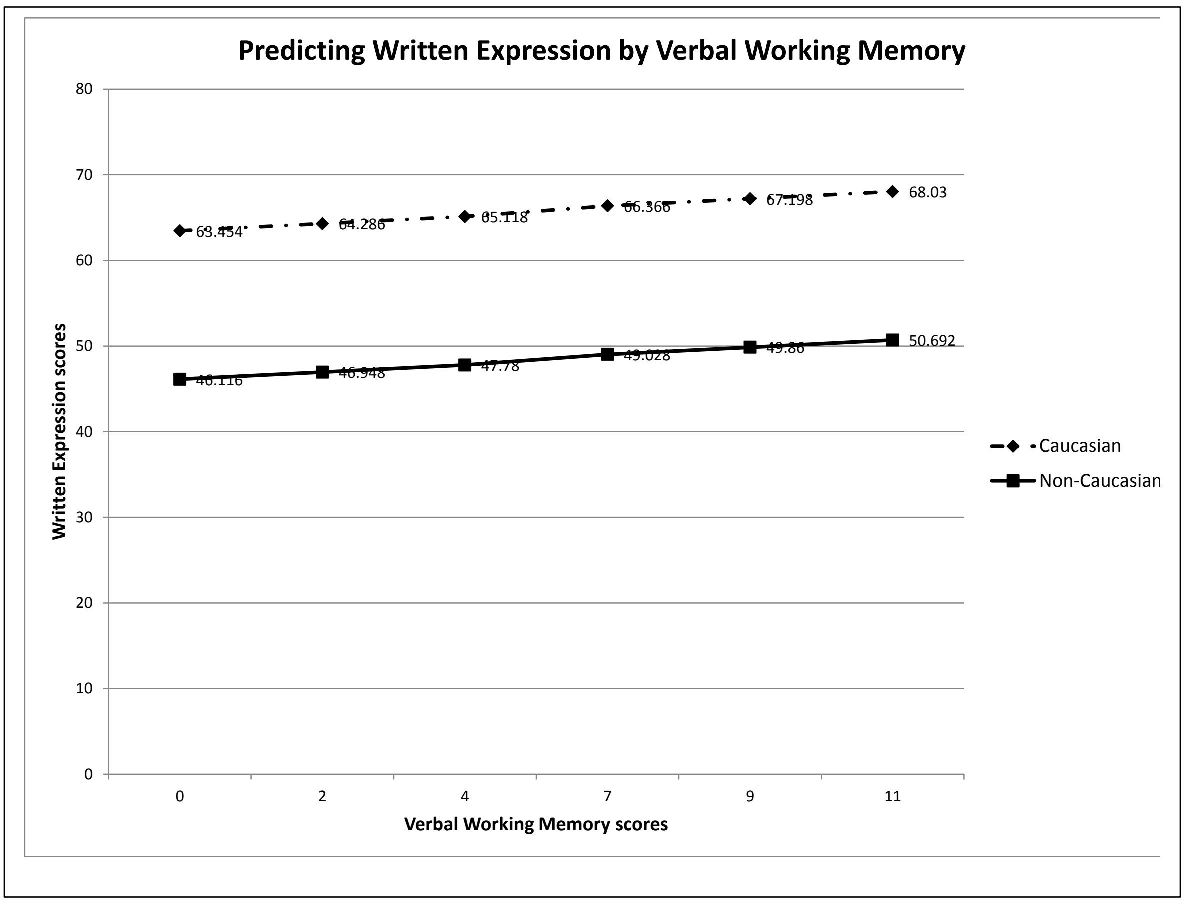

Figure 7

The Prediction of Written Expression by Verbal Working Memory

Table 14

Regression Analysis Results for Written Expression, Ethnicity,& Verbal Working Memory

Model/Predictors	*b*	*β*	*F*	*t*	*p*	R^2	Adj R^2	R^2 Chang
Race/Ethnicity	19.85	.50	15.98	4.00	< .001	.25	.23	-
(3a) Strength and Relation of Verbal WM/Written								
Written/Verbal WM	46.12	-	12.77	3.33	<.001	.35	.32	.09
Cauc/ Non-Caucasian	17.34	.44		3.65	.001			
Verbal WM		.33		2.72	.009			
	0.42							
(3b) Does Attention Significantly Add to the Prediction of Verbal WM/ Written								
Written/Verbal WM/ Att	59.24	-	8.65	2.73	.009	.36	.32	-
Cauc/ Non-Caucasian	17.24	.43		3.61	.001			
Verbal WM	0.39	.30		2.43	.019			
Attention	-.18	-.10		-.79	.436			
(3c) Does Attention Moderate the Relation between Verbal WM/ Written								
Written/Verbal WM/ Attention/ Attention*Verbal WM						.36	.32	-
Cauc/ Non-Caucasian	17.02	.43		3.50	.001			
Verbal WM	.62	.48		.87	.389			
Attention	.19	.10		.17	.866			
Attention*Verbal WM	<.01	-.23		-.33	.740			

Note: Abbreviations: WM= Working Memory Written = Written Expression
* The F test correlation is associated with the R^2 in each analysis.

Visual-spatial working memory.

The prediction of reading achievement by visual-spatial working memory. The next group of analyses reported the results for reading achievement, visual-spatial working memory, and attention. The summarized analyses for each question are stated below, with the full results displayed in Table 15 (see p.111).

Question 4a. What is the direction and strength of the relation between reading achievement and visual-spatial working memory?

As Figure 8 below shows, results from this regression found a significant difference in the prediction of reading achievement by Caucasians and Non-Caucasians [t (47) = 2.25, p < .029]. This suggested the intercepts for the prediction of the written expression differ by ethnicity.

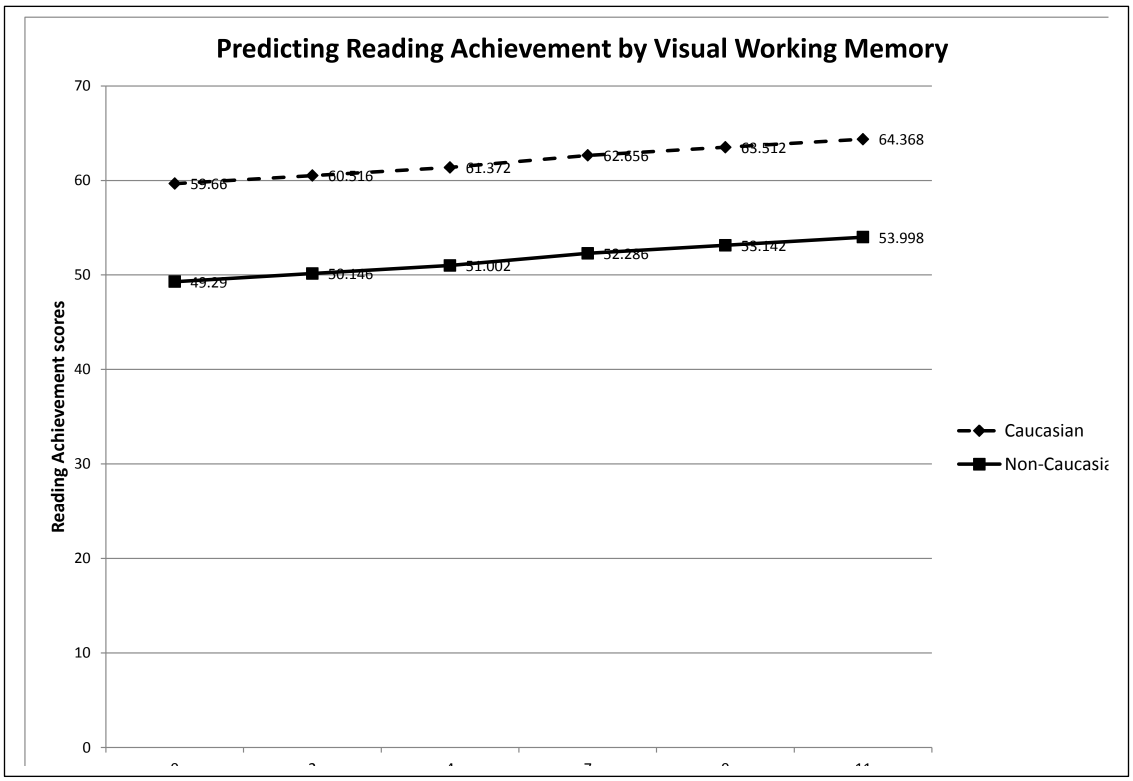

Figure 8.
The Prediction of Reading Achievement by Visual Working Memory.

After controlling for ethnicity, the present study found that as visual working memory increased, the predicted score for written expression increased [t (47) = 2.85, p = .006]. The t was positive, which means that as visual working memory increased, the reading achievement score also increased. The Adjusted R^2 (.28) suggested that race/ethnicity and visual working memory accounted for 28% % of the variance in the outcome measure of reading achievement in this model, with visual working memory contributing 17% uniquely.

Cohen's Effect size was calculated to estimate the effect size for educational research for this prediction of reading by visual working memory. The R^2 change was .17 (see p.111) after adding visual working memory to the model. This was calculated to have an effect size of .20, which was a small effect for the unique contribution of visual working memory to the prediction of reading achievement.

Question 4b. Do attention problems add significantly to the prediction of reading achievement after controlling for visual-spatial working memory and ethnicity? Analysis found that attention did not add significantly to the prediction of reading by visual-spatial working memory [t (46) = -.184, p = .855].

Question 4c. Do attention problems moderate the relation between visual-spatial working memory and reading achievement? A multiple regression was computed on reading achievement with verbal working memory, attention, and the interaction between attention and visual-spatial working memory, controlling for ethnicity. The analysis found the interaction between attention and visual working memory was not significant [t (45) = .544, p = .589].

The prediction of math achievement by visual-spatial working memory. The next group of analyses reported is the relation between math achievement, visual-spatial working memory, and attention. The summarized answer for each hypothesis question is stated below, with full results displayed in Table 16 (p.114).

Question 5a. What is the direction and strength of the relation between math achievement and visual-spatial working memory?

As Figure 9 (see p.112) shows, results from this regression found a significant difference in the prediction of written expression by verbal working memory between the Caucasian and Other groups [t (47) = 1.57, p < .122]. This suggests the intercepts for the prediction of achievement differ by ethnicity.

Table 15

Regression Analysis Results for Reading Achievement, Ethnicity,& Visual Working Memory

Model/Predictors	*b*	*β*	*F*	*t*	*p*	R^2	Adj R^2	R^2 Change
Race/ Ethnicity	15.33	.44	11.27	3.36	.002	.13	.11	-
(4a) Strength and Relation of Reading/ Visual WM								
Reading/Visual WM	49.27	-	10.53	3.65	.001	.31	.27	.17
Caucasian/ Non-Caucasian	10.38	.30		2.52	.029			
Visual WM	0.43	.37		2.85	.006			
(4b) Does Attention Significantly Add to the Prediction of Reading/ Visual WM								
Reading/Visual WM/ Att	95.80	-	5.16	1.15	.255	.31	.27	-
Cauc/ Non-Caucasian	10.38	.30		2.23	.031			
Visual WM	0.42	.37		2.73	.009			
Attention	-0.04	-.02		-0.18	.855			
(4c) Does Attention Moderate the Relation between Reading/ Visual WM								
Reading/Visual WM/ Attention/ Attention* Visual WM						.32	.25	-.02
Caucasian/ Non-Caucasian	10.58	.30		2.25	.029			
Visual WM	-0.03	-.03		-0.33	.974			
Attention	-0.79	-.47		-0.57	.575			
Attention*Visual WM	0.01	.53		.54	.589			

