1-1-2013

Variability Across Repeat Assessment of Working Memory and Processing Speed in Referred Populations

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Submitted in Partial Fulfillment of the Requirements

For the Degree of Doctor of Philosophy in

Educational Psychology and Research

College of Education

University of South Carolina

2013

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DEDICATION

To my parents who gave me a life couched in faith, the value of education, and have loved and supported me throughout my life. To my sisters, you mean so much to me. Your steadfastness of what it means to be a sister has carried me through these past few years.

To my nieces, nephews, and godchildren, it is my hope that this achievement inspires you to reach for your dreams. As long as you have the heart and the will, you can achieve anything you desire.

Lastly, this work is dedicated to God's presence in my life.   It is only through many prayers and grace that I have been sustained to this point in my life.

ACKNOWLEDGEMENTS

I would like to thank Dr. Kellah Edens, my advisor and chair for indulging my topic, which passionately voices the importance of meeting the educational needs of children who have persistent learning issues. I am also very appreciative for her help in making this a better paper. I extend a great deal of gratitude to her and Dr. Gredler for their patience and understanding how important my learning was to me as I moved through and beyond the most challenging time of my life while in pursuit of this degree. My thanks to Dr. Margaret Gredler for her commitment to the principles of good research and educational psychology and for sharing her extraordinary knowledge of learning and especially introducing me to Lev Vygotsky. I extend a special thank you to Dr. Mary de Beus who graciously took part in this last leg of my graduate training; who despite not being a professor at USC, has the same commitment to teaching and the learning process. I also appreciate her insights as a clinician to my committee and most importantly her support these last few years. To Dr. Ellen Potter, thank you for being part of this journey at its beginning and its end. I have appreciated your suggestions and support. To Dr. Matthew Irvin, thank you for your insights and advise on shaping the outline of this work. A special thanks goes to Dr. Roger de Beus who reminded me how much statistics can be fun. I enjoyed our statistics chats and am grateful for your assistance in this dissertation. A special thank you goes to Dr. Sally Conder, whose generosity made this research and my educational pursuit possible. I am grateful for your friendship. A special note of thanks goes to Dr. Carl Adkins who read portions of this dissertation but more importantly reminded me that those who persevere make it to the end. Lastly, I want to acknowledge all of the professors I had the pleasure of knowing at the University of South Carolina. Your extraordinary commitment to excellence in teaching and the value you place on learning and the learning process of students will be one of the most important values I come away with from this program.

ABSTRACT

Developmentally, it is expected that the processes of working memory and processing speed will improve throughout childhood as a child's brain develops. However, students with learning, attention, and other childhood disorders often display difficulties in these areas. This study investigated the use of repeated measures to ascertain variability over time of two important cognitive processes: Working Memory and Processing Speed in a clinically referred population as measured by the WISC-IV to determine if a significant discrepancy exists between administrations. The study also investigated whether differences in Working Memory and Processing Speed from administration to administration would be greater in children with ADHD (Attention Deficit Hyperactivity Disorder) vs. students with SLD (Specific Learning Disability). WISC-IV scores in Working Memory and Processing Speed from two administrations were examined from confidential archival records for 75 children ages 6-14. A two-way repeated analysis of variance (ANOVA) was conducted for hypothesis one with time as the within factor. A mixed ANOVA was conducted for the second hypothesis with group as the between factor and time as the within factor. Time was defined as the interval from one administration to the next. Second administrations were an average of two and a half years later. For hypothesis one, Processing Speed was statistically significant for time as a main effect although results were not statistically significant for Working Memory. For hypothesis two, Working Memory was statistically significant for time and group. The

ADHD students performed significantly higher than SLD on Working Memory. Only time as a main effect was statistically significant for Processing Speed. Additional analyses examined medication status as well as comorbidity and gender as confounds. Those experiencing a medication change from one administration to the next as well as boys were significantly lower on Processing Speed.

Findings suggest students can perform quite variably across time even within the elementary school years. This research highlights the importance of repeat cognitive assessment in evaluating developmental disorders across time. Changes in Working Memory or Processing Speed determine types of interventions as well as accommodations that may be needed. This has ramifications for educational decisions regarding these students.

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LIST OF ABBREVIATIONS

ADHD………..…………………………………Attention Deficit Hyperactivity Disorder

APA………………………………………………American Psychological Association

CHC…………………………………………………………..…Cattell-Horn-Carroll

CPI…………………………………………………………Cognitive Proficiency Index

DSM-IV…………………………………………………Diagnostic Statistical Manual-IV

FAPE………………………………………………….Free Appropriate Public Education

FFD…………………………………………………………Freedom From Distractibility

FSIQ………………………..…………………………..Full Scale Intellectual Quotient

GAI……………………………………………………………......Global Ability Index

IDEA…………………………………………Individuals with Disabilities Education Act

IDEIA…………………………Individuals with Disabilities Education Improvement Act

LEA…………………………………………………………………Local Education Agency

PRI………………………………………………………....Perceptual Reasoning Index

PSI……………………….……………………………………….Processing Speed Index

RTI……………………………………….……………………….Response to Intervention

SED………………………………………………………….State Education Agency

SLD…………………………………………………...….Specific Learning Disabled

TBI…………………………………………………………..Traumatic Brain Injured

WISC……………………………………………Wechsler Intelligence Scale for Children

WMI………………………………………………...……….Working Memory Index

WJ-III……………………………………………………...……Woodcock-Johnson-III

VCI……………………………………………………….Verbal Comprehension Index

CHAPTER 1

INTRODUCTION

"Every cognitive act… involves an unfolding process over time"

(Kaplan, 1989, p. 129)

Understanding the underlying processes of intellectual functioning - i.e., how children process information and learn, is a major focus of educational researchers, school psychologists, and neuropsychologists. For school psychologists in particular, individual and diagnostic assessment of underlying processes and functions has served as a diagnostic tool for making decisions about student placement. Within the context of the school environment, the use of cognitive assessment has traditionally been used to determine the qualification of special needs services. The variability of discrete components of information processing, such as working memory and processing speed, may be a contributor to differential functioning of the cognitive performance of students over time. Yet understanding about how these processes may fluctuate over repeated measures with psychometric instruments is not sufficiently understood.

Examining variability of cognitive functions involved in information processing is important since children with various developmental disorders often have general difficulties processing information. These difficulties processing information may be demonstrated through classroom behaviors such as inability to keep up with the pace of instruction, not being able to retain instructions long enough to initiate and/or complete a task in an efficient manner, difficulties holding and manipulating information in mind for note taking or other academic tasks, or organizing their thoughts to put information on paper. All of these issues as well as other information processing difficulties hinder a student's performance in the classroom and the consistency of their ability to demonstrate what they know. Recognizing this factor suggests that a student, regardless of whether they have a specific learning disability, head injury, Attention Deficit Hyperactivity Disorder (ADHD), other brain disorder, etc. may have information processing difficulties that influence their cognitive performance from one time point to another.

Examining variability of information processing with referred children particularly over repeat assessment also takes into account the co-morbidity of disorders, development, changes in medications, and acquired conditions (Flanagan, Fiorello, & Ortiz, 2010). Using an approach which takes into consideration variability of functioning of underlying processes becomes confusing when similar constructs - e.g., verbal ability, fluid reasoning, and working memory, processing speed are measured in different ways. It is additionally complicated by the changing nature and meaning of a task and developmental level. As such, "strengths" and/or "weakness" contained within the variability of a performance on a task may be the result of multiple reasons and processes. This suggests the importance of considering the inconsistency of individual student's process underlying their performance.

Issues of variability suggest that evaluating a child's cognitive processes, particularly within the context of a theory of intelligence that focuses specifically on the discrete components of information processing, is warranted. The Cattell-Horn-Carroll Theory (CHC) (Carroll, 1993) is a comprehensive example of an approach to understanding cognitive processes. Its structure of denoting processes underlying broader cognitive constructs allows a theoretical structure to guide the process of understanding how underlying cognitive processes are relevant to learning and specific academic skills adding validity to assessment. This theory has evolved and gained prominence as a guiding force not only in test construction but also interpretation (Flanagan, McGrew, & Ortiz, 2000). Using such an approach can assist with developing greater specificity with regards to educational intervention, which should be the focus of assessment (Keith & Reynolds, 2010). By using theory to guide interpretive understanding, cognitive processes are then assessed under a conceptual model.

Examining variability of information processing additionally brings to light processes that may influence global functioning either on an on-going basis or as an indicator of variable functioning that influences day-to-day performance. Flanagan, Fiorello, and Oritz (2010) state it is more difficult to determine the overall intellectual level of students who display significant variability. This is problematic since ability level has long been considered a part of determining whether a student has a learning disability and in turn, may impact whether a student qualifies for a service or not. It additionally affects educators' ability to fully understand the functioning of these children and expectations for them in their classroom when issues of working memory and processing speed exist. Further, it is important to track these processes during development to determine whether these cognitive issues represent a cognitive delay vs. an intellectual disability vs. "expected" underachievement vs. persistent specific learning disability vs. slow learner vs. injury specific issues. Variability of information processing may influence cognitive performance. Further, many confounds, i.e., medication, situational issues, development, etc. may influence cognitive performance accounting for such variability. Assessment of performance across time also recognizes the role of variability in children's performance from one administration to the next. Examining change across repeated measures is also important for referred students. It highlights the heterogeneity within specific disorders like ADHD and Specific Learning Disabled (SLD) even though groups may experience processing difficulties in working memory and processing speed. This is an important area to examine in research given their prevalence in school-age children (Wechsler, 2003).

1.1 The Present Study

The present study investigates repeated measures to ascertain variability over time of two important cognitive processes –Working Memory and Processing Speed. Specifically, the purpose is to examine variability of performance with Working Memory and Processing Speed as measured by the WISC-IV (Wechsler Intelligence Scale for Children-IV) in a repeat measurement design with referred students. The study poses a second question of whether children with ADHD demonstrate greater differences from administration to administration than students with SLD in the areas of Working Memory and Processing Speed. The importance of the second question is that ADHD can often affect the efficiency of processing information and demonstrate variability in performance from day to day.

While a review of the research literature suggests that referred students and specifically, students with ADHD and specific learning disabilities may display distinctive profiles, controversy exists in profile interpretation with these special populations (Collins & Rourke, 2003). These populations may also present with differing cognitive profiles because of individual issues (Mayes & Calhoun, 2004). Overlap in cognitive processing issues and behavioral presentations in the co-morbidity between learning disabled and ADHD may additionally confound results (Barkley, 2006, p. 127; Willcutt, Pennington, Olson, Chhabildas, & Hulslander, 2005). Collins and Rourke (2003) further state that learning disorders are heterogeneous and that they are not a unitary disorder. Such heterogeneity not only informs test performance but also the variability that may be seen particularly across time. Learning disorders include subtypes which complicate profile analysis differentiating them solely on the presence of cognitive performance. Despite differing opinions, standardization of the WISC-IV notes both students with attention disorders and/or specific learning disabilities often have difficulties in working memory and processing speed (Wechsler, 2003).

More recent research also suggests that a central core of ADHD is difficulty with inhibitory control, which affects variability of performance particularly in working memory (Barkley, 2006). The current research examines whether there is greater variation in information processes and specifically working memory and processing speed in students with diagnosed ADHD vs. students identified with a SLD building on research literature suggesting slowed processing speed of students with attentional disorders (Calhoun & Mayes, 2005; Mayes & Calhoun, 2006; Wechsler, 2003).

Examining variability of working memory and processing speed, as measured with the WISC-IV (Wechsler Intelligence Scale for Children-IV) within the context of a repeat measure analysis of variance is important, as these processes are known to change over time and the WISC-IV is one of the most commonly used measures in assessing intellectual functioning. The role of variation of discrete cognitive processes in information processing across a prominent developmental period of schooling lays the foundation for the current research. A plethora of issues both internal and external to the individual may affect Working Memory and Processing Speed in particular, which may in turn influence the variability and vulnerability of information processing. Also, examining variability of Working Memory and Processing Speed performance across time additionally contributes to the limited research on the WISC-IV regarding variability of performance with referred populations.

Variability over time is an important aspect of assessment to investigate as development changes. Variation also may be influenced by differences in these processes due to age. Advances in neuropsychology and developmental theories have come together in demonstrating how brain structures and processes such as working memory and processing speed are different at different ages (Baron, 2004; Fry & Hale, 1996; Hale & Fiorello, 2004). Some of McGrew and Wendling's (2010) research findings with the Woodcock-Johnson Cognitive and Achievement batteries over the last 20 years have additionally demonstrated variability in these functions or processes depending on age. For example, general knowledge increases in importance as a child ages and has acquired basic reading skills.

The current study provides information about these processes during an important developmental period in which working memory and processing speed are developing. A repeat measurement design highlights the value of tracking cognitive processes across an important developmental time period, allowing an examination of variability of school-age children's performance. Such a design provides relevant and current information regarding educational and daily functioning issues. It also reiterates the importance of tracking cognitive information processes such as working memory and processing speed in relationship to brain-based disorders, since these children have to function within an increasingly demanding curriculum and their information processing issues may have broad implications for their learning.

Moreover, understanding current cognitive functioning and variability of information processing with developmental disorders better informs the intervention process about *current* processing issues. Especially important is the way processing issues may affect children in the regular classroom across subject areas, which has implications for instruction and intervention planning. It provides information for interventions that may serve a child on a more global level (Hale et al., 2010).

1.2 Psychometrics and IQ Stability

Despite the importance of looking at processes within intellectual functioning and the question of whether a significant variability exists within information processing, the force of psychometrics has driven an approach in education that has focused on global abilities and certain discrepancies between global IQ and achievement composites. Diagnostic assessments used for making decisions about services have traditionally used 'aggregate' or 'global' capacity, i.e., composite IQ scores. Subsequently examining the value of cognitive processing strengths and weaknesses may not be considered in relation to intervention and daily functioning. The idea of IQ as being stable has been based upon a premise that a global composite as a stable factor (McCall, 1977). Lubinski (2004) notes intellectual performance tends to become increasingly stable over time. This is backed by the research literature, which has suggested an individual's IQ score as a fixed and unchangeable measure. The one-time use of and consideration of only a global composite implies a stability of cognitive functioning. McCall (1977) states this perpetuates a practice that is in keeping with the understanding that a child's IQ becomes increasingly stable as they age. Further, it is expected that because of brain growth development and refinement (pruning) processes such as working memory and processing speed improve as a child ages (Bayliss, Jarold, Baddeley, Gunn, & Leigh, 2005; Fry & Hale, 1996; Weiss, Saklofske, Schwartz, Prifitera, & Courville, 2006). Once students have been placed, they may not be cognitively reevaluated due to the assumption of no cognitive changes. Additionally the newest revision of IDEIA 2004 (U.S. Department of Education) IQ assessment is not necessarily required to determine continued services (http://www.ideapartnership.org). However, this premise does not consider that there may be variability within cognitive areas comprising the assessment scale affecting expression of the global ability score and that such variation might be present (or not) in subsequent evaluations. Subsequently, issues regarding the stability of IQ, the relevancy and value of IQ as relates to intervention, the best use of intervention resources, and demand for evidence-based research with academic interventions suggest further study is needed on the use and value of repeat assessment. Thus, examination of variability with information processes - working memory and processing speed specifically within this context adds to the repeat measurement literature about this aspect of cognitive functioning.

The argument that IQ is immutable and singular does not take Wechsler's definition of intelligence into consideration. Although his definition included words such as "aggregate" and "global", Wechsler also noted that it is composed of elements or abilities that are specific and distinctive (Wechsler, 2003). His selection of the different subtests stressed the importance of considering a variety of cognitive processes as well as non-cognitive factors (Sattler, 2001). Wechsler's argument supports the influence of a number of cognitive processes as well as non-cognitive factors that may influence not only *what* one knows but also one's ability to *access* that knowledge (Wechsler, 1975). Intellectual functioning may not always be stable. Assessing variability in clinical and referred populations illuminates the influence of developmental disorders, developmental changes, and other non-cognitive variables, and is supportive of the foundation underlying Wechsler's scale and also consistent with most intellectual theories today particularly the Cattell-Horn-Carroll theory (Carroll, 1993).

This research considers the extent that information processing may vary from administration to administration due to a plethora of issues related to development, situational circumstances, medication, treatment and intervention, changes in functioning, and/or the influence of neurodevelopmental disorders such as ADHD and SLD. All of these factors may influence the Full Scale IQ score of an intelligence test and point to a need for reassessment of intellectual functioning beyond the initial evaluation providing current information on functioning. This can offer important information for intervention and instruction (http://www.ideapartnership.org). Examining the variability of working memory and processing speed stresses the importance of considering relevant processes within the context of full evaluations for making decisions about referred populations (Dixon, Eusebio, Turton, Wright, & Hale, 2010; Hale et al., 2010).

1.3 Assessment of Working Memory and Processing Speed: WISC-IV

Many psychological processes are essential elements of intellectual functioning. This study focuses on two processes often implicated in brain-based disorders - Working Memory and Processing Speed as measured by the WISC-IV. Calhoun and Mayes

(2005) and Pickering andGathercole (2004) note that referred populations often have difficulties in these areas of information processing. Working Memory and Processing Speed are represented on the Wechsler Intelligence Scale for Children- IV (WISC-IV) in separate indexes along with the Indexes of Verbal Comprehension and Perceptual Reasoning. Given that these four Indexes comprise the WISC-IV's Full Scale Intellectual Quotient (FSIQ), this score may be negatively influenced by great variability or poor performance in either/ or both of Working Memory and Processing Speed. This is problematic in that the FSIQ is often used as the primary determinant in making important decisions. This can affect educational placement decisions resulting in a child possibly not receiving needed interventions and/or other special services (Williams, Weiss, Rolfhus, 2003). The importance of reassessing and tracking psychological and information processing functions is all the more important when making decisions about children's current learning needs and services. This is especially true within the context that Individuals with Disabilities Education Improvement Act (IDEIA 2004) has retained the definition of learning disabilities as being composed of processing deficits and includes a third method which provides for identifying cognitive strengths and weaknesses.

The current revision of the Wechsler scale has attempted to align itself with the most prevailing and influential intellectual theory to date- the Cattell-Horn-Carroll (CHC) Three Stratum Factor Analytic Theory (Keith, Fine, Traub, Reynolds, & Kranzler, 2004; Wechsler, 2003). The processes of working memory and processing speed are subsumed into a three tiered hierarchical structure of the CHC theory that includes both general, as well as underlying, specific processes. It is the composite of all four indexes that has been used almost exclusively in decision making. This score minus achievement composites is typically used to determine qualification for services. Beyond the WISC-IV, both working memory and processing speed are psychological processes prominent in the literature and are often cited as difficulties found in clinical populations (Wechsler, 2003). As operationally defined by the Wechsler scales, these two processes have been found to underlie a number of higher level abilities such as fluid processing and reasoning as well as influence the acquisition of academic skills (Fry & Hale, 2000; Fry & Hale, 1996). Working memory and processing speed are the focus of this study because of their importance in the literature, their relationship to learning, and the prevalence of these types of difficulties in clinical populations. Tracking these issues is important in referred populations since these students do not always qualify for services yet may continue to exhibit difficulties with information processing that affects their academic performance in the regular classroom (Hale et al., 2010).