Note: Abbreviations*:* WM= Working Memory

* The F test correlation is associated with the R^2 in each analysis

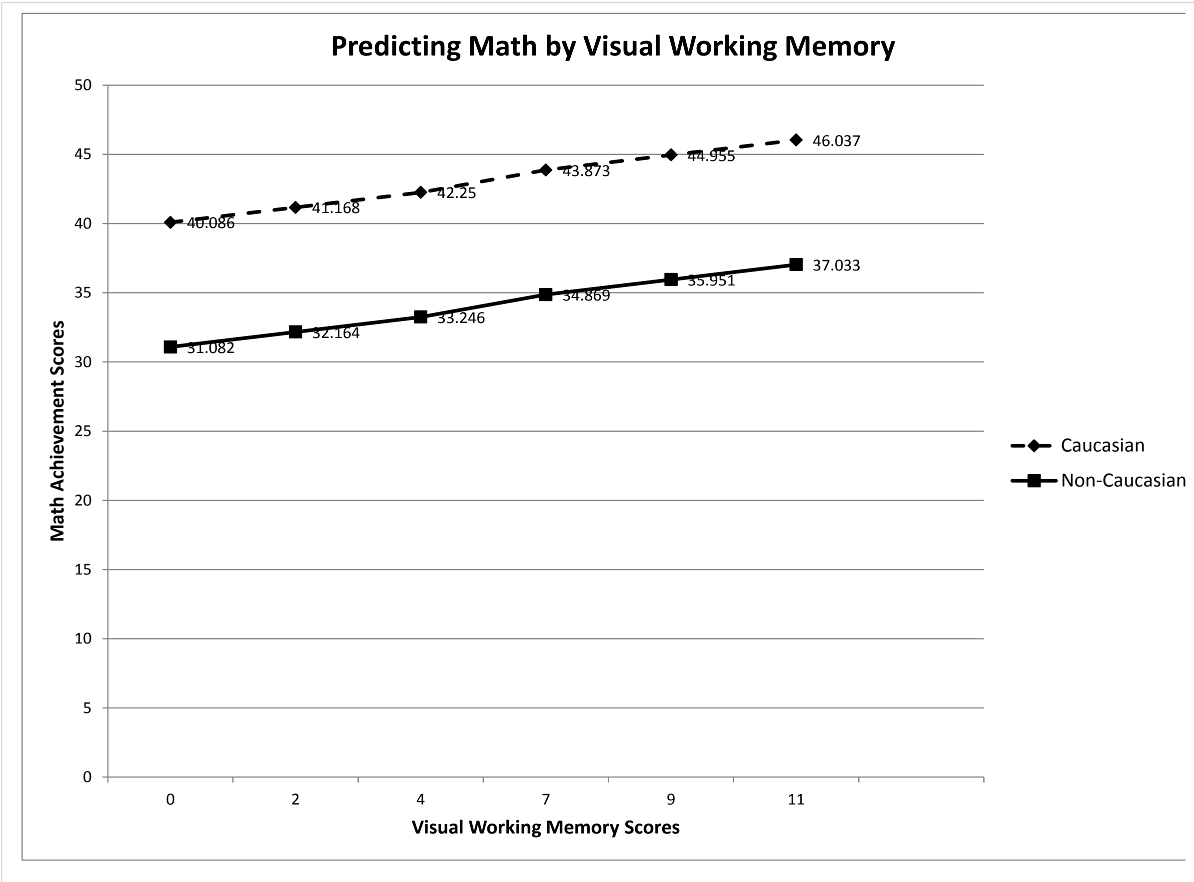

Figure 9

The Prediction of Math Achievement by Visual Working Memory.

After controlling for ethnicity, the present study found that as the score for visual spatial working memory increased, the predicted score for math achievement also increased [t (47) = 2.59, p = .013]. The slopes were positive, so that that as visual working memory increased, math achievement increased. The Adjusted R^2 (.20) suggested that race/ethnicity and visual working memory accounted for 20% of the variance in this model, with 9% of the variance uniquely explained by visual working memory.

Cohen's Effect size was calculated to estimate the effect size for educational research for this prediction of math by visual working memory. The R^2 change of .09 after visual working memory was added to the model was calculated to have an effect size of .09. This was a small effect when considering the contribution of visual working memory to the prediction of math achievement.

Question 5b. Do attention problems add significantly to the prediction of math achievement after controlling for visual-spatial working memory and ethnicity? Attention did not add significantly to the prediction of math achievement after controlling for ethnicity and visual memory [*t* (46) = -0.83, *p* = .409].

Question 5c. Do attention problems moderate the relation between visual-spatial working memory and math achievement? There was not a significant interaction between attention and visual-spatial working memory. Analysis found there was not sufficient evidence that attention moderated the relation between visual-spatial working memory and math achievement [*t* (45) =1.18, *p* = .246].

The prediction of written expression by visual-spatial working memory. The last group of analyses investigated written expression achievement, visual-spatial working memory, and attention (see Figure 10). A summary of the results by question are provided in the following sections, with full results displayed in Table 17 (see p.116).

Question 6a. What is the direction and strength of the relation between written expression achievement and visual-spatial working memory? As Figure 11 shows, results from this regression found a significant difference in the prediction of written expression by visual working memory between ethnic groups [*t* (47) = 3.28, *p* < .002]. This suggested a difference in the intercept by ethnicity.

After controlling for ethnicity, the present study did not find prediction of written achievement by visual working memory significant [*t* (47) = 1.16, *p*= .254]. This suggested the slopes were flat, and that written expression scores did not increase per one point increase in visual working memory. The Adjusted R^2 (.20) suggested that race/ethnicity and visual working memory accounted for 20% of the variance in the outcome measure of written expression in this model.

Table 16

Regression Analysis Results for Math Achievement, Ethnicity, Visual Working Memory and the Variance Explained by Each Model

Model/Predictors	*b*	*F*	*β*	*t*	*p*	R^2	Adj R^2	R^2Change
Race/Ethnicity	12.27	6.80	.35	2.60	.012	.35	.11	-
(5a) Strength and Relation of Visual WM/Math								
Math/Visual WM	43.03	7.15	-	3.05	.004	.48	.20	.09
Cauc/Non-Cauc	7.56		.21	1.58	.122			
Visual WM	0.41		.36	2.59	.01			
(5b) Does Attention Add to the Prediction of Visual WM/Math								
Math/Visual WM/Att	152.64	4.10	-	1.80	.080	.24	.20	-
Cauc/Non-Cauc	7.59		.22	1.57	.122			
Visual WM	0.38		.33	2.36	.023			
Attention	-0.18		-.11	-0.83	.409			
(5c) Does Attention Moderate the Relation between Visual WM/Math								
Math/Visual WM/Attention/ Attention*Visual WM						.27	.20	-
Cauc/Non-Cauc	8.03		..23	1.67	.102			
Visual WM	-0.62		-.54	-0.72	.478			
Attention	-1.84		-1.12	-1.29	.205			
Attention*Visual WM	0.02		.1.19	1.18	.246			

Note: Abbreviations: WM= Working Memory Cauc = Caucasian

* The F test correlation is associated with the R^2 in each analysis

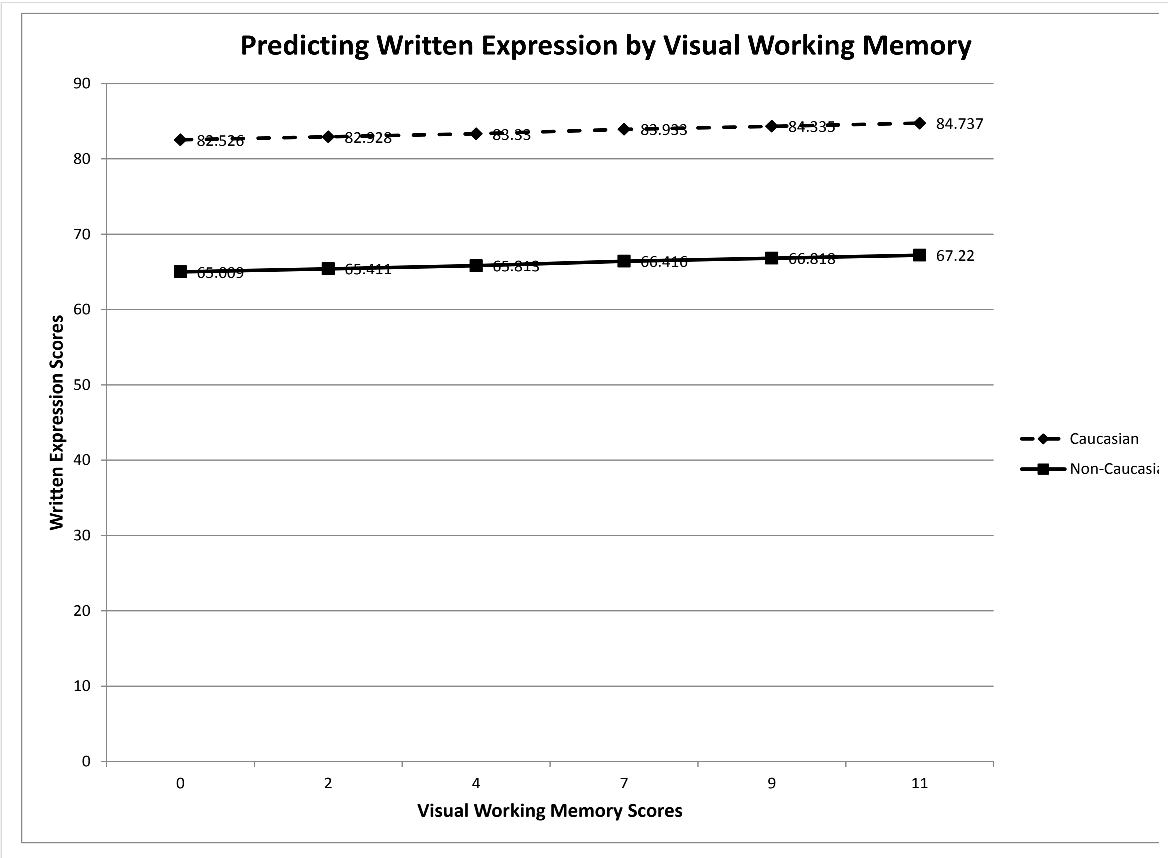

Figure 10

The Prediction of Written Expression by Visual Working Memory

Cohen's Effect size was calculated to estimate the effect size for educational research for this prediction of written expression by visual working memory because there. As there was no change in R^2 after visual working memory was added to the model, no effect size can be attributed to the contribution of visual spatial working memory when predicting written expression with this population of students.

Question 6b. Do attention problems add significantly to the prediction of written expression achievement after controlling for visual-spatial working memory and ethnicity?

Analysis found that attention did not significantly add to the prediction of written expression by visual-spatial working memory[*t* (46) = -1.16, *p* = .25].

Question 6c. Do attention problems moderate the relation between visual-spatial working memory and written expression achievement? Analysis found that the interaction between attention and visual-spatial memory was not significant. There was not sufficient evidence that attention moderated the relation between written expression and visual-spatial working memory [*t* (45) = -.48, *p* = .64].

Table 17

Regression Analysis Results for Written Expression, Ethnicity, Visual Working Memory and the Variance Explained by Each Model

Model/Predictors	*b*	*β*	*F*	*t*	*p*	R^2	Adj R^2	R^2 Change
Race/Ethnicity	19.85	.50	15.99	4.0	<.001	.25	.24	-
(6a) Strength and Relation of Visual WM/Written								
Written/Visual WM	65.01	-	8.71	4.15	<.001	.27	.24	-
Caucasian/ Non-Caucasian	17.52	.44		3.28	.002			
Visual WM	0.20	.16		1.16	.254			
(6b) Does Attention Add to the Prediction of Visual WM/Written								
Written/Visual WM/ Attention	84.60	-	6.30	3.69	.001	.29	.25	.01
Caucasian/ Non-Caucasian	17.56	.44		3.30	.002			
Visual WM	0.16	.12		0.90	.374			
Attention	-.028	-.15		-1.16	.251			
(6c) Attention as a Moderator of the Relation between Visual WM/Written								
Written/Visual WM/ Attention/ Attention*Visual WM						.36	.30	.05
Caucasian/ Non-Caucasian	17.35	.44		3.22	.002			
Visual WM	0.61	.47		.64	.529			
Attention	.48	.25		.30	.767			
Attention*Visual WM	<-.01	-.48		-.48	.635			

Note: Abbreviations: WM= Working Memory, Written = Written Expression

* The F test correlation is associated with the R^2 in each analysis.

Summary of the Results

This study found that verbal-auditory working memory was a significant predictor for all three areas of academic achievement: reading, math, and written expression, with parallel lines between groups representing the prediction of achievement. Visual-spatial working memory was found to be a significant predictor of only reading and math. However, differences in the intercepts for the prediction of academic achievement by ethnicity were found, with Caucasians having higher the intercepts in each area of academic achievement. These differences remained significant, even when other variables were added into the model. After controlling for ethnicity, attention was not found to significantly add to or moderate the prediction of any academic achievement by either verbal-auditory or visual-spatial working memory.

Chapter Five

The Discussion

This chapter will review the goals of the present study, the research findings with reference to previous literature, the limitations of the study with reference to threats to internal validity and external validity, and the contribution to the field. The discussion will suggest areas for further research to explore based on the findings in this present study. Finally, the conclusion will attempt to bridge the gap among theory, research, and practice by suggesting implications for educationalists working with middle school students.

Goals and Research Findings

The present study had three goals which each addressed different aspects of prediction of academic achievement by working memory. The first goal was to examine the prediction of each of three areas of academic achievement by verbal and visual working memory. The second goal was to examine whether a measure of attention problems added to the prediction of academic achievement. The third goal was to examine if a measure of attention problems moderated the relation between working memory and academic achievement. The findings will be discussed with reference to past literature, and also with regards to interesting trends that were found among the data.

Goal 1: The prediction of academic achievement by working memory. The first goal was to examine the relation between working memory and academic achievement. Some previous research examined working memory as a process (Alloway & Alloway, 2010) without examining separate verbal and visual processing components. Other research (e.g., Alderson, Rapport, Hudec, Sarver, & Kofler, 2010; Rogers et al., 2012) specifically examined individual components within working memory as unique predictors. However, previous research did not investigate separate verbal and visual working memory and different areas of academic achievement. For this reason, the discussion of the results from the present study separates each of the three areas of academic achievement (i.e., reading, math, and written expression).

Reading. Previous literature found that working memory predicted reading achievement (Alloway & Alloway, 2010; Barnes, Raghubar, English, Williams, Taylor, & Landry, 2014; Rennie & Beebe-Frankenberger, 2014). Many studies examined correlations with phonological processing, decoding skills (Nevo & Breznitz, 2013) or a battery of working memory assessments (Alloway & Alloway, 2010) and academic achievement, but typically these studies only included a younger population of students. Higher working memory scores predicted higher reading achievement scores. Studies with adolescent students (Rogers et al., 2012) found that verbal-auditory working memory was significantly correlated with reading achievement, while visual working memory was not significantly correlated with reading achievement.

The present study found significant correlations among verbal and visual working memory for reading and math, but only significant correlations by verbal working memory for written expression. These findings differed from the Rogers et al. (2012) research study because Rogers et al. (2012) found no significant correlation between reading achievement and visual working memory.

The present study found significant differences between the mean scores by different ethnic groups, which suggested that ethnicity was an important variable, when discussing the relation between working memory and academic achievement. This finding supported previous literature in the field which documented achievement gaps between African American students and Caucasian students (Rolland, 2011; Elias & Haynes, 2008).

Rogers et al. (2012) did not find a significant correlation between visual-spatial working memory and reading skills, but the present study did find support that visual working memory predicted reading achievement. This is different from past results, as no previous research has found a positive relation between visual working memory and reading achievement. This may be because most past research enquiries have used younger participants. Younger children are more likely to be tested with phonological processing and decoding skills than with reading comprehension skills, so the reading achievement skills being tested are more likely to be different. Therefore, the academic achievement demonstrated by adolescent students may require different working memory processing skills than those needed by younger students.

Younger children may rely on visual processing more than older students because the nature of the content they need to learn may be developmentally different to that which older students use. For example, early picture books for young children rely on pictures to convey the meaning. Early reading books match picture content to concrete nouns (e.g., Sally opened the envelope and found a letter inside). Older students could read the sentence and understand the meaning using only verbal processing of the content of the sentence. Therefore, when younger students lack the vocabulary to understand or appreciate verbal instructions, they may rely on visual processing more with some curriculum content. An example with written expression is that students in kindergarten may be focusing on the "how" of writing. For instance, "The cat sat on the mat." They may need to focus on how to form the letters, how not to reverse any letter, and how to spell the words appropriately, use punctuation, and also capitalization. This form of hand-eye motor co-ordination may use more visual processing than adolescent students who may be allowed to type a passage on a word processor, and who can therefore focus on the content of the passage (e.g., beginning, middle, end) when they are writing a story. The findings support previous findings by Gathercole, Brown, and Pickering (2003) who referred to the differences in curriculum content across age span reflecting the maturation and development of the students as they got older. Specifically, that abstract reasoning skills which may be tested in adolescent students may require different working memory skills than those required for assessments with younger students. This may in part explain why the correlations for the three academic areas of achievement were inter-related at this age group (verbal working memory skills become important across each area of academic achievement to help process abstract reasoning skills).

Second, all the participants in the Rogers et al. (2012) study either had a diagnosis of ADHD, or a comorbid condition – and possibly this could have affected the results. The present study found visual working memory was a significant predictor after ethnicity was controlled. One explanation for the need to control ethnicity was that the frequency of ADHD, and therefore probable use of psycho-stimulant medication, varied by group. Holmes, Gathercole, Place, Dunning, Hilton, and Elliott (2010) and Holmes et al. (2010) reported that psycho-stimulant medications significantly improved visual-spatial memory scores. The present study had a higher ratio of students within the 'Other' (i.e., non-Caucasian) ethnicity groups who reported having a diagnosis of ADHD than within the Caucasian group.

A follow-up analysis was not conducted in the present study to examine the effects on educational achievement with students who had ADHD and were taking psychotropic medications compared to a control group because previous research has already demonstrated a significant difference in neuropsychological functioning between groups of children with and without ADHD (Rennie, Beebe-Frankenberger, & Swanson, 2014). The results from the present study suggested that by controlling for ethnicity the researcher may have also controlled for some of the effects for ADHD or medications those students with ADHD took. This could help explain the reason that visual-spatial working memory was a significant predictor of reading achievement in the present study, but not in the Rogers et al. (2012) study. The Rogers et al. (2012) study did not control for ethnicity, and it only included a population of students who all had either ADHD, or a comorbid condition (e.g., in the control group).

Math. Previous research found support for the relation between working memory and math achievement (Bull & Scerif, 2001; Swanson & Sache-Lee, 2004; Gathercole, Pickering, Knight, & Stegmann, 2004). Rogers et al. (2012) found that both visual and verbal-auditory working memory predicted math achievement in the adolescent sample.

The present study also found support for this finding, with both visual and verbal working memory being significant predictors of math achievement. However, the present study also found significant differences in the relation between working memory and math by ethnicity (i.e., with Caucasian and Other). The differences between ethnic groups were evident in the mean scores for academic achievement, as Caucasians had significantly higher scores for achievement. Caucasians with the same working memory scores as the ‘Other’ group also achieved more. However, there were no significant differences between the Caucasians and ‘Others’ when predicting math achievement by visual working memory. The lack of significant effect for the prediction of math academic achievement by visual working memory may be due to the participants being adolescents. The curriculum for adolescent age groups may have more word problems (which require verbal comprehension skills) rather than math assessments which are mainly computational as they would be for younger students. Computational skills may rely more on visual working memory skills when students are presented with numbers and illustrations simultaneously which depict the numeric value (e.g. 5 oranges + 5 apples = 10 pieces of fruit). Patterns of odd and even numbers may be visually represented with colored squares, and dominos is a game which relies on the players recognizing specific patterns of dots to represent a numeric value. As students gain mastery of the meaning of number and can work without visual aids, it is possible the relation between visual working memory and math changes.

Written Expression. Previous research has documented differences in the prediction of academic results for English exams of children who were 7 years of age and children who were 14. Gathercole and Pickering (2000) examined the relation of working memory as a predictor of results for the National Curriculum assessments in England. They found that working memory scores were less predictive of English results than of Science and Math results. One explanation was that the types of evaluations given to older students required different cognitive processing skills, and therefore the relation with working memory. The differences in cognitive skills required for the achievement tests may mirror expectations for children to develop abstract reasoning as they mature. Rogers et al. (2012) did not examine written expression.

Verbal working memory. The present study found that verbal working memory significantly predicted written expression; however the analysis also found that there were significant differences between Caucasians and others. There were also significant differences in the relation between written expression and working memory among the different ethnic groups. Caucasians had the highest scores. The present study was not able to determine any reason that African American or Hispanic students performed more poorly than their Caucasian peers. This finding was evident across every aspect of academic achievement in the present study, and it is common in other research as well. (Fantuzzo, LeBoeuf, Rouse, & Chen, 2012; Rolland, 2011).

Visual working memory. When examining the relation between visual working memory and written achievement, no statistically significant results were found after controlling for ethnicity. This may be a reflection of the age group being tested. Younger students who are learning to form alphabet letters and beginning to spell words may rely on visual working memory to a larger extent than older students. Adolescent students use writing to record thoughts, and this is uses verbal working memory skills. Writing requires the participant to hold thoughts in their head while sentence construction, grammar, and spelling rules are manipulated.

Goal 2: Do attention problems add to the prediction of academic achievement by working memory. The second goal was to examine whether attention problems added to the prediction of academic achievement by working memory. Previous literature has found a relation between between behavioral inattention, low working memory, and academic achievement (Rogers et al., 2012). However Rogers et al. (2012) reported that working memory mediated the relation between inattention and academic achievement.

The present study examined whether inattention added to the prediction of academic achievement by working memory. No support was found for attentional problems adding to the explanatory power of reading, math, or written expression after working memory and ethnicity were controlled. However, the mean score for the total population of the students in this participant pool was below 70. This means the mean score was below a 'Clinically Significant' level of inattention, and the fluctuations of inattention reported were within the normal range for the age of the student. This may explain why attention problems did not add to the prediction of achievement, as the level of inattention measured was considered within normal ranges. Previous research which examined the relation between inattention and academic achievement used participants who displayed clinically significant levels of inattention (Rogers et al., 2012; Polderman et al., 2010).

To test the theory that only significant levels of inattention either add to the prediction of academic learning, or moderate the relation between working memory and academic achievement, a preliminary analysis was run which examined high and low attention levels. High attention levels were those with Clinically Significant levels of ADHD (8/50) combined with those students whose inattention levels were in the At Risk range (9/50). These data were not all from students with a diagnosis of ADHD. Some were from students with no diagnosis of ADHD. There were 17/50 students who had scores in the At Risk or Clinically Significant range, but only 7 of these had reported a diagnosis of ADHD. This was an interesting fact because an assumption could have been that the students with ADHD would have provided the most Clinically Significant and At Risk scores for inattention.

However, this preliminary analysis still found no clinically significant relations among working memory, academic achievement, and inattention. This may be due to special factors within the participant sample such as highly motivated students and parents (i.e., skewed sample) who worked with tutors or parents at home when any remediation was needed, or from the public school system providing interventions in reading and math for students with deficit skills (i.e., more time to learn the work). These conditions may not have been present in the sample that Rogers et al. (2012) examined. It is possible that the current educational climate assists students to be more successful with academic achievement by providing remediation and interventions to address deficit skills caused by inattention when needed.

A second consideration which could explain why the presence of behavioral inattention did not significantly add to the prediction of academic achievement is that the present study only examined one form of academic achievement, and it did not control for how long the students had taken to acquire the knowledge on which they were being tested. With all academics, and especially with reading, reading comprehension and verbal learning, there are different methods of assessing performance. Teachers use summative and formative assessments, standardized assessments, and running records to help determine and monitor progress throughout a school year. The Woodcock-Johnson Tests of Achievement were used in this study because they are widely respected, standardized assessments which will enable replication of the research. However, the Woodcock-Johnson tests for reading had specific answers required which were marked as either correct or wrong. This methodological assessment method assumed there were specific answers, and did not allow for the meaning of the text to be negotiated by the reader or student.

Some do not agree with this approach to determining a level of reading comprehension or success (Gee, 1996). There are alternate methods of assessing reading comprehension. Teachers can ask open ended questions; or they can ask students to explain perspectives, feelings, or comment on the narrative from the student's own perspective. Within this type of assessment, there would not be a right or wrong answer. Instead, there would be a shared truth, or shared understanding of the text between the author, the student reader, and the teacher or examiner. It is possible that behavioral inattention scores would have significantly affected a more socially situated assessment. After all, if the assessor is asking a student to engage in the text and construe an individual interpretation, and the student is not attending then the student would not be unable to contribute and would fail. This would mean that the socially constructed assessment could not be repeated or replicated at a later point in time, or it would be changed by the events between the point of initial assessment and the point of the second assessment.

Therefore, inattention fluctuations as measured on behavioral rating scales may significantly add, or not add, to the prediction of reading comprehension if reading comprehension were measured in a different way, or from a different methodological base.

Goal 3: Do attention problems moderate the relation between academic achievement and working memory. The third goal was to examine if attention problems moderated the relation between working memory and academic achievement. No statistically significant results were found to support attentional problems as a moderating variable on the relation between working memory and academic achievement.

The present study found no statistically significant results to support attentional problems as a moderating variable. Rogers et al. (2012) reported that inattention partially moderated the path between reading and working memory in the population of students with ADHD. The difference in results between the current study and Rogers et al. (2012) could possibly be explained by the difference in the population of students. The Rogers et al. (2012) study included a sample who all had ADHD, and the control group all had a comorbid diagnosis. This would suggest these samples in Rogers et al. (2012) were skewed towards having significant difficulties with multiple aspects of executive functioning processing, working memory skills, and academic skill deficits. The present study included adolescent students with slightly more than one third of the population reporting a diagnosis of ADHD. Results from the present study suggested that inattention did not significantly affect or moderate the relation between working memory and academic achievement with a population of students which included those who did not report significant inattention problems.

Since the Rogers et al. (2012) study, research has moved forward to examine other variables that may support or moderate the relation between working memory and academic performance. These alternate variables include anxiety (Owens, Stevenson, Hadwin, & Norgate, 2014), anxiety, depression (Owens, Stevenson, Hadwin, & Norgate, 2012), and motor co-ordination (Rigoli, Pick, Kane, & Oosterlaan, 2012). The trend appears to be examining within person characteristics which may arise in certain situations (e.g. anxiety), or which are trait specific to individual participants (e.g. motor co-ordination). Owens et al. (2012) found that higher levels of anxiety and depression were associated with lower academic performance, and that high levels of worry and anxiety are related to reduced working memory capacity. They also found (Owens et al., 2014) that the interaction between anxiety and working memory and their relation to academic achievement differed depending on whether the student had average or low working memory skills. High anxiety levels during test taking were related to changes in test performance. Students with low working memory achieved better results with some anxiety, while students with average or good working memory and high anxiety performed more poorly.