1.4 Problem Statements and Hypotheses

Given the processing difficulties often seen with referred populations, variability due to clinical disorders, comorbidity that can exist with these disorders and particularly the need for tracking cognitive processing issues in children with attentional and learning disorders, the primary research questions for this study are as follows:

1) Does a significant difference in Working Memory and Processing Speed exist from one administration to the next administration in referred populations?

2) Are there greater variations in Working Memory and Processing Speed from one administration to the next administration between students with ADHD as the primary diagnosis vs. students with Specific Learning Disabled as the primary diagnosis?

The main hypotheses for the study are as follows:

H1: Referred populations will demonstrate a significant difference in Working Memory and Processing Speed from one administration to the next administration of the WISC-IV.

H2: Students with only ADHD as the primary diagnosis will differ more significantly than students with only Specific Learning Disabled as the primary diagnosis from one administration to the next administration of the WISC-IV.

These hypotheses are based upon a literature review demonstrating that working memory and processing speed are difficulties often seen in these clinical populations. However, the author also acknowledges the research literature that recognizes co-morbidity amongst developmental disorders that may mitigate differences seen in clinical populations. Additional post analyses also examined the influence of medication vs. being on no medication, experiencing medication changes, co-morbidity, and gender.

1.5 Definition of Terms

Working Memory is defined as, "the ability to actively maintain information in conscious awareness, perform some operation or manipulation with it, and produce a result" according to the WISC-IV Technical and Interpretive Manual. (Wechsler, 2003, p. 16). A number of researchers have reported that developmentally, age-related improvements in working memory mediate the development of intelligence during childhood.

Processing Speed is defined as a measure of visual scanning, sequence, and discrimination of visual information. It involves short-term visual memory, attention, and visual-motor coordination (Wechsler, 2003, p. 17). Processing speed is a basic cognitive function implicated in and connected to intelligence, particularly higher-order cognitive functioning In this context, people with slower processing speed complete fewer mental tasks per unit of time (Tillman, Bohlin, Sorensen, & Lundervold, 2009). Both of these Indexes comprise the *Cognitive Proficiency Index (CPI),* which is defined as a representation of a "set of functions whose common element is the proficiency with which a person processes certain types of cognitive information" (Weiss & Gabel, 2008).

The *Ability-Achievement Discrepancy Method* is defined as a method of identification for special education qualification using a global IQ score in comparison with one or more of the eight achievement areas as defined by the *Individuals with Disabilities Education Act (IDEA)* (Weiss & Gabel, 2008).

Independent variables- Time is the independent variable for the variables Working Memory and Processing Speed. Time is defined as the time period between administrations.

Dependent variables-Working Memory and Processing Speed are the dependent variables in both hypotheses. As noted previously, Working Memory is defined as the ability to hold information in mind and perform some action with it. Processing Speed is defined as a measure of visual scanning, sequence, and discrimination of visual information (Wechsler, 2003).

For the second hypothesis, Group is defined as being a student diagnosed with either ADHD or SLD. Group one is composed of students with ADHD and group two were students with SLD.

Attention Deficit Hyperactivity Disorder is defined as a persistent pattern of inattention and/or hyperactivity-impulsivity that is more frequently displayed and more severe than is typically observed in individuals at a comparable level of development (American Psychiatric Association, 2000).

Specific learning disorders are defined as, "(i) a disorder in one or more of the basic psychological processes involved in understanding or in using language, spoken or written, that may manifest itself in an imperfect ability to listen, think, speak, read, write, spell, or to do mathematical calculations, including conditions such as perceptual disabilities, brain injury, minimal brain dysfunction, dyslexia, and developmental aphasia" (http://www.ncld .org/ld).

1.6 Significance of the Study

The current research examines variability of information processing of two prominent processes involved in learning- working memory and processing speed. This research also stresses the value of idiographic (individual) vs. solely nomothetic (normative) interpretation often used in assessment. The mass of studies with the WISC-IV have examined present performance and short-term stability with normal controls and defined populations. However, there has been very limited longer-term research with the WISC-IV. Long-term stability of coefficients has been examined in only one study to date (Ryan, Glass, & Bartels, 2010). Cluster analytic patterns of performance with the WISC-IV have also been examined with children referred for psychoeducational evaluation who experienced persistent academic difficulties (Hale, 2010). However, there is very limited research with referred and exceptional populations over time. Further, using only group means approaches often minimizes differences obscuring performance variability of individuals however well-defined the group vs. methodology. A repeat measures ANOVA helps to mitigate this issue by having the individual serve as his/her own control. Significant variation is then due to individual variation. There is also a need to look at referred populations who are being re-assessed due to continued difficulties, as this can often be an underserved segment of school children. By bringing attention to variability of information processing, this research hopes to bring attention to the variability and vulnerability of information processing in children. This can better inform the assessment and intervention process during an important developmental and learning period. It highlights cognitive processes involved in learning that need to be considered in the context of interventions within a critically important developmental time period for children. It is only through intra-individual performance that processing issues relevant to a child's learning and instructional issues can be found as they relate to services and interventions children may need. This is more in line with the IDEIA's 2004 definition of identifying a child's cognitive pattern of strengths and weaknesses. Lastly, this research considers what implications these processes have for these children in the regular classroom, how we assess children referred for difficulties in the classroom, what that means within the present atmosphere of empirically-based interventions.

1.7 Limitations of the Study

The mass of studies with the WISC-IV have examined present performance and short-term stability with normal controls and defined populations. However, there has been very limited longer-term research with the WISC-IV. Long-term stability of coefficients has been examined in only one study to date (Ryan, Glass, & Bartels, 2010). There is also very limited research with referred and exceptional populations over time. A repeat measures ANOVA is called for and provides further control by having the individual serve as his/her own control as well as makes possible examining a population at two time points thus examining variability of information processing. A repeat measures design can better inform the assessment and intervention process during an important developmental and learning period. Nonetheless, despite the advantage of repeat assessment in the present study, it is a single population, which is clinical. Thus, there is no control group. However, there is extensive literature on performance of working memory and processing speed with clinical groups as compared to normal controls as well as is present in the standardization of the WISC-IV which provides important information. The author also limits the second hypothesis to ADHD and SLD due to their prevalence in school-age children, although to include other disorders would have extended the usefulness of the research. The author recognizes that even within the disorders of ADHD and SLD that heterogeneity exists, which can also be a limiting factor. The age range is also limited to elementary-middle school students (6-14) vs. the entire range of the WISC-IV standardization to explicitly focus on a time period in which children are most often referred and re-evaluated. This study also utilized a population limited to a specific geographic region.

While the researcher acknowledges the influence of different evaluators, the scoring of Working Memory and Processing Speed involves no qualitative decision making on the part of the examiner. The measures of Working Memory and Processing Speed have standardized administrations with administration and scoring. Test items are either correct or not for the subtests of Working Memory, and the Processing Speed scores are determined by the number of correct items completed in a two minute time period. While inter-rater scoring variability might be considered a variable in performance, individuals who administer the WISC-IV are specifically trained in graduate programs that adhere to certain standards of performance in accordance with APA (American Psychological Association) standards in the administration of cognitive assessment instruments to children. Further, the use of different evaluators is common in the assessment of children, is present in the standardization of the WISC-IV, and is a factor in ecological validity. However, the author recognizes this issue as a possible issue in the current study.

Information was extracted from available records. As such, there are some limitations of extending the conclusions due to some information not being known such as medication at one administration vs. another and methods of identification amongst different practitioners. Where known, medication as a confounding variable was considered due to neurocognitive effects from medications. The author acknowledges that not all confounding variables can be accounted for. To focus on many of these as points of potential interest, however important, would divert focus from the point of this research: that there are many confounding variables that influence a child's cognitive performance at any point in time, which may necessitate repeating cognitive assessment. To attempt to control for additional variables would further detract from the ecological validity that the research is striving to address- the value of repeat assessment due to variability of information processing.

CHAPTER 2

LITERATURE REVIEW

Developmental, cognitive, educational, and neuropsychological research on intellectual development has coalesced in recent years. In particular, research on intelligence has shown that underlying cognitive processes are relevant to learning. The literature review discusses how the definition of intelligence as a construct has evolved from being initially a singular entity to a later focus on multiple processes. This trajectory culminated with the theoretical influence of the Cattell-Horn-Carroll (CHC) Three-Stratum Factor Analytic Theory of Cognitive Abilities by John Carroll (1993). Within this theoretical framework and due to the influence of developmental and neuropsychology, the prominence of working memory in the literature as well as discussion of the influence of processing speed on working memory and higher processes are highlighted.

The literature review secondly discusses what is known about how working memory and processing speed are related to learning and their importance overall to academic performance. Given their particular importance in children who have learning and other brain-based disorders (i.e., clinical populations), working memory and processing speed also are reviewed in relation to developmental disorders. Lastly, variability vs. stability of these processes is discussed with reference to developmental changes and cognitive performance and why it is important to track these cognitive processes within referred populations.

2.1 Theoretical Foundations

One of the earliest influence in examining 'what intelligence is' was made by Charles Spearman who characterized intelligence as a general overriding ability defined as *g* (Spearman, 1904). This perspective was the first to statistically analyze components of intelligence. The idea of a general overriding ability was later expanded to a two-factor theory by his student, Raymond Cattell. Cattell expanded this idea to be composed of general (*g)* and specific(*s)* factors. Cattell's *Fluid-Crystallized Theory of Intelligence* (G*f*-G*c*) (Cattell, 1963) suggested that cognitive abilities fall into two primary components-- fluid or crystallized. *Fluid intelligence* refers to mental operations typically used in novel tasks like problem solving, inductive, and deductive reasoning. Examples include solving a visual analogy or matrix, puzzles involving logic, and pattern construction. In contrast, *crystallized intelligence* was thought to be more dependent upon acquired skills and knowledge developed in response to cultural and educational experiences. Examples include general knowledge and vocabulary. Horn later expanded Cattell's theory (1968).

In the Cattell-Horn theory, nine factors compose intelligence within the fluid and crystallized core components that include memory and processing speed (Cattell, 1963). John Carroll later incorporated the Cattell-Horn theory into the Cattell-Horn-Carroll (CHC) *Three-Stratum Factor Analytic Theory of Cognitive Abilities*, which has become the most prominent contemporary example of factor analytic methodology in forming a model of cognitive abilities (Keith & Reynolds, 2010). Carroll's theory is a hierarchical model, composed of three levels of strata or abilities. At the lowest level are 69 narrow abilities such as sequential reasoning, reading comprehension, and memory span. This underlies the second level in which these 69 narrow abilities subsume into eight broad factors. These factors include *Fluid Intelligence*, *Crystallized Intelligence, General Memory and Learning, Broad Visual Perception, Broad Auditory Perception, Broad Retrieval Capacity,* and *Broad Cognitive Speediness*, *Processing Speed/Decision Speed*. A single factor defined as *g- General Intelligence* is at the third and uppermost level of these eight broad factors (McGrew & Woodcock, 2001).

Flanagan, McGrew, and Ortiz (2000) traced the history and influence of psychometric influences and the role that theory and especially the Cattell-Horn-Carroll CHC) theory has played. Specifically, they state that there have been four waves of psychometric interpretation. The first wave was characterized as a quantification of general level, which was influenced by Spearman's *g* and was used for the grouping of individuals for purposes of identification. The second wave, psychometric interpretation, focused on clinical profile analysis and was seen in the earliest version of the WISC-Bellevue (Wechsler Intelligence Scale for Children). This method focused on interpretation as a way to understand people beyond a global intellectual ability and included focusing on patterns of high and low performance or profile analysis, which was used diagnostically for prescriptive uses. Clinical profile analysis focused on interpretation of verbal-performance differences and the "shape" of the subtest profile, and interpreting subtest scores and item responses. In contrast, the third wave focused more specifically on psychometric profile analysis; interpretation that was based on factor analytic procedures and particularly Cohen's factor analytic procedures, which examined shared variance between subtests (empirically-based factors) and de-emphasized subtest interpretation. While the products of this phase were not supportive of profile analysis, the WISC and its multiple scaled score approach made it a popular and useful approach for identifying learning disabilities. The fourth and most current phase beginning in the 1990s is the integration of theory with research. This approach is more cross-battery focused to enhance interpretation by re-organizing subtests into theoretical clusters specified by a particular theory. The influence of this theoretical perspective for the present study suggests that theory-driven influences have become prevalent in test interpretation and development. The prominence of the WISC scales in each wave of this theoretical progression in test interpretation has entrenched its use in identifying issues relevant to learning. The literature is filled with extant research noting relationships between WISC constructs and learning (Dickerson & Calhoun, 2006; Engle, Tuholski, Laughlin, & Conway, 1999; Flanagan, McGrew, & Ortiz, 2000; Raiford, Weiss, Rolfhus, & Coalson, 2005; Shelton, Elliot, Matthews, Hill, & Gouvier, 2010; Wechsler, 2003; Weiss & Gabel, 2008).

Of importance to the current research is that Carroll's theory extended and expanded the construct of memory and processing speed. The importance of this theory takes into consideration that underlying processes contribute to higher abilities and overall expression of intelligence. Further, it is this highly general information-processing capacity that facilitates reasoning, problem solving, decision making, and other higher order thinking skills. While the WISC-IV was not built from intelligence theory, all four factors are seen in Carroll's encompassing theory of intelligence. Flanagan, McGrew, and Ortiz (2000) further illustrate the WISC's structure into constructs that correspond with aspects of his theory. Keith and Reynolds (2010) note the same distinctions- Working Memory as *Gsm* (short-term memory) and Processing Speed as *Gs* (processing speed). The prevalence and influence of Carroll's theory as well as the extensive use of the WISC-IV in the assessment of cognitive functioning provides a guiding basis for the present study.

2.2 The Wechsler Scales

While the Wechsler scales did not originate from the Cattell-Horn-Carroll (CHC) Striatum Theory, theoretical developments in the measurement of intelligence have increasingly aligned assessment measures with Carroll's theory. This is in addition to factor analytic techniques, which also have guided test construction (Keith & Reynolds, 2010). David Wechsler's early work with Army recruits and then at Bellevue Hospital with immigrants at the turn of the century provided the foundation through which his test development began. This early foundation in intelligence testing was meant to be practical rather than theoretical. For example, Digit Span, a subtest from the WISC-IV considered in the current research was used as early as the 1880s to measure capacity of information that could be held in short-term memory and then recalled (Boake, 2002). Coding, another subtest in the current research, was created around 1900 in an experiment involving college students to demonstrate learning new associations. An example of coding might be a paired association test in which an individual is asked to learn and replicate pairs of associations as quickly as possible. The rationale was to provide a measure of the rapidity with which associations could be learned. Performance suggested that those who are quicker learners in learning associations have a more rapid learning process (Boake, 2002).

Over time, the Wechsler scales continue to emphasize both verbal and visual, nonverbal abilities. This structure reflects the hierarchical influence from early intelligence thinking- Spearman and Cattell- as well as the multi-dimensional nature of intellectual functioning that is reflected today- CHC. The Wechsler Scale's latest revision, the WISC-IV (Wechsler, 2003) places more emphasis on fluid reasoning, working memory, and processing speed, which is based on research in cognition, information processing, and neuropsychology (Maller & Thompson, 2003). In keeping with this, the WISC-IV deviated from its previous revision where a Verbal IQ and a Performance IQ were prominent as composites and reorganized the scale into a four-factor model. These four factors include *Verbal Comprehension, Perceptual Reasoning, Working Memory*, and *Processing Speed*. Each of these four factors includes individual subtests that make up the four composites. In its most recent revision, the WISC-IV was reorganized into more homogeneous composites, which removed or moved subtests that did not load on factors utilized on previous revisions of the WISC. This assisted with making interpretations more construct validated (Flanagan, McGrew, & Ortiz, 2000). However, Carroll's analysis in 1993 of a general factor emerging from studies of intelligence necessitated retaining the Full Scale Intellectual Quotient (FSIQ) because of its wide use in research and assessment (Carroll, 1997; Weiss, Saklofske, Schwartz, Prifitera, &Courville, 2006).

Flanagan, McGrew, and Ortiz (2000) note that despite greater alignment of WISC constructs with CHC theory, the Wechsler scales only cover a small portion of the 10 empirically supported broad G*f*-G*c* (Fluid-Crystallized Theory of Intelligence) abilities. They state that the overall factorial structure of the WISC is limited in scope in comparison to G*f*- G*c* theory, although they acknowledge that its original intention was grounded in a practical and clinical vs. theoretical basis. Additionally, they note that while the WISC's atheoretical foundation placed constraints on the validity of inferences that can be drawn from it, each revision has yielded theoretical improvements in its restructuring. These improvements have resulted in more homogeneous factors providing better factorial structure support and the inferences that can be made from it. The authors state that this fourth wave of test interpretation and specifically the application of G*f*-G*c* theory to the WISC subscales allows for interpretation to be more theoretical. This conceptual framework yields greater internal and external validity of the scale as well as strength to the inferences that can be drawn from the WISC.

2.3 Factor Analysis and Processes Involved in Intelligence

Factorial analysis has driven test development for the most part, which has contributed to theoretical influences into understanding intelligence. Yet psychometric influences have also helped to shape the study of intelligence. Psychometrics includes the study and techniques used in measuring different psychological constructs in test development and factor analysis. This field of study has helped to develop constructs that inform construction of intellectual and cognitive functioning assessment as well as the development of theoretical models of intelligence. Psychometric influences have also contributed to the development of how these processes are defined. This has allowed those who evaluate children to be more attentive to individual differences in learning during the course of development.

Confirmatory factor analysis additionally has been used over the years to examine the construct validity of intelligence tests. These analyses have identified specific factors measured by a test. Psychometric research's use of factor analytic methods have identified as well as provided support of capabilities assessed by these tests. For example, factor analytic methods have identified abilities such as vocabulary knowledge, mathematical understanding, spatial reasoning, perceptual speed, working memory, and processing speed as factors related to intelligence (Calhoun & Mayes, 2005; Chen & Li, 2007; Hale, Fiorello, Kavanagh, Hoeppner, & Gaither, 2001; Johnson, Humphrey, Mellard, Woods, & Swanson, 2010; Pickering, 2004; Wechsler, 2003). Intelligence measures have been administered longitudinally to assess intellectual functioning across developmental and life-span trajectories to determine qualitative and quantitative differences observed over time. This has informed the field about how intelligence functions throughout the life span. Identification of changes in cognition and intellectual development during the life span and differences among how clinical groups perform is important. Factor analysis of constructs measured by intelligence tests has also been instrumental by uncovering underlying processes or mechanisms associated with different modalities (auditory, visual), content domains (figures, numbers, words), and tasks (reaction time, stimulus discrimination, inspection time) (Esters & Ittenback, 1999). What has emerged from this work is that working memory and processing speed are key components of intellectual functioning.

Moreover, the explosion of research on brain functioning (i.e., functional MRI, PET scans) has directed focus on working memory and processing speed. The Wechsler scales and the WISC-IV in particular note contributions from neuropsychology and factor analysis in their latest revision by including Working Memory and Processing Speed as specific composites in addition to the Verbal Comprehension and Perceptual Reasoning composites (Baron, 2005). The composites of Working Memory and Processing Speed are the focus of the current research (Wechsler, 2003).