It is interesting that measurements of students' levels of depression or anxiety interacted with working memory in predicted achievement in the research by Owen et al. (2014), but that the present study found no relation with behavioral inattention. Owen et al. (2012, 2014) took current measurements of how depressed or anxious students felt at the same time they were assessed for working memory skills and academic achievement. However, the present study measured inattention by a reflection on a previous time (e.g., in the learning environment). Perhaps inattention is not a stable trait over time, and therefore it should be assessed at the point of reference for its relation to the environment. This would mean that if the ratings were for a class in school – the academic test should be from that class. Or, if a standardized achievement test were provided – the behavioral inattention scale could be provided afterwards to gather information about how the student's inattention was perceived in the testing environment.

Both the present study and the Rogers et al. (2012) study examined behavioral inattention as if this construct were a within person characteristic that remained constant across environments and over time (i.e., similar to depression). Perhaps future research in this field should examine if behavioral inattention is a construct that would be better researched within the environment where it is situated. That would enable us to consider other ecological factors (e.g., other stressors the student is currently experiencing, classroom environment, size of class, teaching styles, curriculum, past exam experience) which may influence results.

Limitations of the Present Study

The limitations of the present study will be discussed with reference to internal and external validity of the research findings. Internal validity refers to aspects within the research design that might affect the outcome results. External validity refers to the generalizability of the results. The threats to internal and external validity are important to discuss as limitations, as they suggest how the findings might be specific to this study, or how well they generalize to other populations and environments.

Threats to internal validity. There are several factors to consider when examining internal validity. These can include the history, maturation, testing effects, instrumentation, statistical regression to the mean, bias in selection of groups, mortality of participants, and the selection-maturation effect. In the present study, the selection of participants would be considered the greatest threat to internal validity.

Selection of subjects. The selection of subjects is a limitation in this research, because the research was advertised in settings to attract volunteer participants. Although data were collected from 50 adolescent subjects, all the participants had parents who were motivated to support the research study and bring their child for testing outside of school hours. The parents not only signed consent, but also made the effort to schedule a convenient testing time. For this reason, the data were skewed by families who were very supportive.

Within participant differences.

Age of participants. A limitation with both the Rogers et al. (2012) study and the present study was that the research was a cross-sectional snapshot in time. Both studies did not examine changes over lifespan or maturation within participants. Research by Pascual-Leone (2000) reported differences in the capacity storage of working memory over lifespan and differences between children and adults. If the relation between attention, working memory, and academic achievement varies over lifespan, further research would need to examine trends over the lifespan. A heterogeneous participant sample was obtained by recruiting from varied sources. These sources included students who were homeschooled, students enrolled in local public middle schools, and students who were enrolled in local private school settings.

Diagnosis of ADHD. Both typically developing students and those with a diagnosis of ADHD were included. The present study did not seek to inquire which type of ADHD the student currently had because symptoms may change over lifespan. A limitation of the study was that the examiner had no way of controlling for any drug interventions. Treatment for ADHD has a wide variety of medications and dosages. Therefore, any influence of medication any participant may have taken was not factored into the study. The strength of this was that this replicated a typical class of students in school. Teachers typically have no control over whether the students take their medications, or whether they are learning without the assistance of any psychostimulant medications.

Ethnicity. The present study accepted any applications for participation in the study and did not seek to control the ratio of different ethnicities within the group. The analysis of the present study found significant differences in mean scores for working memory, attention, and academic achievement by ethnic group. These differences led the analysis to control for ethnicity. Previous research in the field has not reported the different racial or ethnic groups represented within the data set. The demographic checklist used in the present study provided opportunities to identify race as Caucasian, African American, Hispanic, or Other. The present study combined the groups of African American, Hispanic and Other to form one group named 'Other" to examine trends among the data.

Social–Economic Status. In educational research, social economic status is commonly gathered by reporting Free and Reduced lunch status. Because some of the participants in the study were home-schooled, it was not possible to gather and analyze the data from this. This was not considered a weakness for the study, as previous research (Alloway & Alloway, 2011) has suggested that socio-economic factors and maternal mother's educational level do not influence the working memory results.

Threats to External Validity

External validity refers to the extent the findings from one research study can be generalized to other settings, environments, and replicated with different participants. One threat to the validity of the study is the methodology used and assessments selected. The results of the present study can only be generalized to conditions where self-report behavior rating scales, a standardized academic assessment, and a battery for working memory assessments are used. This methodology assumes that the quantitative scores achieved represent the students' level of skills on the constructs of attention, working memory, and also academic achievement. The discussion on the limitation of these assumptions will be explained in the following sections.

Construct of inattention. After controlling for ethnicity and working memory, no statistically significant results were found for inattention as either affecting the strength of the prediction of academics by working memory, or as a moderator of the relation between working memory and academic achievement. The rating scales used to examine inattention and its relation to working memory are socially constructed measurements of behavior. As such, the scores obtained on the self-report scales may have varied depending on the schooling environment the student was enrolled in. Some students may have no control over who taught them in school, other students may have been able to choose to work with a tutor or teacher they liked and had rapport with. The advantage of the design used in the present study was to obtain a variety of responses which could resemble the responses of a group of middle school students who come from different backgrounds. Self-rating scales are commonly used in schools to determine how students feel in classes, and are considered valid if the F indexes are 'Acceptable.' Another limitation in the score for inattention is that although the assessment measured feelings related to a previous point in time, scores obtained for the inattention problems were based on answers to questions about how the student felt in class at school. The instrument is not able to factor in ecological considerations (i.e., quality of the instruction, school climate). The point is that attention and inattention are not stand alone variables. A quantitative score may represent a numeric value for inattention, but in the educational environment other ecological factors may influence this score. In fact, if the same behavior rating scales were used to predict achievement which was measured on a different kind of assessment (e.g., work portfolio, seminar presentation, or other non-standardized assessment), the predictive correlations and significance of inattention may have been different.

In cognitive psychology, other methods of determining attention are possible. These include, but may not be limited to: length of eye fixation (Just & Carpenter, 1980), or measurement of on and off-task analysis (Shapiro, 1996). If an alternate method of measuring inattention had been used, it is possible different results may have been obtained, but these may not have been compared to the Rogers et al. (2012) study so easily.

Learning environments. The relation between a student and the learning environment may be a factor to consider with adolescents in light of recent research by Fischer, Godwin, and Seltman (2014). In their study with kindergarten students, it was found that students in visually highly decorated classrooms had more difficulty staying on task and attending to the instruction than students in rooms with fewer decorations. The student in barer rooms also had higher learning gains. Although this research has not as yet been conducted with adolescents, it does suggest interplay between environment and attention. This has not previously been discussed in the literature, and the present study was not able to record any information about the diverse learning environments of the students. Therefore, it was not possible to add a level of qualitative comment onto the nature of the environment and interaction between the students, the learning experience, and academic engagement or achievement.

Academic achievement measurement. If the research design for the present study had enabled a group of participants to all engage in the same learning session, and then afterwards they completed the same battery of working memory and academic achievement assessments, a different relation between the variables may have been measured. The inattention rating scale would have measured inattention in the same learning environment as the outcome academic achievement test. If a student had not attended during the session, it is possible their learning and retention for new facts could be less than those students with good behavioral attention characteristics. Future research should attempt to link attention, working memory and achievement within a standardized period of instruction. This would permit differences which could be found to be attributed to the learners, without interference of differences assigned to alternate settings, curriculums, length of instructional periods, and other factors which were not controlled for in the present study.

Teacher instructional styles. Teachers are always using new technologies, text books, and instructional styles. These include direct teaching, online learning programs, and interventions provided to small groups.. Public schools in Florida are required to provide interventions to students with deficit skills, and this means the student receives extra time over and beyond the normal instructional lesson on subjects that require remediation. Most commonly interventions address reading and math skills. For instance, a student who found math challenging and performed poorly in exams could be enrolled in both a grade level math class and an additional class for intensive math. This provides extra time in the learning environment with extra opportunity to learn the content required for subject mastery. These interventions are provided in both small group and also whole class lessons, depending on the subject and age of the student. Therefore, the amount of time students spent with the curriculum and learning process varies, meaning that within a random sample of students, there could be differences in the amount of time each student spent on each curriculum subject.

This process of intervention in public schools may be especially helpful to students who are challenged with inattention or those who have other difficulties, as the extra teaching provides remediation for deficit skills to improve student performance. For those students whose parents provide tutoring outside of school hours, more time is also spent on the subject, which will boost the student’s performance on the outcome measures used in this study. For this reason, the research was limited because there were no controls for the schools, the curriculum, the instructional style of the teacher, or the amount of time each student spent on learning the core subject content. Therefore, the relations between inattention and the outcome variables in the present study may be a reflection of the success of the extra time spent with interventions to gain mastery, despite any behavioral inattention problems.

Contribution to the Field

Significant findings. This research has findings which contribute to the field of verbal and visual working memory, behavioral inattention, and academic achievement. A short summary is provided for each domain in the following sections.

Verbal working memory. The present study contributed to the literature on the relation between verbal working memory and academic achievement in adolescent students aged 12 – 16. The present study found the predictions significant for every area of academics tested: reading, math, and written expression. The present study contributes to the field by adding written expression to the outcome measures, as previously Rogers et al. (2012) only examined reading and math. The findings supported the findings by Roger et al. (2012), and widened the information on the literature as the present study used a population of typically developing adolescents as well as a small group of students with a diagnosis of ADHD. All of these students were receiving instruction in general education settings or were home schooled either part-time or full- time. The present study also found support for the theoretical structure of working memory by Baddeley (2000, 2002, 2003, & 2011), where one of the components identified within the working memory is the phonological loop. Support was found for a positive linear relation between verbal working memory and each of reading and math achievement, meaning that for every 1 point increase in verbal working memory, the achievement score increased by .48.

Visual working memory. The present study found support for a separate visual-spatial working memory which significantly predicted reading and math achievement. The study also contributed to the field by examining the prediction of written expression by visual working memory. The present study found support for the findings of Rogers et al. (2012). Both studies found a positive relation in the relation between math achievement and visual working memory. Rogers did not find the relation between visual working memory and reading significant. However, the present research challenged this result by finding a positive relation between reading achievement and visual working memory after controlling for ethnicity. The present study did not find support for the prediction of written expression by visual working memory. The present study found support for the theoretical structure of working memory by Baddeley (2000, 2002, 2003, &2011), which suggested that there was a visual-spatial sketchpad, which processes and provides short-term storage for visual information independently of verbal information.

***Behavioral inattention*.** The expectation of this study was to find that behavioral inattention would add significantly to the prediction of academic achievement, and that it would moderate the relation between working memory and academic achievement. There is considerable evidence in the literature on ADHD that students with ADHD have attentional difficulties, lower working memory skills, and lower academic results than students who do not have ADHD (DePaul, Volpe, Jitendra, Lutz, LOrah, Gruber, 2004; Marshall, Hynd, Handwerk, & Hall, 1997; Martinussen, Hayden, Hogg-Johnson, & Tannock, 2005; Polderman, Booomsma, Bartels, Verhulst, & Huizink, 2010). However, the present study found no significant relations among behavioral inattention, academic achievement and working memory.

This contributes to the field because it suggests that the relation among behavioral inattention, academic achievement, and working memory was not a significant factor when predicting academic achievement. This may encourage teachers to learn that fluctuations in sub-clinical levels of behavioral inattention is normal with adolescent students, and that only those students who demonstrate significantly high levels of inattention may need interventions to help them cope with the expectations of middle school curriculums and schedules.

Academic achievement. When the results are reviewed by examining the ecological conditions surrounding the data collection, some important changes in educational systems need to be mentioned. Bronfenbrenner's Chronosystem (1994) refers to the time period the event is situated within. The present study was conducted in a time period when technology is becoming integrated with school instruction, and there are virtual and e-learning programs where students progress at their own rate, independent from working with a teacher who provides direct instruction. The data obtained in this study was gathered from students who were enrolled in a mixture of online, virtual, and direct teaching environments. Therefore, there were varied instructional styles, and different lengths of time taken to learn information, as the different programs each required different homework for follow-up, and assessed knowledge with different class tests.

Ethnicity. The present study found significant differences in the means the working memory and achievement tests. This was a surprising find, because previous research had suggested that working memory was a better predictor of academic achievement because it was not biased by maternal mother's educational level, or social-economic status. However, prior research with working memory had not disaggregated the scores for achievement, behavioral inattention, or working memory by race, ethnicity, or any other minority subgroup.

The present study disaggregated the data because since NCLB (2001), schools are required to examine trends by subgroups which include race. When significantly large differences were found in the data set between Caucasian and Non-Caucasian participants, the statistical analysis was computed to control for the effects of ethnicity. However, this does not explain why these differences were present. There were several omitted variables in the study which may have contributed to differences in the scores. More research with working memory batteries may help to determine why differences were found in the present study between the groups of Caucasians and Non-Caucasian participants.

No significant differences were found for inattention as measured on the BASC-2 self-rating scale. This may because the mean for inattention between all students was below a clinically significant level (i.e., below a T-score of 70). The reason the scores on this assessment may not have varied so much by racial/ethnicity factors may be because medications taken by those students with a diagnosis of ADHD may have calmed their behaviors in such a way that their inattentiveness was not captured with the data set in the present study. There was no data gathered on the nature or amount of any medication any student took prior to testing because in regular school environments teachers have no control over this.