2.4 Learning: Working Memory and Processing Speed

Working memory and processing speed are noted prominently in the literature as factors important to intellectual functioning and learning. Hebb (1949) first noted a distinction between short-term memory (STM) and long-term memory (LTM) with regards to temporary electrical activation in STM versus a long-term process of neuronal growth characterizing LTM. Memory is also cited as an important component in developmental theories such as Vygotsky and in instructional design models that take into account information processing, e.g., Gagné (Gredler, 2005). However, studies grounded in the information-processing approach suggested a different memory component that allows for rehearsal of information and assists with maintaining information in mind - in other words, working memory (Baddeley, 2003).

Baddeley (2003) defined working memory as a system for temporary storage used in the holding and mental manipulation of information for tasks such as comprehension, learning, and reasoning. It assumes a limited capacity system and provides an interface between perception, long-term memory, and action. While three primary components are identified within this model- *phonological loop*, *visuospatial sketchpad*, and the *central executive*- there continues to be work done in this area. Both the phonological loop and the visuospatial sketchpad are defined storage systems with limited span because of factors that occur in real time.

A number of studies have examined working memory. Pickering (2004) examined children referred for various learning, attentional, and behavioral problems. The study included 734 children aged 4 to 15 that were part of a standardization study on the Working Memory Test Battery for Children (WMTB-C). Eighty-three children had special needs and were divided into general learning, literacy, language, or behavioral groups. The WMTB-C was used to assess various components of working memory according to Baddeley's model- the central executive and three subsystems including the phonological loop, visuo-spatial sketchpad, and the episodic buffer. This research was important in that it helped further define different aspects of working memory. Children who had general learning difficulties performed more poorly across the central executive, phonological loop, and visuo-spatial sketchpad vs. children referred for language difficulties, who primarily had difficulties with the phonological loop. Their research supported the working memory literature indicating working memory deficits are typically found in children with learning difficulties although they state that these difficulties may vary depending upon the type of learning difficulty.

Pickering's research further demonstrated how aspects of working memory are important not only in storage capacity but also in processing information. For example, the phonological loop is important to learning the phonological structures of words, which is then important for acquiring vocabulary. Like-wise, the visuo-spatial sketchpad is important in math as it involves visual- spatial functions. Pickering's study highlights the different functions of working memory and their importance for storage capacity and allocation of resources used in processing information. It also highlights the influence of cognitive processing demands when learning demands increase in complexity, which can affect acquisition and capacities to store new information.

Lastly, Pickering's study demonstrated that children may have varied working memory difficulties depending upon the differing nature of their learning difficulties. This is consistent with the literature highlighting some of the differential issues with various learning disorders - i.e., phonological and language, visuo-spatial and math. However, it is understood that these relationships are not strict and exclusive to specific disorders alone and that any of these issues can cut across multiple disorders (Johnson, Humphrey, Mellard, Woods, & Swanson 2010; Swanson, 1996; Wechsler, 2003). Overall, research methods into the influence of working memory have demonstrated a number of studies showing a relationship between working memory and learning including reading comprehension and math.

Bayless, Jarrold, Gunn, Baddeley, and Leigh (2005) noted working memory made a significant contribution to reading, math, and fluid reasoning above age-related variance. These findings suggest, along with the literature that working memory is a predictor of a number of cognitive skills such as language comprehension, reading and math, attentional control, and general fluid intelligence. Working memory has also been shown to be an influence on reasoning and problem solving as a factor in more fluid aspects of intelligence (Bayliss, Jarrold, Gunn, Baddeley, & Leigh, 2005). The implication of this research is how working memory is important to both reading and math achievement (Maller & Thompson, 2003). A number of other studies also support working memory's strong relationship to fluid intelligence (Chen & Li, 2007; Conway, Cowan, Bunting, Therriault, & Minkoff, 2002; Engle, Tuholski, Laughlin, & Conway, 1999; Kane, Hambrick, & Conway, 2005; Kyllonen & Christal, 1990).

The field of experimental cognitive psychology has additionally emphasized an attentional control aspect of memory. The third major component of Baddeley's theory is the *central executive* component, which is responsible for providing attentional control. This component enables focus, designation of resources, and connection with long-term memory to bring information into working memory (Baddeley, 2003). The fourth factor - the *episodic buffer*- is a component assumed to be of limited capacity by itself but important for understanding the overall role of the central executive. The episodic buffer's function is to bind together information to form integrated episodes. The central executive controls the process through conscious awareness of attentional control. It influences the 'global workspace' allowing multiple systems to integrate assisting the binding of information as well as retrieval. On-going work regarding the influence of attentional control has further suggested that elements of emotional and motivational control may also play a role in working memory (Baddeley, 2003). Pascual-Leone (1987) and Hester and Garavan (2005) additionally suggest the role of inhibitory control as playing a developmental role in intelligence and that this function is something that increases in the development of intelligence.

Memory is also found to be related to higher level thinking. Shelton, Elliott, Matthews, Hill, and Gouvier (2010) note there is a relationship between working memory and short-term memory that influences fluid intelligence. They used various subtests from the Wechsler scales and complex span tasks to demonstrate an attentional executive control element that actively processes information. As noted previously, this component is an active aspect of working memory that searches secondary memory systems for needed information. Their findings suggest the function of working memory is important in higher order cognition. Higher order cognition involves cognitive variables such as problem solving and abstract reasoning as well as the ability to expand conceptual and declarative types of knowledge, which are aspects of intelligence that are often assessed through a variety of tasks and scales.

In relation to higher thinking, processing speed plays an important role in intellectual functioning. It is therefore important to evaluate when evaluating children with learning difficulties. Processing speed is a basic cognitive function implicated in and connected to intelligence particularly working memory and higher-order cognitive functioning. In this context, people with slower processing speed complete fewer mental tasks per unit of time (Tillman, Bohlin, Sorensen, & Lundervold, 2009). Hale (1990) and Kail (1993) have shown that performance on different processing speed tasks improve as one during childhood suggesting a global developmental trend. De Ribaupierre (2001) noted processing speed accounts for greater variation in the development of children's intelligence than what is seen in individual differences with adults.

Processing speed has also been implicated in correlations with academic measures as well as related to development of specific academic subjects and higher processes. Tillman, Bohlin, Sorensen, and Lundervold (2009) demonstrated the influence of processing speed, working memory, and inhibitory control on fluid intelligence. Hierarchical regression demonstrated that processing speed, working memory and inhibitory interference control contributed uniquely to the explanation of fluid intelligence performance in a sample involving 8 to 11 year olds. This research is consistent with the literature regarding processing speed in general as contributing to intellectual functioning and its relevance as a factor to be examined in the present research.

Lastly, the WISC-IV technical manual cites a number of such studies about how Working Memory and Processing Speed are important to a number of psychological processes related to learning. Swanson (1996) reported that Working Memory is an essential component of higher order cognitive processes and is closely related to achievement and learning. It has also been demonstrated to be related to both reading and math achievement (Maller and Thompson, 2003). Fry and Hale (2000), Mayes, Calhoun, and Crowell (1998), and Tillman, Bohlin, Sorensen, and Lundervold (2009) all provide support for there being a significant correlation between processing speed and general cognitive ability.

2.5 Development: Working Memory and Processing Speed

A number of researchers have reported that developmentally, age-related improvements in working memory mediate the development of intelligence during childhood (Bayless, Jarrold, Gunn, Baddeley, & Leigh, 2005; Case, Kurland, & Goldberg, 1982; de Ribaupierre & Lecerf, 2006; Fry & Hale, 1996). Studies have suggested an age-related factor between working memory, processing speed, and storage ability related to higher level cognition. Fry and Hale (1996) examined the relationship between processing speed, working memory, and fluid intelligence in children ages 7 to 19. Results of a path analysis demonstrated that processing speed and working memory mediated 45% of the age-related increases in fluid intelligence. Further, progression in the development of processing speed accounted for 71% of the improvement in working memory. Age also had a 77% effect on speed of processing.

Developmentally, processing speed plays a role in the development of intelligence in children and accounts for more variation than any other cognitive variable (Fry & Hale, 1996). Research by Fry and Hale suggests that variation in performance is most evident in age-related improvements in processing speed in connection to working memory capacity resulting in improved intellectual functioning. The authors also state that research generally shows that individuals typically perform similar across instruments and that processing speed is relatively independent of the task considered. As noted earlier, processing speed subsequently influences fluid reasoning impacting intelligence test performance.

2.6 Executive Functioning: Working Memory and Processing Speed

Working memory and processing speed are related to executive functioning. Executive functioning as a related issue has taken on a prominent role in recent years. This is particularly important to the current research as it includes ADHD students for whom executive functioning is a prominent difficulty. Garon, Bryson, and Smith (2008) reviewed the executive function literature and the development of executive functioning in children. However, children with specific learning disorders and other developmental disorders may also have executive functioning difficulties. This literature consists of two veins as separate issues - unitary with constituent sub-processes and dissociative (i.e., working memory and inhibition). These two veins have merged in recent years into a more integrative perspective. This integrative perspective also takes into consideration developmental research of children and the nature of development of these underlying constructs that promote executive functioning (Garon, Bryson, & Smith, 2008).

The first vein has highlighted the importance of attention and the central executive component of Baddeley's model. Working memory and inhibition have also been highlighted in research on developmental trajectories. Garon, Bryson, and Smith (2008) noted executive functioning, which includes aspects of working memory, processing speed, and interference control are thought to initially be independent in children but that these become increasingly integrated during childhood. This latter perspective provides further support for how developmental influences play a role in the development of cognitive functions and intellectual functioning. These cognitive functions, in turn, facilitate problem solving and reasoning, which are higher forms of intellectual processing.

Fry and Hale's review of research in 1996 and later in 2000 with focusing on working memory and processing speed in relation to executive functioning also highlights the importance of changes in and development of attention as a related cognitive variable. In addition to the development of attention, it highlights the importance of other underlying components like inhibitory control and processing speed. Garon, Bryson, and Smith (2008) further note that the slow maturation of the frontal cortex in which many executive functions are thought to reside is, in part, dependent upon the environment as an influence on its development and variability of performance.

The presence of these issues in clinical populations offers support for the monitoring of cognitive functioning in children. This is particularly relevant for those children with persistent learning and academic difficulties. Additionally brain-based difficulties and cognitive functions such as executive functioning in childhood developmental disorders may affect the expression of intelligence resulting in variability of performance, which has implications for tracking the stability of these functions across their development.

2.7 Clinical Populations and Information Processing

Regardless of controversies with research using profile analysis, there is still a long history of clinical groups demonstrating particular profiles. This suggests statistically significant characteristic profiles can differentiate clinical groups from each other. Much of this research has been with the Wechsler scales, which have demonstrated characteristic profiles with certain clinical populations (Wechsler, 2003). Fiorello, et al. (2007) asserts idiographic interpretation for children with disabilities so that their individual differences can be identified. This article presents the debate over value and validity of profile interpretation vs. the proven reliability and validity of global and composite scores despite their outdated use in discrepancy formulas. The authors contend that ignoring profile information negates individual cognitive indicators and differences in children's learning. Profile analysis is particularly relevant for clinical populations who demonstrate differences from normative populations even though normal variation is also typically seen in "normal" populations.

Fiorello, Hale, McGrath, Ryan, and Quinn (2002) further note that clinical populations such as specific learning disabled (SLD) and children with ADHD can display significant variability amongst their index scores. They suggest that as this varies, there is less shared variance among the different abilities although they also acknowledge this is characteristic of both clinical and typical populations. However, these researchers do not advocate that profile variability has diagnostic specificity for subsamples of children. Given Processing Speed's importance in cognitive performance and its implication as a variable in children with clinical disorders, it was denoted by its own index with the third edition of the Wechsler scales (WISC-III) and continues with the fourth revision.

In a meta-analysis of studies examining cognitive processing deficits and students with SLD (Johnson, Humphrey, Mellard, Woods, & Swanson, 2010), the authors found moderate to large effect sizes in cognitive processing differences between groups of students with SLD and typically achieving students. Students with reading disorders had the largest deficits in phonological processing, followed by processing speed, and verbal working memory. Receptive and expressive language also produced large effect sizes. With math disabilities, moderate effect sizes were seen in working memory to large effect sizes in executive function, which are behaviors like working memory, flexibility of thinking, problem solving, and impulse control. Differences of high magnitude were seen across many cognitive areas including working memory, processing speed, and executive functions.

Overall, clinical populations typically have issues in cognitive functioning that affect learning. This often involves working memory, processing speed, executive functioning amongst other processes. This brings to the forefront the importance of focusing on intra-individual issues vs. global functioning in such students. This perspective contributes to gathering better information about their specific educational needs and instructional intervention. Developmental, educational, and neuropsychological findings further support examining trends and variability in information processing since information processing changes over the course of development and because of different influences on them at any particular time. This supports the current research of examining working memory and processing speed in individuals with specific learning, attentional, and other cognitive disorders to further understand their variability in referred populations. Changes in development and issues relevant to learning processes also highlight the need for examining these processes over time in referred populations. However, it is recognized that non-intellectual factors such as motivation, depression, fatigue, etc. can also play a role in demonstrated intelligence on any given administration, which may affect performance introducing variability (Allen, Thaler, Donohue, & Mayfield, 2010).

2.8 Clinical Populations of Focus for the Present Study

Assessing cognitive processes over time is relevant, particularly in light of changes within the field of education, special education, and school psychology. Children identified as having ADHD can number 3 to 7 percent (ADHD) (American Psychiatric Association, 2000) and specific learning disorders number approximately 7.66 percent in the population (http://www.cdc.gov). However, referred populations in general show greater numbers. Given the prevalence of these disorders in children, examining their role in variability of cognitive functioning and processing is particularly important. (Hale, Fiorello, Kavanagh, Holdnack, & Aloe, 2007). The following is a review of the disorders considered for the second hypothesis in the current study.

2.9 Attention Deficit/Hyperactivity Disorder (ADHD)

Barkley has stated that ADHD is characterized as having underlying executive dysfunction (Barkley, 2006). Hale, Fiorello, and Brown (2005) also support this in addition to general problems with attention, inhibition, and activity level. Primary symptoms of ADHD include inattention, impulsivity (behavioral disinhibition), and hyperactivity. However, these symptoms may vary according to age and sub-type. The DSM-IV-TR (American Psychiatric Association, 2000) states that an individual must display six or more inattention symptoms for at least six months and that these symptoms impair daily functioning as well as is inappropriate to the developmental level. These symptoms include:

1. Often failing to give close attention to details or makes careless mistakes in schoolwork, work, or other activities,

2. Often has difficulty sustaining attention in tasks or play activities,

3. Often does not seem to listen when spoken to directly,

4. Often does not follow through on instructions and fails to finish schoolwork, chores, or duties in the workplace (not due to oppositional behavior or failure understand instructions),

5. Often has difficulty organizing tasks and activities,

6. Often avoids, dislikes, or is reluctant to engage in tasks that require sustained mental effort (such as schoolwork or homework),

7. Often loses things necessary for tasks or activities (e.g., toys, school assignments, pencils, books, or tools,

8. Often easily distracted by extraneous stimuli,

9. Often forget forgetful in daily activities,

Six or more of the following are required for the hyperactive-impulsive type, which also must have been present for at least six months that it significantly affects daily functioning, and is also inconsistent with developmental level.

1. Often fidgets with hands or feet or squirms in seat,
2. Often leaves seat in classroom or in other situations in which remaining seated is expected,
3. Often runs about or climbs excessively in situations in which it is inappropriate (in adolescents or adults, may be limited to subjective feelings of restlessness),
4. Often has difficulty playing or engaging in leisure activities quietly,
5. Often “on the go” or often acts as if “driven by a motor”,

6. Often talks excessively,

Impulsivity

7. Often blurts out answers before questions have been completed,
8. Often has difficulty awaiting turn,
9. Often interrupts or intrudes on others (i.e., butts into conversations or games).

Additionally, DSM-IV-TR diagnosis requires that some of the hyperactive-impulsive or inattentive symptoms have been present before age 7 years of age, that some impairment of symptoms is present in two or more settings (e.g., at school [or work] and at home), and that there must be clear evidence of clinically significant impairment in social, academic, or occupational functioning. It is further expected that these symptoms do not occur exclusively during the course of Pervasive Developmental Disorder, Schizophrenia, or other Psychotic Disorder, and are not better accounted for by another mental disorder such as a mood or anxiety disorder (American Psychiatric Association, 2000, p. 92-93). Lastly, it is important to rule out other factors that may account for the symptoms. Reviewing the characteristics of this disorder is important since this group serves as a subgroup for the current study.

2.10 Specific Learning Disorders

As noted earlier, a specific learning disorder is defined as, "a disorder in one or more of the basic psychological processes involved in understanding or in using language, spoken or written, that may manifest itself in an imperfect ability to listen, think, speak, read, write, spell, or to do mathematical calculations, including conditions such as perceptual disabilities, brain injury, minimal brain dysfunction, dyslexia, and developmental aphasia" (http://www.ncld .org/ld). Further, the DSM-IV-TR notes that it is diagnosed, "when an individual's achievement on an individually administered, standardized test in reading, mathematics, or written expression is *substantially* below that expected for age, schooling, and level of intelligence" (American Psychiatric Association, 2000). The DSM-IV-TR notes that while this is usually defined as two standard deviations between achievement and IQ, a smaller discrepancy can be used. This method is the standard method used in the ability-achievement model although discrepancy amount varies from state to state and among educational agencies. The DSM-IV-TR states that this discrepancy can be smaller when an individual's performance on an IQ test is compromised by a cognitive processing disorder, mental, or medical disorder. In North Carolina where this study takes place, the discrepancy has been defined as 15 points. However, qualification can still be determined even when the amount of discrepancy is less than 15 point when there is other supporting evidence (NCDPI, 2010).

2.11 Research with these populations on the Wechsler Scales

Several studies by Mayes and Calhoun examining disorders such as ADHD, SLD, and other clinical disorders have found support for distinctive profiles with these disorders. In 2004, Mayes and Calhoun examined similarities and differences between WISC-III and WISC-IV profiles for students with ADHD. They found distinctive profiles not only characteristic of disorders like ADHD but also of other disorders, such as autism, brain injury, and learning disability. In particular, they noted that attention, writing, and performance speed deficits were characteristic of ADHD and learning disabilities. Both the ADHD and learning disabled groups demonstrated low Freedom From Distractibility (FFD) and Processing Speed Indexes with the Coding subtest of this last index being the lowest on the WISC-III. Calhoun and Mayes (2005) again examined profile similarities and differences on the WISC-IV amongst various clinical disorders. Here, sixty-seven percent of the learning disabled students performed more poorly on Working Memory tasks. In contrast, clinical groups including anxiety, Oppositional Defiant Disorder, and mental retardation did not have Processing Speed Index weaknesses with the exception of depression. The implications of this research were that clinical groups tend to have various underlying neurological factors that impact information processing variables including Processing Speed that may influence variability/stability of performance. In addition to Processing Speed as a common occurrence in clinical populations generally, it is commonly viewed as a rate-limiting factor on tests of memory and learning.

Mayes and Calhoun (2006) later compared profiles of children with ADHD and normal intelligence using both the WISC-III and WISC-IV. Mean scores for the Verbal Comprehension Index (VCI) and the Perceptual Reasoning Index (PRI) were higher than the Freedom From Distractibility Index (FFD) (WISC-III)/Working Memory Index (WMI) and Processing Speed Index (PSI) (WISC-IV) for students with ADHD. Index differences were higher for the VCI and PRI on the WISC-IV than the WISC-III. The findings from these three studies suggest that WISC scales play a relevant role in distinguishing clinical groups. They also established the importance of examining information processes like Processing Speed and Working Memory in clinical populations but particularly how much they are changeable or stable over time. The authors suggest that the most recent version of the WISC-IV may be better at distinguishing ADHD than its predecessor. These findings have been found to be consistent with other early findings with the WISC-IV regarding these populations. However, it should be noted that comparisons were using WISC-III and WISC-IV and subsequently based on different groups of children and the authors acknowledge findings could be attributed to differences between groups.