The present study contributed to the field by reporting trends that suggest there are differences by ethnicity, which need to be examined further. The importance of this will be to determine how culturally efficient a working memory battery can be when used with a diverse population. Once further research can help suggest factors that may be significantly related to differences between different racial/ethnicity groups, interventions to address these may help support students with low working memory skills.

Recommendations for Future Research Directions

Based on results from the present study, the recommendations for future research include: examination of the trends by ethnicity in more detail, examining alternate assessments to measure the attention problems, examining the robustness of the findings over time, and also examining these same research questions with younger age groups to see if maturation of the participant changes the relation between the variables.

The researcher recommends examining attention problems while controlling for time in a learning environment to assist in identifying the relation among these variables in a setting where inattention may cause time loss, and therefore less time to complete task assigned. Future research could examine not only the working memory battery, but also the relation between attention and working memory in the process of learning. This type of research could require a pre and post-test session to determine the amount of learning which occurred despite any reported behavioral inattention. There would also be opportunity to examine trends with alternate populations (e.g., students with disabilities, younger students, older students) to determine if verbal and visual working memory have the same or different relations with academic achievement over lifespan.

If this research were to be repeated, it might be interesting to use a different population of students to test the model. The present model tested verbal and visual working memory as a predictor for academic achievement with adolescent students. If only students who did not report having a diagnosis of ADHD were tested, the results would not be influenced by medication side-effects.

Conclusion and Implications for Educationalists

It is hoped that the information from this research will help to provide more insight into problems associated with academic achievement for adolescent students. The first contribution to educationalists is to share the information that there is evidence for two separate processing routes for working memory. The one is the visual-spatial sketchpad, which processes visual working memory, and the second is the phonological loop which processes verbal-auditory learning. There has been a lot of research with younger children with phonological processing and how they learn to read using phonemic awareness, decoding and other phonological processing skills. However, teachers of older students may not realize that adolescents also have these unique processing abilities. Previous memory research has found unique differences in working memory between individuals, and the present study has now examined the relation between these differences and academic achievement. It is important to appreciate that for each 1 point gain in working memory, the results for academic achievement increase.

Educators will be interested to learn that verbal working memory predicts every area of academics (reading, math, and written expression), but that visual working memory only predicted reading and math achievement. This knowledge could help educators prepare lessons which present the material in ways to support the working memory processes. Interventions to address low working memory skills in math and reading could be provided (e.g., check lists for sequence steps, sample calculations for math, organizer charts for creative writing organization, and others). Interventions to support low visual and or verbal working memory skills may assist students to become more successful with their academic achievement (DeMarie & Lopez, 2013).

A second contribution this research provides educators is the information that behavioral inattention by any students in their class may not necessarily impede their academic achievement assessed by a standardized assessment. Although the population of students who participated in this sample may have been a skewed sample, who had motivated parents, perceived behavioral inattention did not add to the prediction of academic success after controlling for ethnicity and working memory. This suggests that if students in a teacher's class are not attending appropriately, interventions provided to address academic skill deficits may help them to gain mastery (through use of interventions and extended time on practice). Whether the interventions are provided during the lesson, after school (extra homework), or an extra intervention class will be at the discretion of the teachers and school the student is attending. It will be reassuring to know that behavioral inattention in itself is not a predictor for failure, as in today's climate, schools are ranked on closing achievement gaps and teachers' salaries may reflect the success of their students' academic achievement.

The third contribution for educators is to suggest that there are differences between students by age, race, and ethnicity. The Caucasian students had the higher achievement scores and higher intercepts for the prediction of academic success by working memory than the students with "Other" ethnicities. Cultural sensitivity is always important with curriculum planning, delivery of instruction, and results from the present study suggest that differences in the learning process are evident by race. Future research may help educators identify other factors not examined in the present study which may help explain why the same working memory score predicts differently for academic achievement by race.

The researcher hopes this research has shed some light on the learning processes. Teachers of adolescent students will be reassured to learn that all children can succeed academically, despite individual differences in behavioral inattention and/or low working memory skills. It is very important that teachers find some ways to help support students who have low working memory skills; because research has now found that higher working memory skills produce higher academic achievement.

References

Adams, W. & Sheslow, D. (1990). *Wide range assessment of memory and learning*. Wilmington, DE: Wide Range.

Aguinis, H. (1995). Statistical power problems with moderated multiple regression in management research, *Journal of Management, 21* (6), 1141-1158

Alloway, T. P. (2007a). *Automated Working Memory Assessment*. London: Pearson Assessment.

Alloway, T. P. (2007b). Working memory, reading, and mathematical skills in children with developmental coordination disorder. *Journal of Experimental Child Psychology, 96*, 20-36.

Alloway, T. P., & Alloway, R.G. (2010). Investigating the predictive roles of working memory and IQ in academic attainment. *Journal of Experimental Child Psychology, 106*, 20-29. doi: 10.1016/j.jecp.2009.11.003

Alloway, T. P., & Archibald, L. M. (2008). Working memory and learning in children with developmental coordination disorder and specific language impairment. *Journal of Learning Disabilities, 41*, 251-262.

Alloway, T.P., Elliott, J., & Place, M. (2010). Investigating the relationship between attention and working memory in clinical and community samples. *Child Neuropsychology*, *16*, 242-254. doi: 10.1080/09297040903559655

Alloway, T. P., Gathercole, S. E., Willis, C., & Adams, A. (2004). A structural analysis of working memory and related cognitive skills in young children. *Journal of Experimental Child Psychology, 87*, 85-106. doi: 10.1016/j.jecp.2003.10.002

Alloway, T.P., Gathercole, S.E., Holmes, J., Place, M., Elliott, J.G., & Hilton, K. (2009). The diagnostic utility of behavioral checklists in identifying children with ADHD and children with working memory deficits. *Child Psychiatry & Human Development, 40,* 353-366.

Alloway, T. P., Gathercole, S.E., Willis, C., & Adams, A. (2004). A structural analysis of working memory and related cognitive skills in young children. *Journal of Experimental Child Psychology, 87*, 85-106.

Awh, E., Barton, B., & Vogel, E. K. (2007). Visual working memory represents a fixed number of items regardless of complexity. *Psychological Science, 18,* 622-628.

Baddeley, A. D., & Hitch, G. J. (1974). Working memory. In G. A. Bower, (Ed.), *The Psychology of Learning and Motivation.* (pp. 47-89). New York: Academic Press.

Baddeley, A. D. (2000). The episodic buffer: A new component of working memory? *Trends in Cognitive Sciences, 4*, 417-423.

Baddeley, A. D. (2002). Is working memory still working? *European Psychologist, 7* (2), 85-97. doi: 10.1027//1016-9040.7.2.85

Baddeley, A. D. (2003). Working memory: Looking back and looking forward. *Neuroscience, 4,* 829-839. doi: 10.1038/nrn1201

Baddeley, A. D. (2011). Working memory: Theories, models, and controversies, *Annual Review of Psychology, 63*(12),12-29. doi: 10.1146/annurev-psych-120710-100422

Baddeley, A. D., & Hitch, G. J. (2003). Development of working memory: Should the Pascual-Leone and the Baddeley and Hitch models be merged? *Journal of Experimental Child Psychology, 77*, 128-137.

Bakalar, N. (2007). Study points to genetics in disparities on preterm births. *The New York Times.* Retrieved from http://query.nytimes.com/gst/fullpage.html?res= 9E01E5DC1E3EF934A15751C0A9619C8B63&sec=&spon=&pagewanted=all

Barkley, R.A. (2003). Attention-Deficit/ Hyperactivity Disorder in E. Mash & R.Barkley (Eds.), *Child Psychopathology* (pp.,75-143), New York: The Guildford Press.

Baron, R. M., & Kenny, D. A. (1986). The moderator-variable distinction in social psychological research: *Conceptual, strategic, and statistical considerations. Journal of Personality and Social Psychology, 51,* 1173-1182

Bartlett, C.J., Bobko, P., Mosier, S.B., & Hannan, R. (1978). Testing for fairness with a moderated multiple regression strategy: An alternative to differential analysis. *Personnel Psychology, 31*, 233-241

Beiderman, J., Mick, E., & Farone, S. V. (2000). Age dependent decline of symptoms of attention deficit/hyperactivity disorder: Impact of remission and symptom type. *American Journal of Psychiatry, 157*, 816-818. doi: 10.1176/appi.ajp.157.5816

Borghese, P. & Gronau, R.C. (2005). Convergent and discriminant validity of the universal nonverbal intelligence test with limited English proficient Mexican-American elementary students. *Journal of Psychoeducational Assessment, 23,* 128-139.

Bracken, B.A., & McCallum, R. S. (1998) Universal Nonverbal Intelligence Test. , Rolling Meadows, Ilinois: Riverside Publishing.

Bronfenbrenner, U. (1994). *Ecological models of human development*. In International Encyclopedia of Education, Vol.3, 2nd Ed., Oxford: Elsevier. Reprinted in Gauviain, M. & Cole, M. (Ed.S.), Readings on the development of children, 2nd ed. (1993, p37-43). NY:Freeman. Retrieved from: http://www.psy.cmu.edu/~siegler/35bronfebrenner94.pdf on June 21, 2013.

Browne-Miller, A. (1995). *Intelligence policy: Its impact on college admissions and other social policies.* New York: Plenum Press.

Bull, R., & Scerif, G. (2001). Executive functioning as a predictor of children's mathematical ability: Inhibition, task switching, and working memory. *Developmental Neuropsychology, 19,* 273-293. dx. doi.org/10.1207/S15326942DN1903 3

Campbell, D.T., & Stanley, J. C. (1963). *Experimental and quasi-experimental designs for research on teaching*. In N. L. Gage (Ed.), Handbook of research on teaching, (pp.171-246). Chicago, IL: Rand McNally.

Castillo, J. J. (2009). *Snowball sampling*. Retrieved May 14, 2010, from http://www.experiment-resources.com/snowball-sampling.html

Cleary, T. A. (1965). *An individual differences model for structural equations*, Dissertation Abstracts, 25(11), 1965. pp. 6750-6751. release date 19650601, accession number: 1965-13257-001

Cleary, T. A. (1968). Prediction of grades of Negro and White students in integrated colleges. *Journal of Educational Measurement, 5*, 118-124.

Cohen, J. (1962). The statistical power of abnormal-social psychological research: a review, *Journal of Abnormal and Social Psychology, 65*, 145-153.

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences*. Hillsdale, NJ: Erlbaum.

Conners, C. K. (2008). Conners Comprehensive Behavior Ratings Scales, Pearson Education Inc., San Antonio, TX.

Cowan, N. (1988). Evolving conceptions of memory storage, selective attention, and their mutual constraints within the human information processing system. *Psychological Bulletin*, *104*, 163-191.

Cowan, N. (2011). The focus of attention as observed in visual working memory tasks: Making sense of competing claims. *Neuropsychologia*, *49*, 1401-1406.

Creswell, J. W. (2008). *Educational research: Planning, conducting, and evaluating quantitative and qualitative research* (3rd ed.). Upper Saddle Creek, NJ: Pearson Education.

Cronbach, L. J. (1951). Coefficient alpha and the internal structure of tests. *Psychometrika*, *16* (3), 297–334.

Crottaz-Herbette, S., Anagnoson, R. T., & Menon, V. (2004). Modality effects in verbal working memory: Differential prefrontal and parietal responses to auditory and visual stimuli. *NeuroImage*, *21*, 340-351.

Dancey, C. P. & Reidy, J. (2002) *Statistics Without Maths for Psychology*, England: Pearson Education Ltd. ISBN:0-13-033633-5

Dally, K. (2006). The influence of phonological processing and inattentive behavior on reading acquisition. *Journal of Educational Psychology, 98*, 420-437. doi: 0.1037/0022-0663.98.2.420

Deary, I. J., Strand, S., Smith, P., & Fernandez, C. (2007). Intelligence and educational achievement. *Intelligence, 35*, 13-21.

De Jong, P. F. (1998). Working memory deficits of reading disabled children. *Journal of Experimental Child Psychology*, *70*, 75-96.

DeMarie, D. & Ferron, J. (2003). Capacity, strategies, and metamemory: Tests of a three- factor model of memory development. *Journal of Experimental Child Psychology, 84*, 167-193.

DeMarie, D., & Lopez, L. M. (2013). *Memory in School*, R. Fivush & P. Bauer (Ed.), The handbook: Development of children's memory. NJ: Wiley-Blackwell

Dempster, R. A. (2004). *Understanding errors in risk assessment: The application of differential prediction methodology*. (Doctoral dissertation). Retrieved from http://ehis.ebscohost.com.ezproxy.lib.usf.edu/eds/resultsadvanced

Diana v. State Board of Education (1970). Retrieved Dec.19, 2006 from, http://questia.com/PM.qst?a=o&se=gglsc&d=5009958603&er=deny.