A number of special group studies were also conducted during the standardization of the WISC-IV with clinical populations and during the elementary and middle school ages relevant to the current study. In special group studies conducted with the WISC-IV, children ages 7 to 13 with a reading disability performed significantly lower on all four composites. Math disorders performed significantly lower on Perceptual Reasoning than matched controls as well. Students with reading, written expression, and math disorders also displayed significantly lower scores on Verbal Comprehension, Working Memory, Processing Speed, and Full Scale IQ as compared to controls. Students who had both ADHD and learning disabilities performed significantly lower on all four composites by an average of 12 points Students who only had ADHD performed significantly lower on Working Memory, Processing Speed, and the Full Scale IQ with an average of 7.3 points on Processing Speed alone (Wechsler, 2003). A limitation of these special group studies is that they consisted of small samples and did not encompass all of the WISC-IV standardization range recruited at different sites.

Additionally, the WISC-IV has been investigated using cluster analytic methodology with children who were referred for psychoeducational evaluation and specifically students who present with persistent academic difficulties using cluster analytic methodology (Hale, 2010). Research was aimed at identifying subtest patterns that were consistent with previously identified taxonomies. A two-stage analysis identified three cluster patterns with the 10 subtests- low scores on all the subtests, low scores on the Verbal Comprehension Index (VCI), and low scores on the Working Memory and Processing Speed indexes. These patterns were found to be reliable, stable, and replicated across various samples. However, clusters previously associated with low performance on Verbal and Performance IQ's (WISC-III) did not emerge. Findings were consistent with previous WISC taxonomic analyses.

Lastly, configural frequency analysis has been used to examine if profile patterns would be evident with the WISC-IV (Wattkinen, 2008). Using mean composite scores, children with learning disabilities in reading demonstrated lower performance on the Working Memory Index in contrast to the other three indexes- all of which fell within the average range. Children with ADHD performed lower on the Processing Speed Index. While Working Memory was also depressed, it was not significantly different in relation to the mean of the other three composites. There were no types or antitypes for ADHD students as compared to the WISC-IV standardization sample.

Given the importance of considering the influence of ADHD subtypes, one study has examined this factor on Working Memory and Processing Speed. Zieman (2010) examined differences in subtypes of ADHD (Zieman, 2010). Working Memory and Processing Speed were examined in a 3 X 4 ANOVA repeated measures design using the WISC-IV. This study is similar to the present one in that it used archival data from a clinical site. The sample was divided into ADHD subtypes- ADHD Inattentive type, ADHD Hyperactive- Impulsive type, and ADHD Combined type. No significant differences between groups or interaction effects for ADHD subtype were evidenced on Working Memory or Processing Speed. Means for all three subgroups groups on

Processing Speed as a whole were reduced in comparison to the other indexes. There was a significant main effect for Index scores with Processing Speed deficits noted for all three subtypes. There were minimal differences evidenced between groups with Working Memory. The authors concluded that Processing Speed as a whole appears to be sensitive to ADHD. Regardless of subtype, results supported Processing Speed is an issue for this population amongst other disabilities.

While the previous studies have examined differences in WISC performance between clinical groups, co-morbidity must also be considered. Willcutt, Pennington, Olson, Chhabildas, and Hulslander (2005) note co-morbidity between ADHD and other learning disabilities can occur as much as 25 to 40 percent of the time. This can confound seeing differences in performance as well as compound students' issues. In assessing differences and similarities between ADHD, reading disorder only, and ADHD plus reading disorder students, the authors found evidence that all three groups demonstrated weaknesses in Processing Speed. However, the ADHD group also demonstrated weaknesses in response-inhibition. Wechsler (2003) also demonstrated ADHD Inattentive type and children with reading disabilities demonstrate reduced Processing Speed on the WISC-IV.

For ADHD, greater within-subject variability or inconsistency in reaction time is also the most consistent finding for ADHD (Bidwell, Willcutt, DeFries, & Pennington, 2007; Castellanos, Sonuga-Barke, Scheres, Hyde, & Walters, 2005; Lijffijt, Kenemans, Verbaten, & van Engeland, 2005). Van De Voorde, Roeyers, Verte', and Wiersema (2010) have also compared children with ADHD, reading disorder (RD), and controls on linguistic (phonological and rapid naming tasks) and executive function measures (go/no go, n-back tasks) using analysis of variance. Children with ADHD were found to be more variable in response time as compared with children who did not have ADHD although children with a RD presented a variable response style as demonstrated by a higher within-subject standard deviation of reaction time. In discussing some possible differences between groups, the authors note that impairments in executive functioning can occur from lower level cognitive processes rather than high order cognitive operations and that considering such differences needs to take into account the multifaceted and complex nature of reaction time.

Finally, Fiorello, et al. (2007) further have examined unique and shared variance with clinical populations on the WISC-IV. They examined the intellectual profiles of students with learning disabilities, ADHD, and TBI. The sample was taken from the normative standardization sample of the WISC-IV. Using regression commonality analysis to examine the unique and shared variance, they found these groups displayed substantial multi-factorial intellectual functioning amongst Index scores on the WISC-IV. No one area for all four factors exceeded 2% of the Full Scale IQ variance. These results suggested the Full Scale IQ score to be not meaningful for the learning disabled group although rather unique contributions of scores in predicting FSIQ were considerable. With the ADHD group, the index factors accounted for 50% of the variance with unique contributions of Verbal Comprehension and Perceptual Reasoning accounting for one-third of the FSIQ variance. These findings suggested support for using the Index scores as interpreters particularly for certain groups- i.e., specific learning disabled. Additionally, the Cognitive Proficiency Index (CPI), which includes the Processing Speed and Working Memory subtests, was additionally significant for the ADHD group lending support for the link between fluid reasoning and executive functioning. While profile interpretation has been of questionable practice, the aforementioned researchers note these findings are consistent with what is known about these clinical populations. However, they also note that interpretation of Index scores is more robust for learning disabled and ADHD groups than other groups. These studies suggest that these indexes play an important role in information processing with developmental disorders and learning disabled and ADHD in particular.

In contrast to previous findings, Maury-Darensbourg (2011) has examined intellectual, academic, and psychosocial functioning in children that were diagnosed with a learning disorder and/or ADHD. However, her research did not support differential profiles on Working Memory and Processing Speed Indexes with the WISC-IV. While many studies note distinctive profiles and specific findings with clinical groups, this research suggests this is not always the case.

2.12 Stability/Variability of Working Memory and Processing Speed with the WISC-IV

Studies examining stability vs. variability of Working Memory and Processing Speed have been limited with children other than what is known about developmental trajectories and performances of students in one time assessments with these factors. In standardization studies, short-term stability (32 days) of the WISC-IV with Working Memory and Processing Speed produced high correlations (.89 and .86 respectively) (Wechsler, 2003). However, the research literature is limited with regards to long-term stability of Working Memory and Processing Speed within the context of the Wechsler scales. Canivez and Watkins (1999) concluded that the Full Scale IQ is the only score that remains stable across longer time intervals for interpretation with individuals. In this study with the WISC-III, 522 students composed of students with learning disabilities, serious emotional disorders, and mental retardation were assessed twice in a mean test-retest interval of 2.87 years. Pearson product-moment correlation coefficients were calculated for the FSIQ, VIQ-PIQ discrepancy, Indexes, and subtest scores. As for long-term stability coefficients, there were no differential effects amongst disability groups. Only the FSIQ produced an acceptable stability coefficient for all three groups. Further, composite score stability coefficients demonstrated greater variability. Their review also noted that in some studies, stability coefficients of composite scores actually declined with retest intervals of approximately three years. Freedom from Distractibility (FFD), Processing Speed, and VIQ-PIQ discrepancy stability scores were also inadequate. For specific learning disabled students specifically, all long-term stability coefficients for each of these scores were significantly different from zero. These long-term stability coefficients were significantly lower than short-term stability coefficients for the VIQ, FSIQ, VCI, FDI, and PSI as compared to short-term stability coefficients noted in the WISC-III manual. Those test-retest intervals in the standardization sample ranged from 13 to 63 days (Wechsler, 2003). The authors state that, “changes in IQ that results from test instability may differentially affect individuals with different disabilities” (Canivez & Watkins, 2001, p. 440). Results were additionally later supported by Watkins and Canivez (2004) demonstrating that subtest profiles were unstable. Further, their previous study (Canivez & Watkins, 1999) found few differential effects of WISC-III stability on the basis of gender, race/ethnicity, and age.

Lastly, Ryan, Glass, and Bartels (2010) examined the test-retest stability of the WISC-IV in 43 elementary/middle school students on two occasions that were 11 months apart. Pearson product-moment correlations were calculated for the WISC-IV FSIQ, Indexes, and subtests. Stability coefficients were corrected for restriction of range based on the variability of the initial testing. Dependent sample t-tests were calculated for subtest and composite scores. Verbal Comprehension, Working Memory, and the FSIQ demonstrated high levels of test-retest stability (0.755, 0.750, and 0.882 respectively). Perceptual Reasoning was 0.681 and Processing Speed 0.544. Dependent samples *t*-tests failed to detect significant differences between scores from test to retest for the WISC-IV variables. Only VC and FSIQ demonstrated high levels of test-retest stability. Further, the magnitude and direction of change (gains and losses) in indexes and with the FSIQ was not associated with age or years of schooling at initial testing. Findings additionally suggested that a student's physical/cognitive maturity level and learning history had no effect on the influence of incidental learning with the WISC-IV initial testing. The range of change for some individuals with the FSIQ was 26% with greater than five points and 16.3% demonstrated decreases of greater than five points. The limitation of this study was that none of the students were officially designated as learning disabled or challenged academically. Students were also from one small private school and participation was part of a voluntary assessment program provided by a local university.

These studies suggest that determining whether cognitive performance is stable or not for individual decision making is important. Further, testing that is typically done at three-year intervals with students who have learning and/or behavioral difficulties may not be sound if disabilities affect stability of information processing and subsequently cognitive functioning. These findings suggest that despite factorial differences between the WISC-IV and its predecessors, certain findings with populations of learning disabled and ADHD students regarding Working Memory and Processing Speed issues are demonstrated to be stable factors with these populations. However these factors may not demonstrate stability with longer time intervals even 11 months later despite a stable FSIQ and support the current research hypothesis that within variability may be evidenced across time.

2.13 Summary of Working Memory and Processing Speed Findings

The literature is abundant with findings demonstrating that working memory and processing speed are important aspects of intelligence and that these processes are important in learning. In particular, the research literature notes particular influences with reading, math, and general comprehension. Studies have been cited as being related to specific higher processes such as fluid reasoning and problem solving. Children in exceptional populations, such as children with learning and attentional problems in particular, have difficulties in these areas although these populations may also perform differently because of the heterogeneous nature of learning and ADHD disorders.

Regarding variability of performance, the research literature also notes that ADHD students can be more variable in their performance overall but that within-subject variability may also be seen in students with learning disorders and reading disorders specifically due to individual issues. Further, co-morbidity can demonstrate additional information processing difficulties. Research in developmental literature would suggest that because of maturation, particularly brain development, these processes improve with as a child increases in age. Studies have also demonstrated that there are age-related differences with children. Developmental increases are seen in cognitive functions-- older children can hold more information in mind as compared to younger children as relates to working memory. In addition, developmental changes influence the speed of information processing with increased speed as a child ages. The research literature has also suggested that these abilities have a relationship and that they often improve in concert with each other. However, most of these studies have been limited to using measures other than the WISC to examine the constructs of working memory and/processing speed- e.g., choice reaction time and computerized tasks.

Nonetheless, the research literature is replete with studies examining variability of working memory and processing speed components in the same children across time with the WISC-IV. Typically, research has been used to predict how Working Memory and Processing Speed influence learning and certain academic subjects. It is important to examine referred populations in subsequent assessments given their persistent issues difficulties. Not only does this further provide information on the stability or variability of these functions, it provides information about performance with these populations over time. What is not known is comparable performance of these processes in same individuals across longer time intervals more typically seen in typical reevaluation periods using the same Wechsler scale. This adds information regarding their stability vs. variability, which additionally speaks to their influence in educational decision making. To date, there is only one study that examined longer-term stability of these processes as measured by the WISC constructs and that study supported these processes are not as stable as short-term stability coefficients which are often cited in standardization studies.

This is an area where the present study can contribute regarding performance in Working Memory and Processing Speed over time with referred populations.

2.14 Conclusions

The understanding of cognitive and intellectual functioning has evolved from simple psychometric tests to theories of intelligence. Research in this area has come to acknowledge its multi-factorial nature and the practical value of this perspective. Additionally, our understanding of the progression of intelligence has been greatly influenced by (1) developmental psychology; (2) imaging technology since the 1990's; and (3) neuropsychology's advancements also during this time period. All these influences have helped educators and evaluators understand the contextual aspects of intellectual functioning. These advances have assisted with understanding the development of underlying cognitive processes of children and influenced uses of these tests for decision making in education in addition to test development. In particular, the literature review highlights working memory and processing speed as relates to development, learning, and clinical disorders. These issues implicate specific processes that are not only relevant to learning but transcend specific academic subjects.

Theoretical advances in information processing particularly in light of CHC theory have additionally given specific focus on cognitive processes such as working memory and processing speed. Research suggests these processes are expected to change over time and improve although stability and variability is questioned due to persistent difficulties. In addition, innumerable variables that may exist influence processing of information. The importance of tracking cognitive functions highly related to learning is the focus of this research in working memory and processing speed. For these populations, it is essential to understand variability over time as they may present with on-going issues without being identified early on as qualifying for a program. The research review has cited only a couple of studies that have investigated longer-term WISC-IV performance in students who have persistent academic difficulties. What is unknown is how individuals with persistent school difficulties perform from one administration to the next on the factors of Working Memory and Processing Speed with the WISC-IV across typical reevaluation time points. Examining this pattern of performance is the next logical step in analysis of cognitive patterns with information processing with referred populations.

CHAPTER THREE

METHODOLOGY

The theoretical foundation and related issues pertaining to the current study were presented in the literature review. This section presents the purpose of the study, research hypotheses, design, measures, procedures, sample, and analyses for the study.

3.1 Purpose and Research Hypotheses

The purpose of the current study is to examine variability of information processing as operationally defined by the two Indexes that comprise the Cognitive Proficiency Index (CPI) of the WISC-IV scale, Working Memory and Processing Speed. The study determines if a significant discrepancy exists between administrations in referred populations. The second research question asks whether this discrepancy will be greater in populations of primarily ADHD vs. primarily SLD students. It is important to understand variability in these populations, as it occurs in intellectual/cognitive performance in assessment situations and within the regular classroom. Given these questions, the following hypotheses are restated:

H1: Referred populations will demonstrate a significant difference in Working Memory and Processing Speed from one administration to the next administration of the WISC-IV.

H2: Students with ADHD as the primary diagnosis will differ more significantly from one administration to the next administration than students with Specific Learning

Disabled as the primary classification in administration to administration of the WISC-IV.

Hypotheses are based upon research with these populations especially as to whether variability/inconsistency of performance often observed with ADHD students will be a differential factor. However, while there can be co-morbidity among developmental disorders and influence on multiple areas of functioning, ADHD and SLD can also stand alone. Additional analyses examined medication status as confounds as well as comorbidity and gender.

3.2 Participants

Sample size included 75 students selected from archival data from a clinical private practice that serves Western North Carolina. Students were referred across the western half of the state but primarily from local pediatric offices in several counties. Children were referred for psychoeducational evaluation due to attentional, learning, and/or behavioral-emotional issues. Parents gave permission for their child to be evaluated.

The initial group for hypothesis one consisted of all 75 students. The participants ranged in age from 6 to 14 years in order to keep the analyses relevant for the elementary to middle school student range. Students were referred for psychoeducational evaluation. Students were selected primarily on the basis of having two standard administrations of the WISC-IV. Full Scale IQ scores were kept between 75 and 120 to avoid the influence of extreme scores. Profile variability was not a variable for inclusion. Repeat administrations of the WISC-IV ranged from one to four years apart, with an average of two and a half to three years. The sample included a variety of diagnoses, students with and without medications, as well as students who had no school services to those who already had individual educational plans in the school setting. Diagnoses for students considered in the primary category of ADHD were diagnosed by a pediatrician or other licensed clinician prior to presenting in the current practice. A psychologist then confirmed the diagnosis although some were diagnosed in the second testing by a psychologist due to continued difficulties. Students meeting the criteria for SLD either came in with this diagnosis or were diagnosed at the second testing due to continued difficulties.

Hypothesis two specifically examined a subgroup composed of two groups– those with learning difficulties (SLD) vs. those who were diagnosed with ADHD. While the WISC-IV age ranges from 6 to 16 were referred, the study focuses on the developmental period of early to middle childhood when cognitive processes and skills are rapidly developing (6-14). Full Scale IQ scores were kept between 75 and 120 to avoid the influence of extreme scores. Profile variability was not a requirement for inclusion in the study. Repeat administrations ranged from one to four years with an average of two and a half to three years, which is the standard re-evaluation time most often seen in reevaluation of students within school settings. Demographic information for the complete sample for hypothesis one is presented in Table 3.1. It provides a breakdown of gender, ethnicity (when known), and clinical and learning disorders of the group. In most categories, services were increased at the second evaluation. The comorbid group contained a mix of disorders none of which were the same exact combination. Disorders generally fell into the following categories: developmental (i.e., autistic spectrum), conduct and oppositional defiant disorders, anxiety, mood, and medical (i.e., epilepsy).

Table 3.1

Demographic Statistics on Sample	*n*	%
Gender		
Male	50	67
Female	25	33
Race/Ethnicity		
Caucasian	52	69
African American	12	16
Hispanic/Latino	3	4
Missing	8	11
Single Disorder	50	67
ADHD	25	33
Learning Disabled	23	31
Reading	14	19
Written Language	8	11
Math	1	1
More than one area	6	8
Speech-language	4	4
Single Other	2	3
Seizure Dis.	1	.01
Bipolar Dis.	1	.01
Co-morbid Disorders	25	33
ADHD and LD	6	8
Co-morbid- Other	19	25

n= 75

Table 3.2 provides a breakdown of the student's educational status.

Table 3.2

Educational Status

Service/Placement	First Evaluation	Second Evaluation	Both
Special Education	0	39	7
Day Treatment/Residential	0	3	0
Section 504 Plan	0	8	0
Neurofeedback/Counseling	0	8	0
Other Health Impaired	0	10	0

n = 75
Note. Educational status was not always known about the first evaluation time period. Numbers may also reflect some overlap of services.

Of the 75 students referred, none were in a special education program for only the first evaluation. Twenty-five students were not involved in any special education or receiving any type of service at either administration. Two students attended private schools and two were home schooled. A total of 33 students across categories were receiving help in reading by the second administration. Ten students were identified as "Other Health Impaired" at the time of the second administration and were composed of students with ADHD or a health impairment like epilepsy. Of the 39 students receiving special education at the second administration, fourteen students were receiving special education services but type was not known.

Table 3.3 notes students' ages at their first and second evaluation. Age at time of evaluation for first and second administrations showed that students were most often evaluated during their elementary school years for the first evaluation and reevaluated before leaving the elementary school setting. Average age time frame between administrations was 2.5 years although ranged from one to four years.

Table 3.3

Age at Evaluation

Age	*Initial Evaluation*	*Second Evaluation*
6	18	0
7	20	6
8	15	8
9	9	10
10	6	16
11	4	12
12	2	11
13	1	5
14	0	7

n = 75 students for each administration
Note: Reevaluation age reflects increase in age of students

Average age at first evaluation was 7.87 years and at the second evaluation 10.44 years. For the subgroups examined for this study, 7.36 was the average age at first evaluation for ADHD children and 7.87 for SLD children. At second evaluation, the average age of ADHD students was 9.76 years vs. 10.70 years for SLD students. Average age of student in the subgroups was similar to the whole sample. The reevaluation period for twelve students was one year, for 31 students it was two years, for 19 students it was three years, and for 13 students it was four years. Average time between evaluations was 2.5 years with a total of 50 students (67%) that were evaluated within the two –three year time frame. Sixty-eight of the 75 were evaluated the first time during their elementary school years with 69% of these being reevaluated before leaving elementary school.

Table 3.4 provides information about whether a student was on medication at the time of evaluation since the influence of medication was considered as an additional analysis. Medication status from the initial evaluation was not known on 19 of the students. Eleven students (15%) were on some type of medication for the first evaluation vs. 37 students (49%) for the second evaluation. Of the students on medication at the second evaluation, the numbers below indicate students were either on different medications than their initial evaluation or were on two or more medications at the second evaluation. Of the 37 students who were on one or more medications at the second evaluation, 10 had been on some type of medication the first evaluation but were on something different or were on more medication for the second evaluation. Only two known students were on the same medication for their first and second evaluations. Twenty-four students (32%) were on more than one medication at second evaluation. Only one student was on more than one medication for the first evaluation. Of the totals of children on medication, 17 students 23% were identified as ADHD vs. 11 students 15% other comorbid disorders.

Table 3.4

Medication Status at evaluation

Medication Status	*First Evaluation*	*Second Evaluation*
Medication	11	37
No medication	45	36
Status Unknown	19	2
Medication- neither time point	31	
Same medication on both	2	

n= 75

3.3 Design

A repeat measure ANOVA with time as the within factor was conducted to test the first hypothesis examining two time points of administration with Working Memory and Processing Speed from the WISC-IV in separate models. Time was defined as the interval between administrations and was an average of 2.5 years. The second hypothesis utilized a mixed repeat measurement ANOVA design to examine performance at two time points of administration with time as the independent subject variable and Working Memory and Processing Speed as the dependent variables in separate models. Group was the between subjects factor and time the within subjects factor. Group one was ADHD and group two those with primary SLD. A repeated measures ANOVA design was selected as these designs are good for special populations when there are smaller numbers. It also allows each individual to serve as their own control, which controls for individual variability as an influence.

The current study contributes to research on changes with these populations during a prominent developmental brain growth period. It is hypothesized that despite increased stability of IQ as a child ages, variability of performance may be seen because of any number of confounding influences even though the overall IQ may be similar across time The research design assists with answering the question of whether significant differences in working memory and processing speed between evaluations are exhibited in referred populations. It secondly examined if there were greater differences between subsequent evaluations of working memory and processing speed in populations with ADHD vs. SLD.

3.4 Measures

3.5 WISC-IV Working Memory

Working Memory is measured auditorally through digit span capacity and working memory tasks of reversing sequence and mental regrouping in a task requiring a student to repeat letters and numbers in a sequence different from how it was presented. Working Memory is comprised of two tasks, Digit Span and Letter-Number Sequencing. Digit Span is broken into two tasks- Digit Span Forward and Digit Span Backwards. The first task requires the participant to repeat increasing strings of digits in the same order. Digit Span Backwards requires the individual to repeat the numbers in the reverse order from what was presented. Digit Span Forward is a measure of rote learning and memory, attention, encoding, and auditory processing (Sattler, 2001). Digit Span Backwards involves working memory, manipulation and transforming of information as well as visual-spatial imagery. Additionally, Digit Span Forward to Digit Span Backwards involves the ability to shift, cognitive flexibility, and mental alertness. In the second subtest, Letter-Number Sequencing, the person is read a number of letters and single digit numbers and asked to reorder them into a specified order of ascending numbers followed by the letters in alphabetical order. Standardized instructions for Digit Span and Letter-

Number Sequencing includes a prescribed manner for delivery in that items are presented one digit/one letter per second (Wechsler, 2003).

3.6 WISC-IV Processing Speed

Processing Speed is defined as a measure of visual scanning, sequence, and discrimination of visual information. It involves short-term visual memory, attention, and visual-motor coordination (Wechsler, 2003, p. 17). It is further reported to be related to mental capacity and the efficient use of working memory, which allows conservation of cognitive resources for higher fluid reasoning types of tasks such as abstract thought (Wechsler, 2003). Research has supported that it is dynamically related to development and intricately connected to the efficiency of the central nervous system, which is sensitive to brain-based disorders such as learning disabilities, ADHD, seizures, brain injuries, etc.

The Processing Speed Index is similarly composed of two tasks, Coding and Symbol Search, both of which involve being timed, as well as visual discrimination of symbols (Sattler, 2001). Coding requires the individual to copy symbols paired with geometric shapes or number type figures using a key. This task requires processing speed, short-term memory, learning ability, visual perception, visual-motor coordination, visual scanning ability, cognitive flexibility, attention, and motivation. Symbol Search requires the individual to scan a group of symbols for a target symbol from a group of two. It involves visual short-term memory, visual-motor coordination, cognitive flexibility, visual discrimination, and concentration. Instructions for Coding and Symbol Search state they are to be completed as quickly as possible. Subjects are timed for two minutes for the tasks' completion (Wechsler, 2003).

3.7 Standardization

In the most recent standardization of the WISC-IV (2003), the sample was comprised of 2,200 children aged 6:0 to 16:11 as well as various special groups. These included Intellectually Gifted, Mild Mental Retardation, Moderate Mental Retardation, Reading Disorder, Reading and Written Expression Disorders, Math Disorders, Reading, Written Expression, and Math Disorders, Learning Disability and ADHD, ADHD, Expressive Language Disorders, Open Head Injury, Closed Head Injury, Autistic Disorder, Asperger's Disorder, and Motor Impairment (Wechsler, 2003).

3.8 WISC-IV Reliability

Reliability and validity is critically important since intelligence measures are used in educational decision making and predicting performance. Test-retest coefficients for the overall WISC-IV standardization sample were calculated using Pearson's Product Moment Correlation and included Fisher's *z* transformation calculations. Correlation coefficients were corrected for variability of the standardization sample. Standardization difference was then calculated using the mean score difference between two administrations divided by the pooled standard deviation. Corrected stability coefficients were .89 for Working Memory and .86 for Processing Speed. Standardization differences using Cohen's *d* effect sizes between the first and second testing was also corrected for the variability of the standardization sample. These were .20 for Working Memory and .51 for Processing Speed. Reliability coefficients for these two constructs ranged from .79- .92 across all ages. Internal reliability or consistency with the WISC-IV using the split-half method/ Spearman Brown correction were: Verbal Comprehension , .94, Perceptual Reasoning, .92, Working Memory, .92, Processing Speed, .88, and Full Scale IQ, .97

across all ages. For the relevant subtests, Digit Span was .87 (range .81- .92 across all ages). Letter-Number Sequencing was .90 (range .85- .92 across all ages). Test-retest stability coefficients were used as the reliability estimates for the Processing Speed subtests since these are timed subtests and split-half would be inappropriate. Coding was .85 (range .72 - .89), and Symbol Search was .79 (range .78- .82) (Wechsler, 2003). Test-retest intervals for two WISC-IV administrations ranged from 13-63 days with a mean of 32 days. It is a factor of reliability coefficients that composite scores are generally going to be higher than individual subtests since a subtest represents only a narrow slice of cognitive functioning vs. a composite score that is summarizing a broader sample of abilities.

Reliability coefficients for various clinical groups are also included. Populations with ADHD have a reliability coefficient of .87 on Digit Span and .94 on Letter-Number Sequencing; Reading Disorders .86 on Digit Span and .90 on Letter-Number Sequencing. Coding and Symbol Search are not available for special groups, as these groups did not participate in the retest (Wechsler, 2003). Intercorrelations of the Working Memory and Processing Speed composites with the Full Scale IQ are as follows: .76 Working Memory and .70 Processing Speed; for the subtests: Digit Span .51, Coding .46, Letter-Number .60, and Symbol Search .57 (Wechsler, 2003).

3.9 WISC-IV Validity

In terms of validity, the WISC-IV manual cites a long and extensive history of subtest performance and the continued use of subtests from previous versions as one sources of content validity (Maller, & Thompson, 2003). Most of the WISC-IV's validity evidence is with other Wechsler scales citing a correlation of .89 between the WISC-IV and WISC-III. Other concurrent validity studies include correlations between the WISC-IV and Wechsler Adult Intelligence Scale-III (WAIS-III) of 98.5 for the FSIQ and nearly identical FSIQ's with the Wechsler Preschool and Primary Scale of Intelligence-III (WPPSI-III). Correlations of the WISC-IV with the Wechsler Individual Achievement Test-II (WIAT-II) note .87 between FSIQ and Total Achievement although there was variability between the four indexes ranging from .58 with Processing Speed to .80 with Verbal Comprehension (Wechsler, 2003).

Critical review of the WISC-IV notes confirmatory factor analysis supports a four-factor framework for the test as specified by the four indexes (Maller, & Thompson, 2003). This restructuring has made obsolete the VIQ-PIQ differentiation that was complicated and at times misunderstood and further assists with understanding underlying neuropsychological constructs- i.e., fluid reasoning, working memory, and processing speed as opposed to crystalized knowledge (Baron, 2005).

3. 10 Procedures

Subjects were selected at from archival data from a clinical private practice that serves Western NC. Students were referred across the western half of the state but primarily from local pediatric offices in several counties. Children were referred due to attentional, learning, and/or behavioral-emotional issues. Socioeconomic status of students was lower to middle class. Parents gave permission for their children to be evaluated. The sample included students who were on and off of medications at either time of WISC-IV administration as well as included a range of psychiatric disorders. The first question addressed whether there were significant differences from one evaluation to the next with these participants. After answering the initial question of significant difference with referred populations, the second question posed whether a significant difference would be seen with smaller sub-samples consisting of two primary groups- ADHD and SLD. The total sample ranged in age from 6 to 14. Records were selected primarily on the basis of having two standard administrations of the WISC-IV. At least one administration included a Full Scale IQ score between 75 and 120 to avoid the influence of extreme scores. Profile variability was not a variable for inclusion. Repeat administrations ranged from one to four years with an average of two and a half to three years, which is the standard re-evaluation time. Efforts were made to include students who were within the elementary to middle school range.

For the second hypothesis, subjects were divided into two groups, those with either primary ADHD or learning difficulties - a total of 25 ADHD and 23 learning disabled. Hypothesis two stated that students with only ADHD as the primary diagnosis would differ more significantly than students with only Specific Learning Disabled as the primary diagnosis from one administration to the next administration of the WISC-IV. Criteria for inclusion into the ADHD group was based upon standard scores of 70 or higher on the Hyperactivity and/or Attention scales from any of the following behavioral rating scales: Behavior Assessment Scale for Children-2 (BASC-2), Conners Revised Rating Scale, and/or Conners 3 Rating Scale reflecting clinical significance, parent interview, exclusion of other psychiatric and/or medical disorder, and ruling out a learning disorder. On each of these scales, the Hyperactivity Scale assesses for symptoms associated with DSM-IV-TR Hyperactive-Impulsive criteria. Examples of items include interrupting others, being overly active, and acting without thinking. The Attention scale on these measures assesses for core symptoms associated with the Attention symptoms as defined by the DSM-IV-TR. Examples include inability to maintain attention and tendency to be easily distracted in tasks requiring attention. Students were diagnosed by a medical physician followed up with confirmation by a psychologist licensed to practice in the state of North Carolina. Criteria for placement in the SLD group was based upon the WISC-IV FSIQ range accepted for this study with a significant discrepancy or qualification in one or more eight academic areas accepted under SLD guidelines as noted in the NC Policies for Governing Services for Children with Disabilities.

3.11 Group Variable - ADHD

Diagnosis for ADHD comes from records, some of which do not note the method of making the diagnosis. Whether or not a student was on a medication was not always reported and this was coded as Missing/Unknown. Prior diagnosis of ADHD coming into the setting was most often done by the child's pediatrician who had referred the student for additional assessment to rule other out other issues. Diagnosis for ADHD was accepted if confirmed by an individual licensed to practice psychology in the state of NC. By confirming the diagnosis coming into the setting at the second assessment, the author is providing greater validity to the diagnosis, since previous evaluations or methods by which a prior diagnosis was made was not always available. Methods for making a diagnosis consisted of parent interview including review of developmental history, test observations of the child, any previous evaluations available, rating scales to rule in/out co-morbid factors, WISC-IV, and academic assessment. Acceptable rating scales for determining ADHD included the Vanderbilt, Conners Revised and Conners 3, and Behavior Assessment Scale for Children-2 (BASC-2). Cut-offs for determining diagnosis were accepted if relevant subscales reflected clinical significance (T-score =/> 70).

Diagnosis was made based upon all of these factors and included ruling out other confounding factors such as medical, mental, and adjustment disorders in accordance with DSM-IV-TR criteria.

3.12 Group Variable – Specific Learning Disabled

Diagnosis of a specific learning disability was based upon a student demonstrating a significant discrepancy in a specific area of achievement in comparison with their IQ, as defined by North Carolina Department of Instruction and in line with DSM-IV-TR guidelines. However, the author recognizes classification can be flexible in that a student may be qualified as a child with a learning disability even though they do not have a discrepancy of 15 points because of confounding variables like psychological/information processing variables that may be influencing the Full Scale IQ. In this case, use of the Global Ability Index (GAI) which includes the Verbal Comprehension and Perceptual Reasoning subtests was acceptable in making the learning disability determination.

3.13 Analyses

Analysis considered whether the assumptions for the ANOVA design have been met, as well as descriptive statistics including mean, standard deviation, skewness, and kurtosis. Secondary factors considered in additional analyses examined the influence of medication during the first and/or second evaluations, medication changes as an influence as well as comorbidity of disorder and gender.

CHAPTER 4

RESULTS

This study examined variability of information processing in a two-way repeated measures analysis of variance (ANOVA) design with two variables in separate models - Working Memory and Processing Speed, as defined and measured by the WISC-IV. It is expected that variability of information processing is an important variable in evaluating children that should be considered and examined.

Two hypotheses guided the study 1) Referred populations will demonstrate a significant difference in Working Memory and Processing Speed from one administration to the next administration of the WISC-IV, and 2) Students with ADHD as the primary diagnosis will differ more significantly from one administration to the next administration than students with SLD as the primary classification from one administration to the next with the WISC-IV.

The first ANOVA contained only one within factor - time. The second hypothesis was examined with a mixed design. The between factor was "group" and the within factor "time". Time was defined as the time interval between administrations. Group was defined by being either a student with ADHD or SLD. ADHD was group one and SLD group two.

The entire sample consisted of 75 students with various developmental disorders. This sample was used to test the first hypothesis and the second hypothesis used two subgroups from the whole sample - 25 students with a primary diagnosis of ADHD and 23 with a primary diagnosis of specific learning disabled (SLD). Analysis considered whether the assumptions for the ANOVA design had been met, as well as descriptive statistics including mean, standard deviation, skewness, and kurtosis. Following an examination of both Working Memory and Processing Speed analysis of variance, additional analyses were conducted on the primary issue of medication as a confounding factor, as well as single vs. comorbid disorder, and gender. Records were selected from the population of interest, students with two evaluations scores from the WISC-IV. This was the only criteria for inclusion. Additionally, observations were independent of each other as a subject's score from one administration was not dependent upon score from the other administration.

4.1 Descriptive Statistics

Distributions for each variable at both time points were evaluated for normality. These were generally symmetrical as evaluated through examination of the box and whisker plots of each dependent variable at both time points as well as skewness and kurtosis values, which were close to zero, as noted in Table 4.1. Normality was also demonstrated through adequate sample size, similar means, and standard deviations. Further, homogeneity of variance was noted in non-significant Shapiro-Wilks values for all variables at both time points ($p > .05$). Scatter plots additionally noted linearity and normality of each dependent variable at both time points with no significant outliers. Variables were designated as Working Memory 1 (wm1), Working Memory 2 (wm2), Processing Speed 1 (ps1), and Processing Speed 2 (ps2). Additionally, Levene's Test of Homogeneity of Variances for all groups was non-significant ($p > .05$).

Table 4.1

Descriptive Statistics

Variable	M	Min	Max	SD	Sk	Ku
Wm1	89.09	62.00	120.00	12.00	0.28	-0.29
Wm2	90.95	62.00	123.00	12.57	-0.32	-0.01
Ps1	93.39	59.00	126.00	14.74	0.04	-0.28
Ps2	87.09	53.00	128.00	14.48	0.33	0.16
Wmd	8.65	0.00	39.00	7.65		
Psd	12.04	0.00	38.00	9.04		

n = 75
Note. Working Memory 1=Wm1, Working Memory 2= Wm2, Processing Speed 1=Ps1, Processing Speed 2= Ps2, Working Memory Mean difference= Wmd, Processing Speed Mean difference= Psd

As shown in Table 4.1, the average Working Memory score difference was 8.65 points with fluctuations that ranged from 0 to -39 points for first evaluation. Thirty-four students demonstrated increases in their Working Memory vs. 28 students who demonstrated decreases. Thirteen experienced no change in Working Memory. In Processing Speed, the average difference over time was 12.04 points with a range of differences that extended from 0 to + 38 points. Table 4.2 notes that of the 75 students in the sample, 62 students (83%) overall experienced changes in one direction or the other. In Processing Speed, 18 students increased their Processing Speed vs. 49 demonstrated decreases. Eight experienced no change in Processing Speed. Of the 75 students in the sample, 67 (89%) experienced changes in Processing Speed.

Table 4.2

Working Memory and Processing Speed Changes for Whole Sample

Variable	Increased	Decreased	No Change	Total Students Changed
Working Memory	34	28	13	62
Processing Speed	18	49	8	67

n= 75

Table 4.3 provides correlations of Working Memory and Processing Speed from one administration to the next. These values suggest moderate variation between first and second administrations within Working Memory and Processing Speed respectively. Correlations were low but most were statistically significant when comparing Working Memory to Processing Speed variables with each other from first to second administrations. Overall, the lack of strong relationship between Working Memory and Processing Speed regarding longer term stability is in keeping with the literature of stronger stability coefficients with the Full Scale IQ vs. Index scores (Canivez & Watkins, 2001; Wechsler, 2003). Given that both Working Memory and Processing Speed did not increase or decrease together, scores suggest Working Memory may operate independently from Processing Speed in referred populations, even though the literature review noted that there tends to be growth in both of these variables that may act in concert with each other in general (Fry & Hale, 1996 & 2000).