DuPaul, G. J., Volpe, R.J., Jitendra, J., Lutz, G., Lorah, K. S., & Gruber, R. (2004). Elementary school students with ADHD: Predictors of academic achievement. *Journal of School Psychology, 42*, 285-301. doi: 10.1016/j/jsp.2004.05.001

Engle, R. W. (2002). Working memory as executive attention. *Current Directions in Psychological Science, 11*, 19-23. doi: 10.1111/1467-8721.00160

Erdfelder, E., Faul, F., & Buchner, A. (1996). GPOWER: A general power analysis program. *Behavior Research Methods, Instruments & Computers*, *28*, 1-11.

Erdfelder, E., Faul, F., & Buchner, A. (2005). *Power analysis for categorical methods*. In B. S. Everitt & D. C. Howell (Eds.), Encyclopedia of statistics in behavioral science (pp. 1565-1570). Chichester, UK: John Wiley & Sons, Ltd.

Ferri, B.A. & Connor, D.J. (2005). Tools of exclusion: Race, disability, and (Re) segregated education. *Teachers College Record, 107*, (3), 453-474.

Ferri, B.A., & Connor, D. J. (2005a). In the shadow of Brown: Special education and overrepresentation of students of color, *Remedial and Special Education, 26,* (2), 93-100

Field, A. (2005). *Discovering Statistics Using SPSS*, Daniel B. Wright (Ed). London: Sage Publications. ISBN: 0-76194-452-4

Flaugher, R.L. (1978). The Many Definitions of Test Bias. *American Psychologist, 33,* 671-679.

Flynn, J. R. (1987). Massive IQ gains in 14 nations: What IQ tests really measure. *Psychological Bulletin, 101*, 171-191. doi: 10.1037/0033-2909.101.2.171

Flynn, J. R. (2010). Problems with IQ gains: The huge vocabulary gap. *Journal of Psychoeducational Assessment, 28*, 412-433. doi: 10.1177/0734282910373334

Freberg, M., Vandiver, B.J., Watkins, M.W., Canivez, G. (2008). Significant factor score variability and the validity of the WISC-III full scale IQ in predicting later academic achievement. *Applied Neuropsychology, 15*, 131-139.

Funtuzzo, J., LeBoeuf, W, Rouse, H., & Chen, C. (2012) Academic achievement of African-American boys: A city-wide, community-based investigation of risk and resilience. *Journal of School Psychology, 50,* 559-579.

Fuchs, D., Fuchs, L., Mathes, P., Lipsey, M., & Roberts, H. (2002). *Is "learning disabilities" just a fancy term for low achievement? A meta-analysis of reading differences between low achievers with and without the label*. In R. Bradley, L. Danielson, & D. Hallahah (Eds.), Learning Disabilities: Research to Practice   (pp.737-762). Mahwah, NJ: Erlbaum.

Gathercole, S. E., Brown, L., & Pickering, S.J. (2003). Working memory assessments at school entry as longitudinal predictors of national curriculum attainment levels. *Educational and Child Psychology, 20*, 109-122.

Gathercole, S. E., Durling, E., Evans, M., Jeffcock, S., & Stone, S. (2008). Working memory abilities and children's performance in laboratory analogues of classroom activities. *Applied Cognitive Psychology, 22*, 1019-1037. doi: 10.1002/acp.1407

Gathercole, S. E., & Pickering,, S. J. (2000). Assessment of working memory in six- and seven-year old children. *Journal of Educational Psychology*, *92*, 377-390.

Gathercole, S. E., Pickering, S. J., Knight, C., & Stegmann, Z. (2004). Working memory skills and educational attainment: Evidence from national curriculum assessments at 7 and 14 years of age. *Applied Cognitive Psychology, 18*, 1-16. doi: 10.1002/acp.934

Gee, J. (1996). *Social linguistics and literacies: Ideology indiscourses. Critical perspectives on literacy and education*. London: Taylor & Francis Ltd. ISBN:0- 7484-0499-6

Ghiselli, E. E., (1956). Differentiation of individuals in terms of their predictability. *Journal of Applied Psychology, 40*, 374-377

Ghiselli, E.E. (1960a). The prediction of predictability. *Educational and Measurement*, *20*, 3-8

Ghiselli, E.E., (1960b). Differentiation of tests in terms of the accuracy with which they predict for a given individual. *Educational and Psychological Measurement, 20*, 675-684

Gioia, G.A., Isquith, P.K., Guy, S. C., & Kenworthy, L. (2000). *Behavior Rating Inventory of Executive Function*: Professional Manual. Lutz, FL: Psychological Assessment.

Gioia, G.A., Isquith, P.K., Guy, S. C., & Kenworthy, L. (2000). Confirmatory factor analysis of the behavior inventory of executive function in a clinical sample. *Child Neuropsychology,8* (4), 249-257.

Goldberg, E., & Podell, K. (2000). Adaptive decision making, ecological validity, and the frontal lobes. *Journal of Clinical and Neuropsychology, 22*, 56-68.

Goodman, R. (1997). The strengths and difficulties questionnaire: A research note. *Journal of Child Psychology and Psychiatry, 38,* 581-586. doi: 10.1002/scp.934

Gresham, F.M. & Vellutino, F.R. (2010).What is the role of intelligence in the identification of specific learning disabilities? Issues and clarifications. *Learning Disabilities Research & Practice, 25* (4), 194-206.

Greven, C.U., Harlaar, N., Chamorro-Premuzie, T., & Plomin, R. (2009). More than just IQ. School Achievement is predicted by self-perceived abilities – but for genetic rather than environmental reasons. *Psychological Science, 20*(6), 753-762.

Gustafsson, J. E. (1984). A unifying model for the structure of mental abilities. *Intelligence, 8,* 179-203. doi: 10.1016/1060-2896(84)90008-4

Hamidi, M., Slagter, H. A., Tononi, G., & Postel, B. R. (2009). Repetitive transcranial magnetic stimulation affects behavior by biasing endogenous cortical oscillations. *Frontiers in Integrative Neuroscience*, *3*, 1-12. doi: 10.3389/neuro.07.014.2009

Hamilton, C., Coates, R., & Hefferman, T. (2003). What develops in visuo-spatial working memory development? *European Journal of Cognitive Psychology, 15*, 43-69.

Hart, B., & Risley, T. (1995). *Meaningful differences*. Baltimore, MD: Brookes.

Hoff, E., & Tian, C. (2005). Socioeconomic status and cultural influences on language. *Journal of Communication Disorders, 38*, 271-278.

Holmes, J., Gathercole, S. E., Place, M., Dunning, D. L., Hilton, K. A., & Elliott, J. G (2010). Working memory deficits can be overcome: Impacts of training and medication on working memory in children with ADHD. *Applied Cognitive Psychology, 24,* 827-836.

Hopkins, W. G. (2010, February). *A new view of statistics: A scale of magnitudes for effect statistics.* Retrieved from:http://www.sportsci.org/resource/stats/index.html. doi: 1002/acp.1589

Hoskyn, M., & Swanson, H.L. (2000). Cognitive processing of low achievers and chidren with reading disabilities: A selective meta-analytic review of the published literature. *School Psychology Review, 29*, 102-119.

Huebner, E. S. (1990). The generalizability of the confirmation bias among school psychologists, *School Psychology International, 11*, 281-286

Jaekel, J., Wolke, D., & Bartmann, P. (2013). Poor attention rather than hyperactivity/impulsivity predicts academic achievement in very preterm and full-term adolescents. *Psychological Medicine, 43*, 183-196.

Jarvis, H. L., & Gathercole, S. E. (2003). Verbal and nonverbal working memory and achievements on national curriculum tests at 11 and 14 years of age. *Educational and Child Psychology, 20,* 123-140.

Kane, M.J., & Engle, R.W. (2002). The role of prefrontal cortex in working memory capacity, executive attention, and general fluid intelligence: An individual differences perspective. *Psychonomic Bulletin and Review, 9*, 637-671.

Kane, M. J., Hambrick, D. Z., & Conway, A. R. (2005). Working memory capacity and fluid-intelligence are strongly related constructs: Comment on Ackerman, Beier, and Boyle (2005). *Psychological Bulletin, 131,* 66-71. doi: 10.1037/0033-2909.131.1.66

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-age children-present and lifetime version (K-SADS0PL): Initial reliability and validity data. *Journal of American Academy of Child Adolescent Psychiatry, 36* (7), 980-988.

Kemps, E., De Rammelaere, S., & Desmet, T. (2000). The development of working memory: Exploring the complementarity of two models. *Journal of Experimental Child Psychology, 77*, 89-109.

Kibby, M. Y., & Cohen, M.J. (2008). Memory functioning in children with reading disabilities and/or attention deficit/hyperactivity disorder: A clinical investigation of their working memory and long-term memory functioning. *Child Neuropsychology, 14*, 525-546. doi:10.1080/09297040701821752

Kranzler, J. H. (1997). Educational and policy issues related to the use and interpretation of intelligence tests in the schools. *School Psychology Review, 26* (2), 150-162.

Landry, S., Miller-Loncar, C., Smith, K., & Swank, P. (2002). The role of early parenting in children's development of executive processes, *Developmental Neuropsychology,21*, 15-41.

Larry P. v. Riles (1979). Retrieved April 6, 2013, from, http://www.gnxp.com/MT2/archives/002326.html

Locurto, C. (1990). The malleability of IQ as judged from adoption studies. *Intelligence, 14*, 275-292. doi: 10.1016/S0160-2896(10)80001-7

Loftus, E. (1980). The impact of expert psychological testimony on the unreliability of eyewitness identification. *Journal of Applied Psychology, 65*(1), 9-15.

Marshall, R., Hynd, G.W., Handwerk, M.J., & Hall, J. (1997). Academic underachievement in ADHD subtypes. *Journal of Learning Disabilities*, *30*, 635-642.

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*, 377-384. doi: 10.1097/01.chi.0000153228.72591.73

Marx, I., Hubner, T., Herpetez, S. C., Berger, C., Reuter, E., Kircher, T., Herpertz-Dahlmann, B., & Konrad, K. (2010). Cross-sectional evaluation of cognitive functioning in children, adolescents, and young adults with ADHD. *Journal of Neural Transmission*, *117* (3), 403-419. doi: 10.1007/s00702-009-0345-3

Mayringer, H., & Wimmer, H. (2000). Pseudoname learning by German-speaking children with dyslexia. Evidence for a phonological learning deficit. *Journal of Experimental Child Psychology*, *75*, 116-133.

McElree, B., & Dosher, B. A. (1989). Serial position and set size in short-term memory: The time course of recognition. *Journal of Experimental Psychology: General*, *118*,346-373.

Mc Grew, K. S. , Werder, J. K., & Woodcock, R.W. (1991). Woodcock-Johnson *Technical Manual*. San Antonio. Texas: DLM

McNemar, Q. (1975). On so-called Test Bias, *American Psychologist*, *30* (8), 848-851.

Melby-Levag, M., & Hulme, C. (2013). Is working memory training effective? A meta-analytic review. *Developmental Psychology*, *49* (2), 270-291. doi:10.1037/a0028228

Naglieri, J.A., & Bornstein, B.T. (2003). Intelligence and achievement: Just how correlated are they? *Journal of Psychoeducational Assessment, 21*, 244-260.

Neuman, W. L. (2006). Social research methods: Qualitative and quantitative approaches (6th ed.). Boston, Massachusetts: Allyn & Bacon.

Nigg, J. T., Willcutt, E. G., Doyle, A. E., Sonuga-Barke, E. J. (2005). Causal heterogeneity in attention deficit/hyperactivity disorder: Do we need neuropsychologically impaired subtypes. *Biological Psychiatry, 57*, 1224-1230. doi: 10.1016/j.biopsych.2004.11.011

Nisbett, R.E., Aronson, J., Blair, C., Dickens, W., Flynn, J., Halpern, D.F., Turkheimer, E. (2012). *American Psychologist, 67* (2), 130-159.

No Child Left Behind (2001). Retrieved September 29th, 2014, from http://www2.ed.gov/policy/elsec/leg/esea02/index.html.

Oberauer, K. (2002). Access to information in working memory: Exploring the focus of attention, *Journal of Experimental Psychology: Learning, Memory, and Cognition, 28,* 411-421.

Owens, M., Stevenson, J., Hadwin, J., & Norgate, R. (2014). When does anxiety help or hinder cognitive test performance? The role of working memory capacity. *British Journal of Psychology, 105*, 92-101. DOI: 1111/bjop.12009

Pamela Lewis v. New Haven School District (1994). Retrieved April 6, 2013 http://www.freerepublic.com/focus/f-news/1164277/posts

Parker, D.R., & Benedict, K.B. (2002). Assessment and intervention: Promoting successful transitions for college students with ADHD. *Assessment for Effective Intervention, 27*(3), 3-24.

Pascual-Leone, J. (1970). A mathematical model for the transition rule in Piaget's developmental stages. *Acta Psychologica, 32*, 301-345.

Pascual-Leone, J., & Baillargeon, R. (1994). Developmental measurement of mental attention. International Journal of Behavioral Development, 17, 161-200.

Pickering, S. J., & Gathercole, S. E. (2001). *Working memory test battery for children.* London: Psychological Corp.