Table 4.3

Correlation Matrix of Working Memory and Processing Speed over Time

Variable	Wm1	Wm2	Ps1	Ps2
Wm1	1.00			
Wm2	0.57*	1.00		
Ps1	0.30*	0.33*	1.00	
Ps2	0.10	0.34*	0.56*	1.00

$^*p < .05$

4.2 Major Findings

4. 3 Hypothesis One

Hypothesis one stated that referred populations would demonstrate a significant difference in Working Memory and Processing Speed from one administration to the next administration of the WISC-IV. Working Memory ANOVA results for hypothesis one did not find a statistically significant difference in Working Memory from first administration to the second [F (1, 74) = 1.97, p = 0.165], as noted in Table 4.4. However, the general trend for the whole sample was upwards, indicating improvement on the second administration of Working Memory using age based norms (see Table 4.1).

Table 4.4

Summary Table for One-Way Repeated Measures ANOVA for Working Memory with Referral Populations

Source	SS	df	MS	F	p
Working Memory	128.8	1	128.8	1.97	0.16
Within Groups	4847	74	65.00		
Total	4975.8	75			

n = 75

ANOVA results for hypothesis one examining Processing Speed, time as a main effect for change in performance from the first to second administration was statistically significant [F (1, 74) = 15.74, p = 0.0002, η^2 = 0.18]. Eta square provided a percentage of variance accounted for by the main effect of time (.18) suggesting 18% of the variance for Processing Speed was accounted for by time. Cohen's *d* for the mean difference between time one and time two for Processing Speed was .43 indicating a close to medium effect size difference. However, 18% of the variance would suggest that other factors play a role in the variance of Processing Speed. Results for Processing Speed for the referred group as a whole are noted in Table 4.5. The general trend for the whole group was lower on second administration as noted in Figure 4.1.

Table 4.5

Summary Table for One-Way Repeated Measures ANOVA for Processing Speed with Referral Populations

Source	SS	df	MS	F	p	ES η^2
Processing Speed	1485	1	1485	15.74	0.000166	0.18
Within Groups	6982	74	94			
Total	8467	75				

n = 75

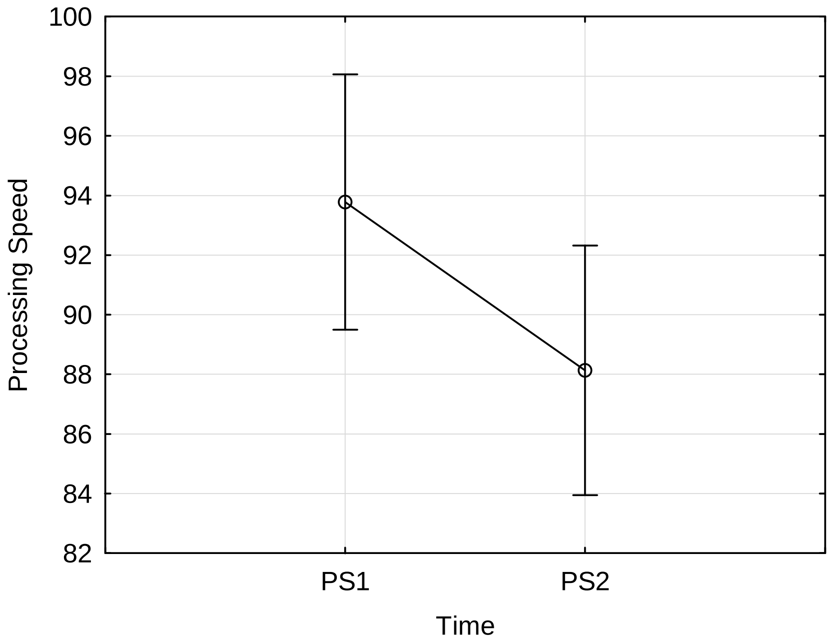

Figure 4.1
Processing Speed Across Time- LS Means.
Note. Vertical bars denote 0.95 confidence intervals.

4. 3 Hypothesis Two

The second hypothesis included two subgroups of the original 75 students - 25 ADHD and 23 SLD students, with group as the between factor and time as the within factor. Table 4.6 contains mean, minimum and maximum scores for each variable, standard deviation, skewness, and kurtosis for these two subgroups.

Table 4.6

Descriptive Statistics for ADHD and SLD Subgroups on Working Memory and Processing Speed- First and Second Administrations (Total n =48)

ADHD

Variable	M	Min	Max	SD	Sk	Ku
Wm1	92.08	71.00	116.00	11.61	0.37	-0.41
Wm2	97.92	83.00	123.00	10.21	0.43	-0.22
Ps1	93.52	68.00	126.00	13.11	0.56	0.68
Ps2	88.92	68.00	128.00	13.30	0.84	1.75

Specific Learning Disabled (SLD)

Variable	M	Min	Max	SD	Sk	Ku	Wm1
	82.87	62.00	104.00	9.73	0.12	0.20	
Wm2	86.09	62.00	104.00	11.77	-0.53	0.02	
Ps1	94.04	62.00	123.00	16.31	-0.07	-0.58	
Ps2	87.35	56.00	118.00	15.48	0.29	-0.14	

Note. ADHD= 25, SLD = 23
Note2. Wm1= Working Memory first administration, Wm2= second administration, Ps1= Processing Speed first administration, Ps2= second administration.

For both subgroups, skewness, kurtosis, means, and standard deviations were all similar. Skewness and kurtosis values were close to zero for both groups as a whole with the exception of one set of values. Processing Speed 2 with the ADHD group produced a positive skewness of 0.84 and kurtosis of 1.75. This indicates there were more scores towards the lower end of the distribution meaning a greater number of students performed lower on second administration. Despite this, the Shapiro-Wilks values were non-significant supporting normality being fairly robust despite the minor deviation noted in these values.

Hypothesis two stated that students with ADHD as the primary diagnosis would differ more significantly from one administration to the next administration with the WISC-IV than students with SLD as the primary classification. The ADHD group performed significantly higher than the SLD group on Working Memory. ANOVA for subgroup performance on Working Memory main effect for group was [F (1, 46) = 14.41, p= 0.0004, η^2=.19]. The eta square effect size of .19 indicates 19% of the variance for Working Memory was accounted for by Group. Main effect for time was also statistically significant [F (1, 46) = 9.40, p = 0.004, η^2= 0.03]. Time accounted for 3% of the variance for Working Memory performance, which is considered a small effect of variance. While both time and group were significant factors in accounting for a statistically significant difference in performance from one administration to the next, the proportion of variance they together account for in the Working Memory would appear close to medium. There was no interaction between these factors influencing Working Memory yielding a non-significant effect for time by group [F (1, 46) = 0.79, p = .38]. The trend for both groups on Working Memory was upward (Figure 4.2) and is similar to the larger sample. Both groups improved, but the ADHD group performed significantly higher than the SLD group as a whole on both Working Memory 1 and Working Memory 2, as noted in Figure 4.3. These findings indicate large effect sizes (Cohen's d = .87 and 1.00 respectively).

Table 4.7

Summary Table for Two-Way Repeated Measures Mixed ANOVA in Working Memory by Group (ADHD vs. LD)

Source	SS	df	MS	F	p	ES (η^2)
Between Subjects		47				
Group	2652.4	1	2652.4	14.41	0.0004	0.19
Residual Between	8466.5	46	184.1			
Within Subjects		48				
Time	491.4	1	491.4	9.40	0.004	0.03
Time X Group	41.2	1	41.2	0.79	0.379	
Residual Within	2403.6	46	52.3			
Total	14055.1	95				

n = 48

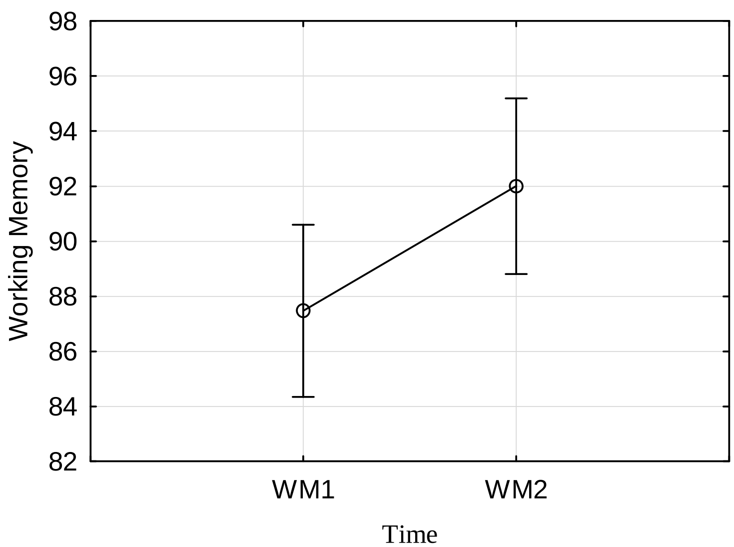

Figure 4.2
Main effect of Time for Subgroup Performance- LS Means.
Note. Vertical bars denote 0.95 confidence intervals

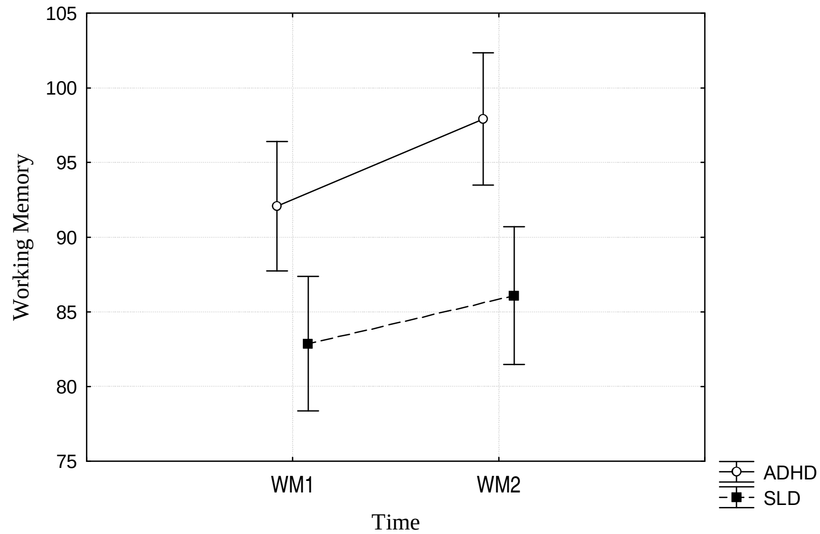

Figure 4.3
Working Memory Across Repeat Measures for ADHD and SLD.
Note. Vertical bars denote 0.95 confidence intervals.

Figure 4.4 shows Processing Speed, a statistically significant main effect for Time [F (1, 46) = 8.60, p = 0.005, η^2=0.04]. For Processing Speed, a main effect was not evidenced for group [F (1, 46) = 0.02, p = 0.88]. The effect size of this variance would indicate that time accounted for only 4% of the variance of Processing Speed. As with Working Memory, there was a non-significant interaction effect for time by group [F (1, 46) = 0.02, p = .89]. There was not a significant difference between how students with ADHD performed on Processing Speed vs. SLD students, as noted in Table 4.7.

Table 4.8

Summary Table for Two-Way Repeated Measures Mixed ANOVA in Processing Speed by Group (ADHD vs. LD)

Source	SS	df	MS	F	p	ES η^2
Between Subjects		47				
Group	6.60	1	6.60	0.02	0.89	
Residual Between	15408.8	46	335.0			
Within Subjects		48				
Time	764.2	1	764.2	8.60	0.005	0.04
Time X Group	26.3	1	26.3	0.30	0.59	
Residual Within	4089.4	46	88.9			
Total	20295.3	95				

n = 48

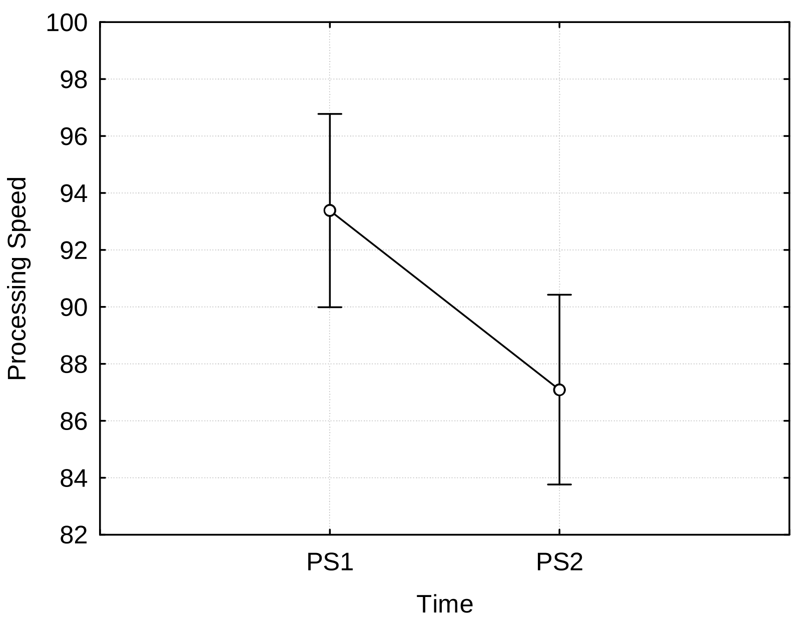

Figure 4.4
Processing Speed for ADHD and SLD Subgroups Across Time.
Note. Vertical bars denote 0.95 confidence intervals.

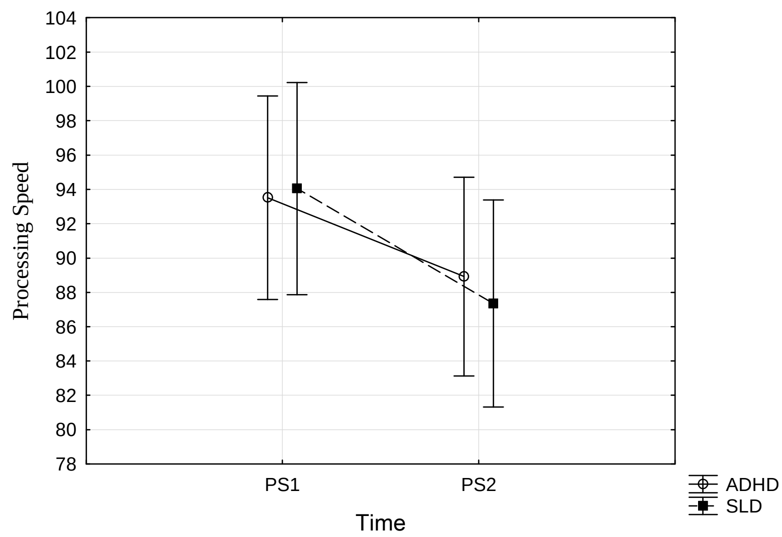

Figure 4.5 Processing Speed for Subgroups: Time by Group- LS Means.
Note. Vertical bars denote 0.95 confidence intervals

As a whole, Working Memory went up both in the overall sample as well as in subgroups while Processing Speed went down over time. In the ADHD and SLD groups, the ADHD group performed better than the SLD group on Working Memory although both groups performed similarly on Processing Speed. As with the large group, average age at first evaluation was approximately age 7 and age 10 at the second evaluation although ADHD was average 9.76 at the second evaluation vs. 10.7 for SLD. The general trend for both groups was downward across time as noted in Figures 4.4 and 4.5. Again, this was similar to the larger sample.

4. 4 Additional Comparative Analyses

Additional comparative analyses examined medication, comorbidity, and gender to see if these were factors that accounted significant differences. As in main hypotheses, time was often a statistically significant variable. However, differences between groups based on medication, medication changes, gender and comorbidity confounds did not always account for such differences over time. Of primary concern was the influence of medication as a confounding factor on performance. Additional factors considered gender and single disorder vs. comorbid disorders. Additional comparisons were conducted on the whole sample and were examined in the two primary subgroups involve. Additional analyses were Bonferroni or Unequal N HSD depending upon numbers within the groups involved. The Unequal N HSD test is used as a modification of the Tukey HSD test to determine between group means whenever numbers in comparison groups are unequal. To account for reducing the chance of committing a Type 1 error, the adjusted alpha level used to reject the null hypothesis was .05/4= .0125 for whole group analysis. All assumptions using Levene's Test for Homogeneity of Variances yielded non-significant results ($p > .05$). Table 4.9 lists all additional comparisons conducted and results by category for the whole sample. The comparisons included the influence of medication changes, single vs. comorbid disorders, and gender.

4.5 Medication change

The first additional analysis examined the influence of medication change vs. no medication change over time. Unequal N HSD was used to determine the difference due to significantly unequal numbers within these two groups. Of the total n for this analysis, 19 experienced a change in medication status vs. 35 who did not. This included 33 who were not on medication plus two students who remained on the same medication for both administrations. There were 21 unknowns due to missing information regarding medication status for the first administration. Having a medication change (noted as MedChange) had an impact from Ps1 to Ps2 that was statistically significant ($p = 0.006$). However, both groups demonstrated a downward trend with a significantly lower mean change for the group who experienced a medication change vs. no change, which was similar to the trend of the whole sample. Having a medication change did not have an impact on Working Memory (*p* = 0.30).

When examining the subgroups of ADHD and SLD, a total of 34 students were included. Results were not statistically significant for Working Memory or Processing Speed ($p > 0.05$). Of the 34 students, eight of the ADHD experienced no medication change including five of which were on no medication at either time point. Nine experienced a change in medication status. Ten had missing medication information from time point one. Of the SLD students, 15 were not on any form of medication and two had a medication change. Four SLD students' medication status was unknown or missing. Of the ADHD/SLD group (n= 6), one was on the same medication, two were not on any medication, two had unknown/missing information about medication status for time point one, and one experienced a change in medication. Students were often on different or more than one medication at the second administration of the WISC-IV as compared to the first time they were evaluated.

A second medication analysis was conducted to examine time by being on medication at either time point vs. no medications at either time point. Again, there was a downward trend. However, Bonferroni did not yield statistically significant findings for either Working Memory or Processing Speed for either group having more change vs. the other when considering the adjusted corrected alpha level. Mean changes are noted in Table 4.9. Of the 66 students included, 35 were on medication at either time point vs. 31 who were not on medication at either time point. Nine were unknown due to missing information regarding time point one. Of the ADHD students, 18 of the 25 (72%) were on some form of medication at either or both time points vs. only three (13%) of the SLD students. Twelve of the Other (Comorbid) disorder group (67%) was on medication at either time point. Three of the six students with both ADHD and SLD (50%) were on a medication at either time point. Of the medications noted, 25 students were taking a stimulant or amphetamine, 12 were taking an anti-depressant, 10 an anti-psychotic, 1 blood pressure, 8 anti-convulsants, 3 anti-hypertension, 1 anti-anxiety, 4 neuro-reuptake inhibitors, 3 alpha agonists, and 1 ACE inhibitor. However, the aforementioned medication totals were often combinations of the these medications with 24 students (32%) who were on more than one medication- all at the second administration with the exception of one. Number of students not on medication the first time but on medications the second time was 27 (36%). All students who were on medications the first time were on one medication. Only two students were on more than two medications the first administration.

For subgroups, a second medication analysis examined no medications at both time points vs. being on medication(s) at either time point. Bonferroni yielded statistically significant results with mean changes from 91.14 to 97.33 for Medication group (p = .05) from Wm1 to Wm2. The group that were on no medications (NoMeds) changed from 85.86 to 90.00, although this was not a statistically significant change (p = 0.37) for Working Memory. Processing Speed was not statistically significant (p = .66 and 0.08) respectively for both groups. Sample totals for this analysis included 21 on medications at either time point vs. 22 on no medication at either time point. However when correcting with Bonferroni, this was not significant.

4.6 Single vs. comorbid disorder

Single vs. Comorbid disorder was considered as a variable since there were children whose diagnosis was added onto in the second evaluation and/or children who presented with more than one diagnosis. Follow-up Unequal N HSD was not significant for Working Memory ($p = 0.09$). Time was significant for Processing Speed ($p = 0.00010$) although this trend was similar to the group as a whole. Follow-up Unequal N HSD noted a significant change for both single and comorbid groups in Ps1 to Ps2 ($p = 0.04$ and 0.03) respectively with both experiencing a significant change in mean although the downward trend is consistent with the trend for the group as a whole. Both experienced a significantly lower mean on Ps2. Of the total n, 50 students were identified as having a single disorder vs. 25 with comorbid disorders present. Of the 50 students with a single disorder, 48 were either ADHD or SLD with 2 students having a single health disorder i.e., epilepsy. Of the 25 students with comorbid disorder, 6 were identified as having both ADHD and SLD.

4.7 Gender

Regarding gender, Unequal N HSD was not statistically significant regarding Working Memory ($p > .05$) but was for Processing Speed ($p = 0.008$). Results indicated that boys accounted for more of the difference in the change from Ps1 to Ps2 than girls although it should be noted that there was twice as many boys as girls.

Table 4.9

Additional Comparative Analyses

Variable Category	Working Memory 1	 2	Processing Speed 1	 2	Significance level
Medication change vs. No change in medication status (Unequal N HSD)					
Med Change	89.42	89.79	-	-	NS
No change	88.40	91.63	-	-	NS
Med Change	-	-	95.58	84.90	.006*
No Change	-	-	93.57	88.00	NS
N= Med change 19, No change 35 (including 33 no medications), Unknown/Missing 21					
Medication either time point vs. No medication (Bonferroni)					
Medication	91.17	93.03	-	-	NS
No Medication	87.10	90.39	-	-	NS
Medication	-	-	92.43	86.66	NS
No medication	-	-	94.94	86.66	NS
N= Medication 35, No medication 31, Unknown/Missing 9					
Single disorder vs. Comorbid Disorders					
Single	87.74	91.68	-	-	NS
Comorbid	91.80	89.48	-	-	NS
Single	-	-	93.78	88.40	.04
Comorbid	-	-	92.60	84.48	.03
N= Single 50, Comorbid 25					

Table 4.9 Continued

Variable	Working Memory		Processing Speed		Significance level
Category	1	2	1	2	
Gender (Unequal N HSD)					
Boys	88.14	90.72	-	-	NS
Girls	91.00	91.40	-	-	NS
Boys	-	-	93.94	87.46	.008*
Girls	-	-	92.28	86.36	NS

N= Boys 50, Girls 25

*Note. *Adjusted alpha level p < .0125*

Given variability and differences in the upward performance with Working Memory vs. downward movement of Processing Speed, statistics of age groups were examined to look at trends in mean changes as children aged.

Table 4.10

Age Statistics for Working Memory and Processing Speed

Age	WM1	WM2	PS1	PS2
6	91.94 (11.36)	95.94(12.47)	96. 56 (14.73)	87.56 (17.52)
7	88.70 (10.43)	86.10(10.67)	87.70 (14.93)	83.10 (11.97)
8	89.93 (14.80)	93.33(11.95)	92.60 (12.45)	88.33 (12.37)
9	91.00 (13.20)	91.00 (10.55)	95.56 (14.53)	86.33(15.70)
10	82.00 (12.25)	88.33 (20.76)	105.67 (15.07)	94.17(19.30)
11	82.00 (10.80)	90.75 (15.28)	91.25(20.5)	93.00(13.40)
12	92.50 (6.36)	87.00 (5.66)	89.50(2.12)	90.00(9.90)
13	80.00 (0.00)	86.00 (0.00)	85.00 (0.00)	75.00 (0.00)

n = 75

Note 1. Means and standard deviations
Note 2. One student in the last age group

The wide variability at each age group contributed to large standard deviations allowing for overlaps in performance. The greatest variance in the Age 1 for Working Memory was at age 10 with the least amount of variance in the 12-14 year old group. However, there were also more students in the lower age group as a whole. Age 2 overall demonstrated greater variability with the greatest variance in performance between ages 10 and 14. A plot of means with 95% confidence intervals noted that, overall, there was little variability at Age 1 across the 6 to 9 year olds but variability becoming more of an issue at age 10.

With regards to Processing Speed, each age went down at Ps2 with the exception of the 11 and 12 year old groups although their changes were not significant (within 1 point). The greatest variations at Ps1 were at age 9 and 12- 14. At Ps2, the greatest variations were with age 8, 13, and 14 although again, there were relatively fewer n's in the older group compared to the middle elementary school age. As noted with Working Memory, there was little variation across Age 1 in Processing Speed until later at age 11 and 12. However, Ps2 noted greater variability overall with performances up and down on Ps2 downward from ages 8 to 9 and back up as dramatically from ages 9 to 10 and again a similar downward trend from ages 12 to 13 and from ages 13 to 14.

4.8 Conclusions

A repeated measures ANOVA was conducted on two administrations of the WISC-IV in two separate models examining Working Memory and Processing Speed. Hypothesis one stated referred populations will demonstrate a significant difference in Working Memory and Processing Speed from one administration to the next administration of the WISC-IV. Working Memory did not demonstrate a statistically significant difference over time but Processing Speed was statistically significant over time. Hypothesis two stated that students with ADHD as the primary diagnosis would differ more significantly from one administration to the next administration than students with Specific Learning Disabled as the primary classification in administration to administration of the WISC-IV. The main effects of time and group were significant for Working Memory with the ADHD group performing significantly higher than the SLD group although both groups demonstrated improved performance consistent with the whole sample. There was no time by group interaction. For Processing Speed, the main effect of time was again significant but not group. Explained variance would suggest there are a number of other factors that play a role in both Working Memory and Processing Speed. Additional analyses examined medication as a confounding variable. A student who was on medication at either time point vs. no medications at all was not statistically significant. A significant drop was evidenced in Processing Speed with students who experienced a medication change although this was consistent with the overall trend for the sample. Single vs. comorbid disorder noted changes with lower performance on second administration of Processing Speed. However, this was not statistically significant with an adjusted alpha level. Again, the movement of scores was similar to the whole sample of lower performance on second administration. Regarding gender, boys performed significantly different on the second administration of the WISC-IV on Processing Speed. Boys' scores changed 6.48 points downward compared to 5.92 points downward for girls, which was statistically significant.

CHAPTER 5

CONCLUSION

Studies have been very limited examining the variability of information processing with referred children and even more so studies examining their performance over time. However, researching this population is important because referred children may not initially qualify for special services, yet may continue to have school difficulties. Lack of special services may cause these children to be re-referred after later falling further behind. Therefore, examining variability of information processing, specifically Working Memory and Processing Speed, as measured on the WISC-IV through a repeat measures design not only allowed for assessing such variability but also permitted each child to serve as his or her own control. These factors are particularly important considering the prevalence of disorders such as ADHD and/or SLD in referred children. These groups are defined by specific features yet can be heterogeneous within respective groups. Within this study, variance of information processing within an identified group was demonstrated quite variably and individually over time. Results with this sample revealed that individual variability is a greater defining factor than being in a specific group.

5.1 Hypothesis One

Hypothesis one stated that referred populations would demonstrate a significant difference in Working Memory and Processing Speed from one administration to the next with the WISC-IV. Difference in Working Memory was not statistically significant although difference in Processing Speed was. Results indicated that referred populations may still demonstrate wide variability on this variable that results in significant changes in information processing over time. Eighty-three percent of the children changed from one administration to the next on Working Memory. Nearly half (45%) scored higher on the second administration vs. about 37% whose scores were lower at second administration. Processing Speed was statistically significantly different at second administration, which is in keeping with the literature on this cognitive variable as the most variable cognitive function (Calhoun & Mayes, 2005; Fry & Hale, 2000). Only eight students didn't change in either direction leaving 89% who did change higher or lower than their previous score. Processing Speed's moderately high correlation with the Full Scale IQ on the WISC-IV (.70) (Wechsler, 2003) suggests along with the literature that it does play a prominent role in the expression of intelligence. It is particularly involved with working memory and fluid reasoning (Tillman, Bohlin, Sorensen, & Lundervold, 2009). As a result, the FSIQ on the WISC-IV may be influenced quite significantly by variability of Processing Speed.

5.2 Hypothesis Two

Hypothesis two stated that students with ADHD as the primary diagnosis would differ more significantly from one administration to the next than students with SLD as a primary classification in Working Memory and Processing Speed. The ADHD group performed significantly higher ($p = .0004$) than the SLD group on Working Memory but not on Processing Speed ($p = .89$). Meaningful differences were exhibited with both first and second administrations on this variable (Cohen's $d = .87$ and 1.0 respectively), which are very large reflecting meaningful differences for students with ADHD (as a group) as compared to SLD. While the variables of time and being ADHD vs. SLD were both important in influencing Working Memory, there was no interaction between them affecting Working Memory. That children with SLD performed more poorly on Working Memory is consistent with extensive literature noting working memory difficulties in children with learning disabilities (Pickering & Gathercole, 2004; Shelton, Elliott, Matthews, Hill, & Gouvier, 2010; Wechsler, 2003). However, it is somewhat at odds with the mixed opinion regarding the importance of working memory as a core deficit of ADHD (Barkley, 2006). These results would suggest that Working Memory, as measured by the WISC-IV is not always an issue for these students and children with this disorder can vary widely depending on individual issues.

Even though students with SLD performed significantly lower on Working Memory than students with ADHD, both groups performed similar to the larger sample. Processing Speed also demonstrated a similar downward trend for both groups although being ADHD vs. SLD was not statistically significant as it was in the larger n. These findings highlight the issue of individual variability and differences that may be exhibited between groups such as ADHD and SLD over time even within these populations.

5.3 Additional Comparative Analyses

Additional analyses with medication, co-morbidity, and gender were limited primarily to the whole sample given the larger n provided greater power and evidence of similar findings being observed for both subgroups although medication issues were also examined at the sub-group level. Secondly, the question of a statistically significant difference for group performance on hypothesis two was answered with the first level of analysis, as ADHD students performed significantly higher than SLD students on

Working Memory. However, overall variability was just as much an issue with ADHD students as SLD. Performances of adjacent age groups often overlapped because of larger standard deviations consistent with the overall variability seen. Mean performances were similar with overlapping performances for these subgroups, as reflected in means and standard deviations presented in Table 4.6 in Ch. 4.

Children who experienced medication changes dropped significantly in their Processing Speed performance of almost 10 points. Those who didn't experience a medication change also dropped in Processing Speed although not to the point that it was statistically significant. Sample characteristics revealed that many more ADHD students were on medication vs. SLD, (72% vs. 13%), which may speak to the possible influence of medication on performance and changes that may result from being on a specific medication particularly stimulants or multiple medications. The finding of ADHD and other referred students being on different psychotropic medicines at the second time point may certainly add to the variability that may be seen across repeat assessment. It further adds support to the importance of repeat cognitive assessment due to changes in neuropsychological functioning that may affect the stability of information processing and performance from agents designed to produce neuropsychological changes.

A third analysis examined the effects of having a single vs. comorbid disorders. Both children with single disorders and comorbid disorders dropped in performance significantly although when a correction was applied to correct for the number of additional analysis hypotheses, it was not statistically significant. Still, co-morbidity was found one-third of the time at the second evaluation and 42 students came in with prior diagnoses. Eight students had diagnoses added on in the second evaluation. Given these issues, it has implications for such influences that may affect variability of information processing. It further speaks to examining a student's psychological status at a second evaluation to note what changes have been made in their functioning, as co-morbidity can make a difference in performance on assessment as well as in the classroom. Comorbidity highlights the multiple influences on children's cognitive functioning.

The variability of performance evidenced in these analyses further justifies the need for comprehensive evaluation even in instances when there is only a primary question of whether a learning disability is present. Justification for second evaluations during this time period is important that confirm or refute original findings, if new information comes forward that wasn't present in the original evaluation, or whenever circumstances change. While certain profiles may be expected with certain populations, these findings suggest that referred and clinical child populations can be quite heterogeneous in nature and perform quite variable over time. This not only affects cognitive performance but also has implications for performance in the classroom. Finally, there was a statistically significant gender difference although there were twice as many boys as girls in the sample, which suggests considering this finding within that context.

5.4 Variability, Cognitive Functioning, and Learning

As sample characteristics suggested, referred children may experience issues with processing information that can vary greatly because of individual circumstances, e.g., changes in medication, age, maturation, intervention, socio-economic status, etc. Individual circumstances like the above may be contributing factors to the variability of both Working Memory and Processing Speed but particularly Processing Speed. While time was significant for Processing Speed, it explained only a small percent of the variance. This suggests there could be other things to influence changes in performance. Many factors beyond time may play a role even beyond those mentioned above in the variance of Processing Speed. Why this variability was seen across age and subsequent evaluations may lie in different underlying neural circuitry for Processing Speed vs. Working Memory. Processing Speed may also be particularly vulnerable to the nature of developmental, brain-based disorders, which involve physiological functioning of different areas of the brain communicating with each other.

More students performed lower on Processing Speed on the second administration, which suggests that Processing Speed was not keeping pace with age for many of these students based upon use of age norms for these analyses. For these students, the cognitive ability of processing speed may not mature at the same rate, may be delayed in maturation, may not develop adequately at all, or may only come together later when the functions of processing speed and working memory (as suggested) are more in concert with each other. There may also be additional factors - even multiple factors on processing speed as a whole - e.g., adding additional medications, medication changes, acquired comorbidity that further impacts cognitive performance of this variable. Stability of cognitive functions may only become evident as a child reaches 15-16 years old when adult levels of performance are more expected if it occurs at all (Baron, 2004).

These findings have implications for children with slower processing speed in the regular classroom. Children with processing speed issues may get further behind in trying to keep up with the increased demands of the curriculum with each grade, as well as have difficulties completing assignments in a timely fashion, completing timed tests within allotted times, keeping up with the pace of instructions, etc. These difficulties may further be complicated by changes in medication status. Staying abreast of a student's medication status and understanding that changes as well as adding additional medications may further affect that student's ability to keep up in the regular classroom are important. Changes in medication impact students' neuropsychological functioning. Additionally, implications of slower processing speed for the teacher's instruction in terms of cognitive load and pace of instruction for these students should be considered. It is important for teachers to understand that processing speed is quite vulnerable to the many changes that may occur in a child's life. It may necessitate adjustment of accommodations and/or the addition of other accommodations the student may need to more fully engage in instruction.

5.5 Variability and Assessment

Variability of information processing may further illuminate processing issues related to and possibly influenced by Working Memory and/or Processing Speed that further influences learning. As noted by Fiorello, Hale, Holdnack, Kavanagh, Terrell, and Long (2007), variability within a profile should alert examiners to individual cognitive indicators that may be impacting a child's learning. This should prompt consideration of what the Index scores are providing and that the FSIQ may not be providing the best representation. The Full Scale IQ may be obscuring underlying processing issues in children referred for learning difficulties, which may impact qualification decisions Fiorello, et al. (2007) also state regression commonality analysis of WISC-IV indexes offers additional evidence of discrete elements that are more warranted with children with disabilities- i.e., ADHD, SLD. Examining variability of performance and what the Indexes are providing is in keeping with current thinking of intelligence as multi-factorial.

This is where the Cognitive Proficiency Index (CPI), which includes Working Memory and Processing Speed can provide current information about a child's proficiency in processing information vs. higher processes and alert professionals to information processing issues (Weiss & Gabel, 2008). Results suggest the need for further assessment of other sub-component information processing abilities if either or both of these variables are significantly different given the wide variability of Working Memory and Processing Speed performance. Stability of these factors with one administration should not be assumed over time even within a limited time period of elementary school years when so many cognitive functions are in a process of developing and so many factors may be impacting a child's functioning. Hale (2011) notes that, "what is being measured are psychological processing states and those states can change and should change from one administration to the next". This is why variability of information processing makes repeat cognitive assessment important. He goes on to state that, "a profile can be reliable at one time point and the second time point may also be reliable; but, processing states based upon age, maturation, etc. can change those states". This is reflected in Index factors not necessarily showing long-term stability and only moderate correlation with each other over time (Canivez & Watkins, 2001; Ryan, Glass, & Bartels, 2010).

As Hale points out, time is an important variable in and of itself. In the current research, time was often a significant factor across both hypotheses either in main hypotheses tested or additional analyses. This speaks to the influence of *time* being an important variable in the assessment of children's issues as a variable in and of itself. Over time, many intervening issues occur. These may include ongoing educational challenges, changed life circumstances, age, maturation, medication changes, and development of secondary disorders like anxiety or depression. Frustration and self-esteem issues may additionally, in part, impact educational difficulties. Not receiving interventions and accommodations that would make them more successful in the regular classroom and getting further behind compounds the situation. These compounding factors may interfere with optimal cognitive processing and cause a student to continue to struggle in school. This is often found to be the case upon second evaluation. The results characteristics seen with this study's sample further suggest that the full impact of a disorder may not always be completely evident at the first evaluation.

Variability in information processing suggests there may often be differences in Working Memory and Processing Speed when children are reevaluated with the WISC-IV. Even within a two to three year period contained in the elementary school years, referred populations may demonstrate great variability –either upward **or** downward depending upon any number of circumstances. Even without a statistically significant result being evidenced with Working Memory, 83% of students varied in Working Memory and 89% percent of students varied on Processing Speed. Furthermore, only 17% experienced no changes on Working Memory and only 11% on Processing Speed. These results are significant given that 62% of the children were re-evaluated before leaving their elementary school years, which may suggest great variability of functioning within a period of rapid cognitive change. This tendency towards individual variability adds to the importance of re-assessment of cognitive functioning. Furthermore, variability of information processing adds support to the value and importance of repeat assessment to determine the stability or continued difficulty with areas of information processing. This gives greater credence to monitoring and tracking issues with information processing beyond student performance, as this can influence qualification decisions. It can impact types of interventions and resources the child may need. Tracking such issues appears crucial at transition points, particularly from elementary to middle school and whenever there has been a change in life circumstances for a child. Variability of performance across time additionally highlights that these processes may be quite vulnerable with referred children when viewed within the context of sample characteristics.

5.6 The Importance of Assessing Cognitive Function

Variability in performance highlights individual factors that often suggest further assessment. This issue received attention in a recent 2009 Supreme Court case- Forest Grove School District v. T.A. decision (Dixon, Eusebio, Turton, Wright, & Hale, 2010). At center is that the school district's evaluation did not adequately address all of the referral concerns resulting in not identifying any specific learning disabilities. Consequently, the student did not qualify for special education. As it asserted, FAPE (free and appropriate public education) had been denied. The Supreme Court held the school system liable for reimbursement of the student's private education expenses since the public school had not met T.A.'s educational needs. ADHD had been discussed by the school but no evaluation of this issue had been conducted. Further, the limited evaluation missed the disability and resulted in limited interventions. The evaluation only addressed whether the student qualified as specific learning disabled and did not address *all* areas related to suspected disability *regardless* of category. Issues related to attention and executive functioning had been passed off as motivational issues. A private, more in-depth psychological evaluation found cognitive and neuropsychological deficits in auditory memory and discrimination, sequential processing, language formation, retrieval and expression, organization, processing speed, and fluency. Beyond academic insult, these processes were identified as having affected more broad processes including organizational ability, note taking, and work completion. Identification of these issues resulted in a more complete intervention plan. This case highlighted the inadequacies of solely using restrictive methods for qualification in students with specific learning disorders. The additional issue raised by this case was that using the assessment only to determine qualification did not identify underlying *reasons* for not responding to the school's intervention which would have yielded more precise interventions (Dixon, Eusebio, Turton, Wright, & Hale, 2010).