Plaus, S. (1993). *The Psychology of Judgment and Decision Making*, McGraw-Hill. ISBN 978-0-07-05047706, OCLC 26931106

Polderman, T.J., Boomsma, D.I., Bartels, M., Verhulst, F.C., Huizink, A. C. (2010). A systematic review of prospective studies on attention problems and academic achievement, *Acta Psychiatrica. 122*, 271-284. doi: 10.1111/j.1600-0447.2010.01568.x.

Quin, P. C., & Liben, L. S. (2008). A sex difference in mental rotation in young infants. *Psychological Science, 19*, 1067-1070; doi: 10.1111.j.1467-9280.2008.02201.x

Reynolds, C. R. & Kamphaus, R. W. (2002). *The Clinician's Guide to the Behavior Assessment System for Children*, The Guildford Press, New York, NY.

Reynolds, C. R. & Kamphaus, R. W. (2004). *The Behavior Assessment System for Children – 2nd Ed.*, Pearson Assessment, Toronto, ON.

Reynolds, C. R. & Suzuki, L. (1990). *Bias in psychological assessment*. In Reynolds, C & Kamphaus, R. (Eds.), *The Handbook of Psychological and Educational Assessment of Children* (pp82-113) New York: Guildford Press. Retrieved from http://lp.wileypub.com/HandbookPsychology/SampleChapters/Volume10.pdf doi: 10.1002/9781118133880.hop210004

Rhode, T.E., & Thompson, L.A. (2007). Predicting academic achievement with cognitive ability. *Intelligence, 35*, 83-92.

Rogers, M., Hwang, H., Toplak, M., Weiss, M., & Tannock, R. (2012). Inattention, working memory, and academic achievement in adolescents referred for attention deficit/hyperactivity disorder (ADHD). *Child Neuropsychology, 17*(5), 444-458.

Ruchkin, D. S., Berndt, R. S., Johnson Jr., R., Ritter, W., Grafman, J., & Canoune, H. L. (1997). Modality-specific processing streams in verbal working memory: evidence from spatio-temporal patterns of brain activity. Brain Research and Cognition, 6, 95-113.

Sackett, P.R., Laczo, R. M., & Lippe, Z.P. (2003). Differential prediction and the use of multiple predictors: the omitted variables problem. *Journal of Applied Psychology,88* (6), 1046-1056. doi: 10.1037/0021-9010.88.6.1046

Sandrini, M., Fertonani, A., Cohen, L. G., & Miniussi, C. (2012). Double dissociation of working memory load effects induced by bilateral parietal modulation. *Neuropsychologia*, *50*, 396-402.

Sattler, J.M. (2001). *Assessment of Children Cognitive Applications 4th Ed*. San Diego: Sattler Publications Inc.

Shaywitz, S. E., Shaywitz, B. A., Fulbright, R. K., Skudlarski, P., Mencl, W. E., Constable, R. T., Pugh, D. R., Holahan, J., Marchione, K. E., Lyon, J. C., & Gore, J. C. (2003). Neural systems for compensation and persistence: young adult outcome of childhood reading disability. *Biological Psychiatry, 54* (1), 25-33. doi: 10.1016/S00006-3223(02)01836-X

Seigneuric, A., Ehrlich, M. F., Oakhill, J.V., & Yuill, N.m. (2000). *Working memory resources and children's reading comprehension*. Reading and Writing, 13, 81-103.

Senn, T. E., Espy, K.A., & Kaufman, P.M. (2004). Using path analysis to understand executive function organization in preschool children. *Developmental Neuropsychology, 26*, 445-464.

Silver, C. H. (2000). Ecological validity of neuropsychological assessment in childhood traumatic brain injury. *Journal of Head Trauma Rehabilitation, 15,* 973-988.

Smith, E. E., & Jonides, J. (1996). Working memory in humans: Neuropsychological evidence. In M. Gazzagniga (Ed.), The cognitive neurosciences (pp. 1009-1020). Cambridge, MA, US: The MIT Press.

St. Clair-Thompson, H., & Gathercole, S.E. (2012). Executive functions and achievements in s chool: Shifting, updating, inhibition, and working memory. *The Quarterly Journal of Experimental Psychology, 59* (4) 745-759.

Stone, B. J. (1992). Prediction of achievement by Asian-American and white children. *Journal of School Psychology, 30*, 91-99.

Suβ, H., Oberauer, K., Wittmann, W. W., Wilhelm, O., & Schulze, R. (2002). Working-memory capacity explains reasoning ability – and a little bit more. Intelligence, 30, 261-288. doi: 10.1016/S0160-2896(01)00100-3

Suchan, B., Linnewerth, B., Koster, O., Daum, I., & Schmid, G. (2006). Cross-modal processing in auditory and visual working memory. *Neuroimage*, *29*, 853-858.

Swanson, H.L. (1998). Short-term memory and working memory: Do both contribute tour understanding of academic achievement in children and adults with learning disabilities? *Journal of Learning Disabilities, 27*, 34-50.

Swanson, H. L., & Beebe-Frankenberger, M. (2004). The relationship between working memory and mathematical problem solving in children at risk and not at risk for math disabilities. *Journal of Educational Psychology, 96*, 471-491.

Swanson, H. L., & Sachse-Lee, C. (2001). Mathematical problem solving and working memory in children with learning disabilities: Both executive and phonological processes are important. *Journal of Experimental Child Psychology, 79*, 294- 321

Swanson, J. Schuck, S., Mann, M., Carlson, C., Hartman, K., & Sergeant, J. (2005). *Categorical and dimensional definitions and evaluations of symptoms of ADHD: The SNAP and the SWAN Ratings Scales.* Retrieved from:www.adhd.net/SNAP_SWAN.pdf/

Tannock, R., Hum, M., Masellis, M., Humphries, T., & Schachar, R. (2000). Children's academic performance, attention, behavior, and learning evaluation: Teacher Telephone Interview (TTI). Unpublished manuscript, The Hospital for Sick Children, Toronto, Ontario, Canada.

Tuckey, M., & Brewer, N. (2003). How schemas affect eyewitness testimony over repeated retrieval attempts. *Applied Cognitive Psychology, 17* (7), 785-800.

Taylor, J. (2007). *The role of attention in creating a cognitive system. Attention in Cognitive Systems.* Theories and Systems from an Interdisciplinary Viewpoint, 4840, 21-41. doi: 10.1007/978-3-540-77343-6_2

The Riverside Publishing Company (2006). *Woodcock--Johnson® III Tests of Achievement.* Retrieved January 16, 2007, from http://www.riverpub.com/products/wjIIIAchievement/details.html

Toplak, M. E., Bucciarelli, S. M., Jain, U., & Tannock, R. (2009). Executive functions: Performance-based measures and the Behavior Rating Inventory of Executive Function (BRIEF) in adolescents with attention deficit/hyperactivity disorder (ADHD). *Child Neuropsychology, 15*, 53-72. doi: 10.1080/09297040802070929

Trampush, J. W., Miller, C. J., Newcorn, J. H., & Halperin, J. M. (2009). *The impact of childhood ADHD on dropping out of high school in urban adolescents/ young adults.*

Journal of Attention Disorders, 13, 127-136. doi: 10.1177/1087054708323040

Vellutino, F.R., Scanlon, D.M., Zhang, H., & Schatschneider, C. (2008). Using response to kindergarten and first grade intervention to identify children at risk for long-term reading disabilities. Reading and writing: *An Interdisciplinary Journal, 21*, 437-480.

Vygotsky, L. (1978). *Interaction between learning and development, in Mind in society: The development of higher psychological processes*, Chapter 6, 79-9. Cambridge, MA: Harvard University Press

Warner-Rogers, J., Taylor, A., Taylor, E., & Sandberg, S. (2000). Inattentive behavior in childhood: Epidemiology and implications for development. *Journal of Learning Disabilities, 33*, 520-536. doi: 10.1177/002221940003300602.

Was, C. A. (2010). Individual differences in reading are more than just working memory: The case for available long-term memory. *Individual Differences Research, 8* (3), 132-139.

Watkins, M. (2010). Structure of the Wechsler Intelligence Scale for Children-Fourth Edition among a national sample of referred students. *Psychological Assessment, 22* (4),782-787.

Watkins, M. W., Lei, P., & Canivez, G. L. (2006). Psychometric intelligence and achievement: A cross-lagged panel analysis. *Intelligence, 35*, 57-68.

Wechsler, D. (1990). *Wechsler Pre-School and Primary Scale of Intelligence – Revised UK* Edition. London: Psychological Corp.

Wechsler, D. (2003). *Wechsler Intelligence Scale for Children (4th Ed.).* San Antonio, TX: The Psychological Corporation.

Wechsler, D., Kaplan, E., Fein, D., Kramer, J., Morris, R., Delis, D., Maelender, A. (1971-2004). *The Mental Measurements Yearbook 17*, San Antonio, Texas: The Psychological Corporation, Harcourt Assessment Company. doi: 17013214

Weiss, L. G., & Prifitera, A. (1995). An evaluation of differential prediction of WIATT achievement scores from WISC-III FSI-IQ across ethnic and gender groups. *Journal of School Psychology, 33*, 297-304

Willcutt, E. G., Doyle, A.E., Nigg, J. T., Faraone, S. V., & Pennington, B. F. (2005). Validity of the executive function theory of attention deficit/hyperactivity disorder: A meta-analytic review. *Biological Psychiatry, 57*, 1336-1346 .doi:10.1016/j.biopsych.2005.02.006

Willcut, E. G. & Pennington, B. F. (2000). Comorbidity of reading disability and attention deficit/hyperactivity disorder: Differences by gender and subtype. *Journal of Learning Disabilities, 33* (2),179-191. doi:10.1177/002221940003300206

Woodcock, R. W., McGrew, K. S., & Mather, N. (2001). *Woodcock-Johnson tests III of achievement.* Itasca, IL: Riverside.

Xu,Y., & Chun, M. M. (2006). Dissociable neural mechanisms supporting visual short-term memory for objects. *Nature, 428*, 91-95.

Yen, C., J., & Konold, T. R., & McDermott, P. A. (2004). Does learning behavior augment cognitive ability as an indicator of academic achievement? *Journal of School Psychology*, *42*, 157-169.

Young, J.W. (1994). Differential prediction of college grades by gender and by ethnicity: A replication study, *Educational and Psychological Measurement, 54*, 1022-1029.

Zedeck, S. (1971). Problems with the use of "moderator" variables. *Psychological Bulletin, 76* (4), 295

Appendices

Appendix A.
Minimal Risk Consent Form

UNIVERSITY OF
SOUTH FLORIDA

Parental Permission to Participate in Research Involving Minimal Risk

Information for parents to consider before allowing their child to take part in this research study

IRB Study # Pro13171

The following information is being presented to help you and your child decide whether or not your child wishes to be a part of a research study. Please read this information carefully. If you have any questions or if you do not understand the information, we encourage you to ask the research.

We are asking you to allow your child to take part in a research study called:

Predicting Adolescents' Academic Achievement: The Contribution of Attention and Working Memory

The person who is in charge of this research study is Diane E. Napier. This person is called the Principal Investigator. However, other research staff may be involved and can act on behalf of the person in charge. She is being guided in this research by Dr. Darlene De Marie.

The research will be conducted at: 2730 Via Cipriani, Clearwater, FL 33764

Why is this research being done?

The purpose of this study is to find out how well subtests from intelligence tests (working memory) can predict academic achievement. Full scale intelligence tests have been found to be culturally biased, but certain subtests have been found to be good predictors, and not culturally biased. This research also wishes to examine how student self-perception of attention problems may moderate the prediction of academic success.

Why is your child being asked to take part?

We are asking your child to take part in this research study because he/she is the right age group (11-16). Previously there are many research studies on younger elementary aged students, but few students include the adolescent age range.

Should your child take part in this study?

This informed consent form tells you about this research study. You can decide if you want your child to take part in it. This form explains:

- Why this study is being done.
- What will happen during this study and what your child will need to do?
- Whether there is any chance your child might experience potential benefits from being in the study.

- The risks of having problems because your child is in this study.

Before you decide:

- Read this form.
- Have a friend or family member read it.
- Talk about this study with the person in charge of the study or the person explaining the study. You can have someone with you when you talk about the study.
- Talk it over with someone you trust.
- Find out what the study is about.
- You may have questions this form does not answer. You do not have to guess at things you don't understand. If you have questions, ask the person in charge of the study or study staff as you go along. Ask them to explain things in a way you can understand.
- Take your time to think about it.

The decision to provide permission to allow your child to participate in the research study is up to you. If you choose to let your child be in the study, then you should sign this form. If you do not want your child to take part in this study, you should not sign the form.

What will happen during this study?

Your child will be asked to spend about 1.5 hours maximum in this study. There is a battery of several short tests, and one achievement test. The short subtests take approximately 7 minutes each, although some students may take longer or shorter periods of time. The achievement test may take anywhere from 30 minutes to 50 minutes depending how many answers are provided and speed of working. There are many questions which are not timed, so the student takes as long as they want.

Your son/daughter may bring a bottle of water for refreshment, and take breaks between subtests. The first series of subtests may last 15 – 20 minutes and after that your son/daughter will be offered a restroom break, or time to walk around the room. The achievement test has a series of subtests which enable short breaks for relaxing between them.

At the visit, your child will be asked:

Read questions and circle answers that best fit, and also write answers onto a student answer sheet with a pencil. Pencils will be provided.

- Behavior Assessment of School Children – Self-Rating scale: measures self-perception of how the child feels about school situations. Data will be collected on the score for attention problems.

  Wechsler Intelligence Scales for Children- Subtests: Digit Span and Letter Number sequence to measure Verbal Working Memory

  Universal Nonverbal Intelligence Test – Subtests: a Spatial Memory subtest will be provided to measure Visual Memory

  Woodcock Johnson Tests of Academic Achievement III – Standard Battery which measures reading, math and written performance...

- Your son/daughter will be asked to complete all the subtests and achievement test, but if he/she does not want to continue at any time, the testing will stop. There will be only one testing session.

- There will be no video-taping or photography and all personal identifying information will be removed from the data set after it is scored, so that confidentiality is maintained.

How many other people will take part?

About 50-60 individuals will take part in this study. A total of 53individuals may participate in the study between any/ all sites.

What other choices do you have if you decide not to let your child to take part?

If you decide not to let your child take part in this study, that is okay.
Instead of being in this research study your child can choose not to participate.

Will your child be compensated for taking part in this study?

If your son/daughter participates in the study the examiner will offer to mail to you a print out of the academic achievement results. If you would like this option, please check YES in the box below and provide your address so the scores can be provided to you. There will be no cost to you for any of the testing, or provision of score results. Please bring a self-addressed stamped envelope for the examiner to mail results to you.

☐ YES I would like to receive a copy of the scores from the Woodcock Johnson Tests of Achievement. I understand there will be no charge for the testing, and results will be mailed to the address I provide.   I understand results are not available from the other subtests, but I will be able to read the results in the final study document once published with the University of South Florida.

____Signature of Parent/Guardian

☐ NO, I do not need or want a copy of the score results from the Woodcock Johnson Tests of Achievement. I understand that if I change my mind and request a copy after testing date the examiner will not be able to provide these results because all personal identifying information will be removed from data set once protocols are scored. . I understand results are not available from the other subtests, but I will be able to read the results in the final study document once published with the University of South Florida.

You will receive no payment or other compensation for taking part in this study.

What will it cost you to let your child take part in this study?

It will not cost you anything to let your child take part in the study.

What are the potential benefits to your child if you let him / her take part in this study?

The potential benefits to your child include:

- You will have the opportunity to learn about your child's academic achievement which is measured on a standardized assessment. Scores will be provided with a description which will let you know if the test scores achieved are Average, Below Average, or Above Average for his/her age and grade level. This may help you guide his educational planning for the next school year.

By volunteering you are helping us learn more about how Working Memory and Attention relate to Academic Achievement in Adolescent children. What we learn may help others in the future by suggesting interventions in class or at home to encourage successful attention and improve learning outcomes.

What are the risks if your child takes part in this study?

There are no known risks to those who take part in this study.

Conflict of Interest Statement

The Principal Investigator is working as a school psychologist, but the testing in this research is not a psychological evaluation. Participants who volunteer to take part in this study may receive a copy of the academic achievement test results if they request this at time of signing consent.

How Do I Withdraw Permission to Use My Child's Information?

You can revoke this form at any time by sending a letter clearly stating that you wish to withdraw your authorization to use of your child's information in the research. If you revoke your permission:

- You child will no longer be a participant in this research study;
- We will stop collecting new information about your child;
- We will use the information collected prior to the revocation of your authorization. This information may already have been used or shared with other, or we may need it to complete and protect the validity of the research; and

To revoke this form, please write to:

Principal Investigator: Diane E. Napier

For IRB Study # Pro 13171

XXXX XXXX, Clearwater, FL 33764

While we are conducting the research study, we cannot let you see or copy the research information we have about your child. After the research is completed, you have a right to see the results of the study as allowed by USF policies.

Privacy and Confidentiality

We will keep your child's study records private and confidential. Certain people may need to see your child's study records. By law, anyone who looks at your child's records must keep them completely confidential. The only people who will be allowed to see these records are:

- The research team, including the Principal Investigator, study coordinator, and all other research staff**.**
- Certain government and university people who need to know more about the study. For example, individuals who provide oversight on this study may need to look at your records. This is done to make sure that we are doing the study in the right way. They also need to make sure that we are protecting your rights and your safety.
- Any agency of the federal, state, or local government that regulates this research. This includes the Office for Human Research Protection (OHRP).
- The USF Institutional Review Board (IRB) and its related staff, who have oversight responsibilities for this study, staff in the USF Office of Research and Innovation, USF Division of Research Integrity and Compliance, and other USF offices who oversee this research.

We may publish what we learn from this study. If we do, we will not include your child's name. We will not publish anything that would let people know who your child is.

What happens if you decide not to let your child take part in this study?

You should only let your child take part in this study if both of you want to. You or child should not feel that there is any pressure to take part in the study to please the study investigator or the research staff.

If you decide not to let your child take part:

- Your child will not be in trouble or lose any rights he/she would normally have.

You can decide after signing this informed consent form that you no longer want your child to take part in this study. We will keep you informed of any new developments which might affect your willingness to allow your child to continue to participate in the study. However, you can decide you want your child to stop taking part in the study for any reason at any time. If you decide you want your child to stop taking part in the study, tell the study staff as soon as you can. Even if you want your child to stay in the study, there may be reasons we will need to withdraw him/her from the study. Your child may be taken out of this study if he/she does not attend scheduled testing session. We will let you know the reason for withdrawing your child's participation in this study.

You can get the answers to your questions, concerns, or complaints.

If you have any questions, concerns or complaints about this study, call Diane E Napier at XXX XXX XXXX.

If you have questions about your child's rights, general questions, complaints, or issues as a person taking part in this study, call the USF IRB at (813) 974-5638.

Consent for My Child to Participate in this Research Study

It is up to you to decide whether you want your child to take part in this study. If you want your child to take part, please read the statements below and sign the form if the statements are true.

I freely give my consent to let my child take part in this study and authorize that my child's test results may be collected/disclosed in this study. I understand that by signing this form I am agreeing to let my child take part in research. I have received a copy of this form to take with me.

____ ____________

Signature of Parent of Child Taking Part in Study Date

____ ____________

Printed Name of Parent of Child Taking Part in Study Date

Statement of Person Obtaining Informed Consent

I have carefully explained to the parent of the child taking part in the study what he or she can expect from their child's participation. I hereby certify that when this person signs this form, to the best of my knowledge, he/ she understands:

- What the study is about;
- What procedures will be used;
- What the potential benefits might be; and
- What the known risks might be.

I can confirm that this research subject speaks the language that was used to explain this research and is receiving an informed consent form in the appropriate language. Additionally, this subject reads well enough to understand this document or, if not, this person is able to hear and understand when the form is read to him or her. The parent signing this form does not have a medical/psychological problem that would compromise comprehension and therefore makes it hard to understand what is being explained and can, therefore, give legally effective informed consent. The parent signing this form is not under any type of anesthesia or analgesic that may cloud their judgment or make it hard to understand what is being explained and, therefore, can be considered competent to give permission to allow their child to participate in this research study.

____ ____________

Signature of Person Obtaining Informed Consent Date

____

Printed

UNIVERSITY OF SOUTH FLORIDA

Appendix B
Child Assent Form

Child Assent form

IRB Study # Pro13171

We are asking you to allow your child to take part in a research study called:

Predicting Adolescents' Academic Achievement: The Contribution of Attention and Working Memory

The person who is in charge of this research study is Diane E. Napier.

This person is called the Principal Investigator. She is being guided in this research by Dr. Darlene De Marie who is her professor at the University of South Florida.

The research will be conducted in Clearwater at a location agreed by your parent that is convenient for you.

Why is this research being done?

The purpose of this study is to find out about how children learn, and how you (as a student) feel about learning. We want to learn about this so we can help students be successful in school.

What will happen during this study?

You will come for testing to an agreed place, and will work through some assessments. These will include:

- A rating scale for you to tell us how you feel about school and learning
- Some matrixes and memory tests
- An achievement test which will measure what you can do in Reading, Math and Written expression

You may bring a bottle of water for refreshment, and take breaks between subtests. You will be offered a restroom break, or time to walk around the room when you need a break.

How many other people will take part?

About 50-60 individuals will take part in this study. We need at least 50 students to make this a good research study.

What other choices do you have if you decide not to take part?

If you decide not to take part in this study, that is okay.

You can choose not to participate.

What will you get out of this?

We cannot give you a gift, but we can tell your parents the results of your academic test. This will help you know how you are doing compared to other students your age.

What are the potential benefits to you?

The potential benefits to you are that :

Your parents will have the opportunity to learn about your academic achievement which is measured on a standardized assessment. Scores will be provided with a description which will let you know if the test scores achieved are Average, Below Average, or Above Average for his/her age and grade level.

By volunteering you are helping us learn more about how Working Memory and Attention relate to Academic Achievement in Adolescent children. Your contribution may help future students.

How Do I Withdraw Permission?

You can withdraw from this study at any time by telling the Principal Investigator.

To revoke this form, please write to:

Principal Investigator: Diane E. Napier

For IRB Study # Pro 13171

XXXX XXXXX, Clearwater, FL XXXX

While we are conducting the research study, we cannot let you see or copy the tests we will do. However, the results of all the scores from all the students will be reported in a paper for the University of South Florida.

Privacy and Confidentiality

We promise to keep your records private and confidential. Only a few people will be allowed to see these records are: the research team, including the Principal Investigator, study coordinator, and all other research staff**.**

We may publish what we learn from this study. If we do, we will not include your name.

You can get the answers to your questions, concerns, or complaints.

If you have any questions, concerns or complaints about this study, call Diane E Napier at XXX XXX XXXX. You may also call the USF IRB at (813) 974-5638.

Consent to Participate in this Research Study

I freely give my time and consent to take part in this study and authorize that my test results may be collected/disclosed in this study. I understand that by signing this form I am agreeing to participate in research. I have received a copy of this form to take with me.

____ ____________

Signature of Child Taking Part in Study Date

____ ____________

Printed Name of Child Taking Part in Study Date

Statement of Person Obtaining Informed Consent

I have carefully explained to the child taking part in the study what he or she can expect from their child's participation. I hereby certify that when this person signs this form, to the best of my knowledge, he/ she understands:

- What the study is about;
- What procedures will be used;
- What the potential benefits might be; and
- What the known risks might be.

I can confirm that this research subject speaks the language that was used to explain this research and is receiving an informed consent form in the appropriate language. Additionally, this subject reads well enough to understand this document or, if not, this person is able to hear and understand when the form is read to him or her. The child signing this form does not have a medical/psychological problem that would compromise comprehension and therefore makes it hard to understand what is being explained and can, therefore, give legally effective informed consent. The child signing this form is not under any type of anesthesia or analgesic that may cloud their judgment or make it hard to understand what is being explained and, therefore, can be considered competent to give permission to allow their child to participate in this research study.

____ ______

Signature of Person Obtaining Informed Consent Date

____ ______

Printed Name of Person Obtaining Informed Consent Date

Appendix C

Contact and Demographic Information

Name (Last, First) ____

Please check any of the conditions which apply to your child. My child:

☐ Has autism

☐ Has a severe intellectual disability

☐ Has limited English proficiency

☐ Is blind or deaf

☐ Has a sibling already participating in the research study

☐ Is enrolled in a special education self-contained unit

If none of the above boxes are checked, please complete the following:

My child is willing to participate in this study ☐ yes ☐No

Gender ☐ Male

☐ Female

Race: ☐Caucasian

☐African American

☐Hispanic

☐Other

☐Do not wish to disclose

Medical: ☐ Has diagnosis of ADHD or ADD

☐ No diagnosis of ADHD or ADD

Birthdate: ___________________________

Contact Address:

____

Contact Telephone

Number:____

Any other information you wish to

share:____

Appendix D
Flyer to Recruit

USF UNIVERSITY OF SOUTH FLORIDA

Volunteers Wanted for a Research Study
USF IRB #Pro00013171

Predicting Adolescents' Academic Achievement:
The Contribution of Attention and Working Memory.

The purpose of the research is first to examine the relation between working memory in the prediction of academic achievement, and second to examine the relation of attention problems as a moderator for this prediction.

WE WANT YOU !!!!

Each volunteer will take:

- an academic achievement test which may take up to 45 minutes,
- a rating scale which describes how they feel, and
- a few short working memory subtests which will not take longer than 10-15 minutes.

The total length of time required is approximately 1½ hours to include time for breaks and refreshments.

Eligibility criteria: age: 12-16 years

Exclusionary criteria: any disability which would require special testing accommodations (e.g., blind, deaf, severe intellectual disability, and/ or autism, limited English).

Location: xxxx XXXX, XXXXX, XXXXX, or other as agreed.

To learn more about this research:
Contact: Diane E. Napier
Cell: XXX XXX XXXX
Email: xxxxxxxxxxxxxx

Department of Psychological and Social Foundations,
College of Education, University of South Florida.
This research study is part of a doctoral study

IRB Number: Pro00013171
Flyer to Recruit Participants

IRB Consent Rev. Date: 07/24/13
Version #:1