Despite the value of fuller cognitive evaluations that the Forest Grove School District v. T.A. highlights, the use of IQ assessment as part of the diagnostic process in the discrepancy model has been called into question. With the last reauthorization of the Individuals with Disabilities Education Improvement Act (IDEIA) in 2004, Response-to-Intervention (RTI) came to the forefront as a replacement model. RTI is defined as a multi-level method of problem-solving and preventions system that uses data-based decidion making and progress monitoring prior to the identification of special education services. The key components are screening, progress monitoring, data-based decision making, and multi-level prevention system (http://www.rti4success.org/). Use of cognitive assessment as relates to intervention, best use of staff resources, and the restructuring of assessment models was called into question. However, RTI has yet to consider the influence of cognitive variables such as working memory and processing speed (Reynolds & Shayowitz, 2009). A distinguished panel of experts in the cognitive assessment and learning disabilities fields recently published a white paper concurring that neither model alone is effective in making determinations of learning disabilities (Hale et al., 2010). Methodological issues have been noted in both models in determining services for students. Additionally, the authors argue against global interpretations and use of Full Scale IQ's because they are an aggregate of disparate cognitive constructs. Use of the FSIQ when indexes are discrepant confounds and underestimates *g* making for faulty decisions, which are often critical in determining services for students. The FSIQ with clinical groups can obscure meaningful differences between groups of children preventing identifying groups solely on the basis of a particular pattern (William, Weiss, Rolfhus, 2003). Thus, these results support that Index scores provide greater interpretive value for referred students when considering learning issues (Flanagan, McGrew, & Ortiz, 2000). Further, using theoretical structure allows different tests from different batteries to be used so there is better loading on theoretical factors, which can provide a more comprehensive and validity-based evaluation of cognitive functioning. This method of idiographic interpretation and theoretically driven hypotheses of underlying cognitive factors is additionally supported by Hale, Fiorello, Kavanagh, Holdnack, and Aloe (2007) as well as Reynolds and Shayowitz (2009). It is consistent with the third method noted in the statutes, which makes provisions for considering processing strengths and weaknesses within the student's performance.

As mentioned previously, Reynolds and Shaywitz (2009) argue that RTI has many of the same methodological problems the point-discrepancy models have had, viz. vagueness in definition, variability and subjectivity of methodology and implementation, inconsistent progress monitoring models, the lack of knowledge regarding proper assessment and measurement procedures, as well as varying methods of employment as dictated by State Education Agencies (SEA) and Local Education Agencies (LEA). A one-size-fit all conceptualization is also perpetuated in addition to the aforementioned reliability and validity issues. These were all short-comings that also plagued the ability-achievement method. Fuchs, Deshler, and Reschly (2004) further state concerns over the variability in classification criteria in identifying learning disabilities under differing discrepancy formulas. Fuchs, Fuchs, and Compton (2004) suggest the use of different measurement systems using different criteria have resulted in the identification of different groups of children. This continued implementation of a one-size fits all model, "fails to recognize that there are psychological processes involved in learning" (Reynolds & Shaywitz, 2009, p. 132-133). Disability then becomes, "defined in the context of the classroom and not the individual. Both point-discrepancy and RTI have all too often contained vagueness in identifying psychological cognitive processes that would allow for greater understanding the student, enhancing the data collection process, and subsequently better intervention planning.

Hale, Kaufman, Naglieri, and Kavale (2006) advocate a position that recognizes the importance of RTI and the data gathering it requires. The positive side of RTI is that it has made evidence-based intervention mandated for children at-risk. Reynolds and Shaywitz (2009) state acknowledge that RTI has assisted a number of learners including learners who are slower in their learning and who would be left out in the qualification process in the point-discrepancy model. However, the importance of comprehensive evaluations as part of the identification process seems critical particularly when considering the individuality of psychological processes involved in learning. Reynolds and Shaywitz (2009) further state that the non-use of IQ assessment in the process ignores the notion that cognitive processes are somehow unrelated to learning and how instruction is carried out. They further make the point that assessment of cognitive abilities can and do contribute to instructional planning. They advocate that the purpose of a comprehensive evaluation assists with deriving hypotheses about *why* a child may not be responding to intervention. This *is* the intent of evaluation and the third method- addressing learning difficulties regardless of etiology that are intrinsic to the child and that would assist with intervention planning. This is in alignment with the White Paper by the Learning Disabilities Association. Hale et al. (2010) notes the use of repeat measures to scrutinize individual cognitive processes provides *current* and *on-going* information contributing to improvements in planning and implementing educational and academic interventions. Repeat cognitive assessment stresses the importance of tracking cognitive development in referred populations and that diagnostic information obtained from such assessments can add value to the intervention process.

5.7 The Third Method

The aforementioned proponents - representative of cognitive assessment, educational and neuropsychological fields point out that cognitive and neuropsychological assessment using a process approach is the only method that provides underlying reasons for a child’s learning problems, which is most aptly addressed through the third method. Statute 34 CFR Parts 300 and 301 of the Federal Register states that, “300.309(a)(2)(ii) permits, but does not require, consideration of a pattern of strengths and/or weaknesses, or both, relative to intellectual development if the evaluation group considers such information relevant to the identification of SLD” (http://www2.ed.gov/legislation/FedRegister/finrule/2006-3/081406a.pdf , p. 46651). Hale, et al. (2010) states it allows for assessment of discrete cognitive processes and focuses more closely on a student’s strengths and weaknesses, which may be causing a child to have difficulties processing information including their ability to respond to interventions. This same group advocates that considering cognitive functioning within the third method perspective emphasizes individual processes as relates to learning. Flanagan, Fiorello, and Ortiz (2010) note this is the only method in place that provides for a processed approach to evaluation. This may be best assessed by examining variability of information processing within context of repeat cognitive assessment, which further allows for examining these processes over time. Repeat assessment additionally takes into consideration the influence of development in processes that operate differently at different ages. The consideration of a more processed approach to assessment encourages the merging of theory to guide test interpretation, which is in line with contemporary influences in testing and the structure of the CHC theory (Flanagan, McGrew, & Ortiz, 2000).

The CHC theoretical influence with cognitive functioning is reflected in revisions of cognitive measures such as the WISC-IV as well as the Woodcock-Johnson-III Cognitive Battery and others. Process methods include Cognitive Hypothesis Testing and the Concordance- Discordance Model. This latter model for assessing children takes into account neuropsychological factors as well as development and is based on a Lurian model using CHC theory (Hale & Fiorello, 2004). There are also process approaches by Kaplan (1988) and the WISC-IV Integrative Process Approach (Miller & Hale, 2008). These methods and others are designed as a means of targeting specific processes that underlie academic issues aligning the relationship of cognitive strengths and weaknesses with academic strengths and weaknesses that would provide greater specificity regarding the development of interventions for such students.

5.8 Cognitive Intervention

This research offers some support for considering cognitive intervention within the RTI model and reassessment of cognitive functioning. The LDA White Paper (Hale, et al, 2010, p 6) advocates that assessment of cognitive and neuropsychological processes should not only be used for identification but also intervention. This has been a criticism of neuropsychological assessments in education- their relevancy to intervention planning. Hale, Kaufman, Naglieri, and Kavale (2006) demonstrated in a case study of how cognitive assessment as part of RTI can utilize cognitive assessment methods in a more active and targeted way with a student who was not responding to typical RTI methods. They demonstrated how information obtained from cognitive assessment-in this case the WISC-IV was used in the ”concordance-discordance” model for assessment and intervention. This was used to not only hypothesize about underlying processes contributing to difficulties with learning, but then followed up with specific, targeted interventions to improve difficulties with attention, self-monitoring, spatial-motor construction, and social skills. Certain processes within a more individualized design targeted the student's underlying cognitive issues that were interfering with his learning both individually and within the regular classroom.

Cognitive intervention might also be considered in a more prominent role vs. the frequent use of medication to treat children. The changes and often addition of multiple medications during a course of rapid cognitive development is disturbing. It speaks to the importance of addressing cognitive issues early on so that second assessments yielding additional difficulties might be lessened obviating the need for more medications. In an editorial from Blakemore and Bunge (2012), the authors note cognitive intervention through neuroscience and education is foraging a new partnership in showing how understanding the biology of the developing brain learns new information can better inform intervention in education. Examples such as video gaming and meditation, as well as specific cognitive training programs designed to strengthen working memory and other executive functions are offered for consideration. There is a plethora of brain games and other cognitive simulations out today designed to address strengthening various cognitive functions- e.g., Cog Med, Luminosity, etc. as well as neurofeedback. Nirvi (2012) also notes how research in brain-science is beginning to be used in the educational setting. He cites several private schools and higher institutions where brain science is being used in the classroom to affect changes in educational performance e.g., meditation, self-instruction. One such example of a brain training program is Brain Ware Safari - a video game learning environment that is designed to build memory skills, visual and auditory processing, thinking, and sensory integration. Findings from one school district noted a three year, one month improvement on cognitive tests after using the program for 12 weeks.

Clearly, possibilities for educational and instructional design research are rich in the area of cognitive learning via the medium of videogame environment. These efforts are consistent with Ceci (1991) who noted in a meta-analytic study that there is a strong association between the enhancement of cognitive function and schooling. While there are others who suggest there is lack of evidence for transfer (Melby-Lervag & Hulme, 2012), efforts in developmental and neuroscience fields in conjunction with research in education and instructional design suggest there is potential in use of cognitive intervention. This is where the cutting edge of where neuroscience and education can meet especially with working memory (Melby-Lervag & Hulme, 2012).

Specific work in working memory is gaining prominence and much research is being conducted in this area. Jonides notes the particular importance of working memory stating that working memory and cognitive control allows us to selectively process information from the environment and to use that information for problem solving and reasoning (http://www.nytimes.com/2012/04/22/magazine/can-you-make-yourself-smarter.html). They point out that while there is a genetic component to IQ, at least 20-50% of the variation in IQ is due to other factors, school, social, family, SES, circumstances. Jaeggi, Buschkuehl, Jonides, and Shah (2011) stress the importance of cognitive training particularly training working memory since working memory underlies so many cognitive areas. In a study involving 76 elementary school-age children, they demonstrated improved fluid reasoning using a videogame-like working memory training task where the individual was required to remember a previous symbol, location, or audio sound that preceded the present screen in comparison to controls who only engaged in a knowledge-based task. The high training group additionally showed transfer to measures of G*f*. These results remained intact as measured three months later even after training had stopped. Jaeggi, Studer-Luethi, Buschkuehl, Su, Jonides, and Perrig (2010) additionally found similar results for transfer of ability. Loosi, Buschkuehl, Perrig, and Jaeggi (2010) further demonstrated that training working memory can improve reading skills in elementary students with just two weeks of working memory training Such studies are beginning to show that intensive cognitive training can alter brain function and boost specific cognitive skills. Also, studies are beginning to show that benefits from cognitive training can lead to neural changes and that these benefits can transfer to untrained tasks (Buschkuehi, Jaeggi, & Jonides, 2012). These studies suggest that cognitive intervention and educational research is a place of contribution where findings of variability of information processing might be addressed. It further suggests that teachers play a prominent role with regards to interventions with referred students regardless of whether the student qualifies at the first evaluation or not at all.

5.9 The Role of the Teacher

For educators, the findings of lower processing speed in referred children at second evaluation has implications for cognitive load in instruction - a prominent theory in educational psychology, and use of instructional methods such as Gagne'. Such methods focus on addressing information processing issues within instructional design in the regular classroom and where these children have to function. It has great implications for pace of instruction in the regular classroom as well as remedial instruction with these children. It also stresses paying additional attention to factors of information processing such as repetition and pace in the design of instruction. Such methodology can benefit children who may struggle with working memory, as they may easily forget instructions, steps in problems and other tasks, putting information down on paper, difficulties taking notes, etc.

The nature of the multi-disciplinary team and the role of the classroom teacher within the educational setting in particular can also be further enhanced through the third method process. Dynamic assessment is a term originally coined by Luria but based upon Vygotsky's framework of using assessment for purposes of instruction that intertwines these two processes in a much more intimate way (Poehner & Lantolf, 2010). This method is different from psychometric methods that view cognition as a static entity. According to Luria, the psychometric method inappropriately assumes a person's performance on a test represents a complete picture. From the second perspective, intelligence and intellectual functioning is viewed more as *states* that are in the process of forming.

The use of dynamic assessment and the Zone-of-Proximal Development (ZPD) also by Vygotsky (Gredler & Shield, 2008) forms the basis of assessment that is more *collaborative* between student and adult. It is more process oriented, designed to influence cognitive development, and provide instruction that *leads* development. What becomes much more important is what a person can do *with* the assistance of someone else. They not only benefit in completing the present task but are then able to transfer what has been internalized through this mediated process to other tasks (Poehner & Lantolf, 2005). Assessment takes on greater cooperative meaning, as assessment tasks are worked through together by mediating the student's performance through performance prompts, hints, leading questions, etc. This allows the adult to understand what processes are emerging or developing within the child thus providing information about *future* (potential) development.

Within the educational field this provides unity between theoretically-driven assessments that has great implications for referred children who may demonstrate great variability in processing information. It can provide greater specificity for how such processes may be interacting with skill acquisition. This processed approach can contribute much to the assessment process as a whole. Examples that incorporate this process approach include the Learning Potential Assessment device (LPAD), which is based upon the theory of Structural Cognitive Modifiability and Mediated Learning Experience (Feurstein, 1985). This unit of analysis moves beyond the student to *interaction* and *instruction* as the focus.

5.10 Implications for Further Research

To further assess variability of information processing across development with Working Memory and Processing Speed among referred populations, current research could be extended to include three administrations. There were several students who had been evaluated multiple times. One had been evaluated with the WPPSI, WISC-R, WISC-III and then WISC-IV. Two others had been evaluated with the WISC-III before being evaluated twice with the WISC-IV and one student had been evaluated three times with the WISC-IV. This could additionally highlight the influence of neurodevelopmental gains (or not), interventions including special education, cognitive interventions, medication influence, and examining growth curves in tracking changes in children with developmental disorders. Given the gaining prominence of cognitive brain training today and particularly what is being demonstrated between neuroscience and education, it would be useful to explore repeat measurement in conjunction with interventions before and after reassessments of intellectual and cognitive functioning. The advantage of following individuals who have been exposed to such interventions in determining whether these types of interventions have transfer of learning has the potential to impact learning and education in a broad way.

5.11 Limitations

While this research used group means which is often criticized for obscuring individual differences, the use of repeat measurement added an additional design factor for the individual to serve as their own control through repeat measures. Regardless, closer inspection of performance over time based upon different age groups would have provided additional information about performance in these groups across time. Examining age differences and patterns through growth learning curves would have been additionally fruitful although was also beyond the scope of this research. Additionally, the use of age-based norms may reduce some differences seen and affect generalizability of findings for other clinical samples. This is a factor characteristic of norm-referenced tests.

That there was missing information regarding medication is also unfortunate although not entirely uncommon. Greater specifics would have allowed for additional contrasts to be examined although many children's medications were often changed in between assessments. Parents may not always know what, how much, and for how long their child took a particular medication and whether they were taking it at the time of the first evaluation. This only adds importance to repeat assessment and whether this information is known at the second evaluation or not since referred populations such as students with ADHD may often experience medication changes even within the elementary time period. Additionally, medication effects produce changes in cognitive assessment and the classroom. This can limit generalizability of findings due to the specific medications noted with this population.

Regarding the issue of inter-rater reliability and administration of the WISC-IV, the author recognizes that variability of different examiners is a potential confound in a repeated measure design; however, it is also recognized that the realities of IQ assessment in the real world often includes different examiners. This is often the case with referred students who may access different intervention services over the course of their childhood. That they can be assessed in a variety of places and times is a factor that is recognized by the author. Even the very standardization of an instrument and one with a national sample as the WISC-IV includes the use of different examiners.   Examiners qualified to administer the WISC-IV have received specific training through graduate programs, which require a certain level of proficiency or competence in accordance with APA (American Psychological Association) standards.   However, the author acknowledges that there can be differences in how diagnosticians make diagnoses of psychiatric/psychological disorders. For this sample, 19 of the 75 students were tested by the same evaluator and 56 were tested by different evaluators. So, while training regarding administration of the WISC-IV requires certain standards in training programs, the author acknowledges that focus of training may vary with level of program as does the experience of the clinician once they are evaluating children in the community. Additionally, employment of diagnostic criteria may vary between medical doctors vs. psychologists based upon paradigm differences in training.

Ecological validity is also limited to students who perform within the IQ range included for this research study. Subsequently, results may not extend to students in the Borderline or below as well as Superior ranges of intelligence. The author acknowledges there are many psychological/cognitive processes that influence learning and intellectual functioning even beyond those that are noted here and that not all could be accounted for.

5.12 Conclusions

The current research study hopefully highlights the variability of information processes like working memory and processing speed and how important it is to track such processes. This information is particularly crucial when considering issues with referred and clinical populations. Such information is additionally important when there is the added influence of medications and co-morbidity as well as thinking about how all these processes may be operating within the context of a child's age and development. Repeat cognitive assessment acknowledges the many variables that can influence assessment. Examining children's performance across time suggests that cognitive functioning may be vulnerable to many circumstances and issues. Additionally, marked drops in particular with Processing Speed performance between assessments is also an indicator of concern. Of interest is what instruction a student has missed out on and/or lost as a result of delayed services such as needed interventions, identification of strategies for keeping up and coping when students do not qualify, and/or changing accommodations. The importance of additionally considering cognitive intervention would also seem to have broad learning implications during a prominent cognitive period of development. Using static as well as dynamic types of assessment methodology to further explore cognitive processes may contribute more fully to understanding the child, their cognitive process, and its influence in the intervention process. It would make the multi-disciplinary approach a richer, more fruitful experience. Stability of information processing cannot be assumed.

Lastly, this research highlights the importance of full evaluations in decision making regarding referred populations and heightens the responsibility of schools and evaluators to conduct assessments that address ALL aspects of the referral concerns. It hopefully contributes to better understanding referred populations, as first evaluations have the potential to affect a child's ability to engage in intervention and classroom instruction. Examining variability of information processing takes into account the premise that Wechsler did not view and define intelligence in terms of *capacity* but rather *performance* and acknowledges that these processing states change over time. The WISC-IV was not developed to measure the end quantity of one's intelligence but rather how one performed on a test of intellectual functioning. Considering intelligence as a performance variable is in keeping with Wechsler's definition of an individual's ability to adapt to the environment and constructively solve problems. Added to this is the understanding that children can perform quite variably during a significant and rapid time of cognitive development, and that it is important to understand how a child is currently functioning when making important decisions about their educational life. Given the variability of cognitive processes as evidenced here, these results support Kaplan's initially stated proposition that cognitive functioning and intellectual development in children involves a process that indeed unfolds over time.

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