RELATIONSHIP AND COLLECTIVE IMPACT OF ATTENTION, PROCESSING SPEED, AND WORKING MEMORY: VALIDATION OF THE COGNITIVE FACILITATION/INHIBITION DOMAIN OF THE INTEGRATED SNP/CHC MODEL

A DISSERTATION

SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF PH.D. IN SCHOOL PSYCHOLOGY

IN THE GRADUATE SCHOOL OF THE

TEXAS WOMAN'S UNIVERSITY

DEPARTMENT OF PSYCHOLOGY AND PHILOSOPHY

COLLEGE OF ARTS AND SCIENCES

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AUGUST 2014

ACKNOWLEDGMENTS

This document along with the accomplishment and labor it represents was made possible largely by the support offered by my husband, Richard Goodnight. You have been my closest friend and strongest supporter throughout this process. No other person knows quite as well as you the nature of that accomplishment and labor as I experienced it. Secondarily, this document was made possible via the perpetual votes of confidence I received from the women who believed in me before there was any valid reason for that belief: Mrs. Dixie Fournier, Ms. Alyson Fournier, Dr. Denise Maricle, Dr. Jennifer Morrison, and Dr. Marsha Gabriel. The support I received from my friends and cohort-mates, Ms. Angela Canas and Mrs. Cristina Petrini Sevadjian, was also integral to this process. Finally, I owe some amount of gratitude for this accomplishment to my father, Dr. Donald C. Fournier. I hope there is some way you can know how greatly you have positively influenced me; and, I hope somehow this gives you peace.

ABSTRACT

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AUGUST 2014

A great deal of research has focused upon the relationship between attention and working memory (WM; Cowan, 2010a; Oberauer & Bialkova, 2009) and WM and processing speed (PS; Fry & Hale, 2000; Kail, 2007; Nettelbeck & Burns, 2010). Each of these neurocognitive constructs has been viewed by numerous researchers as supportive of higher-order cognitive processes; however, the relationship between attention, PS, and WM is rarely investigated (Fry & Hale). In recognition of the consistencies between these three constructs, a recent model of pediatric neuropsychological functioning proposes a relationship between attention, PS, and WM. The Integrated School Neuropsychological (SNP)/Cattell-Horn-Carroll (CHC) model suggests that neuropsychological functioning can be tapped by assessing across four, broad domains of neurocognitive functioning including sensorimotor functions, cognitive facilitators/inhibitors, basic cognitive processes, and acquired knowledge (Miller, 2013). The cognitive facilitation/inhibition domain is hypothesized to be composed of attention, PS, and WM which act in concert to enable or constrain higher-order cognitive processes. The purpose of this study was to first examine the relationship between attention, PS, and WM. Secondarily, the collective impact of these three constructs upon basic cognitive processes was investigated. The data used in this study were culled from an archival database containing neuropsychological case studies submitted as part of the Kids, Incorporated School Neuropsychology Post-Graduate Certification Program. Only those scores associated with measures of cognitive facilitation/inhibition and basic cognitive processes were used in the current study. Confirmatory factor analysis and structural regression modeling were conducted in order to determine the relationship between and collective impact of attention, PS, and WM. The findings suggested that there was no meaningful relationship between these three neurocognitive constructs; however, a significant relationship between attention and WM was observed. The results also revealed that attention and WM were predictive of a number of basic cognitive processes outlined in the Integrated SNP/CHC model including visuospatial, auditory, and executive processes. Taken together, this indicated that the aspects of the Integrated SNP/CHC model examined for validation were not entirely supported or refuted. Additional research is necessary in order to substantiate the current findings and further validate the Integrated SNP/CHC model.

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CHAPTER I

INTRODUCTION

The field of pediatric neuropsychology has its roots in two broad disciplines including medicine and psychology (Lajiness-O'Neill, Pawluk, & Jacobson, 2011). Diverse medical fields that influenced the development of pediatric neuropsychology include neurology and pediatric medicine. With regard to psychology, pediatric neuropsychology has been greatly influenced by child clinical psychology, school psychology, and adult clinical neuropsychology. Specific interest in pediatric neuropsychology developed in the 1970s and resulted in a definition of the field that distinguished it from other fields in psychology. Pediatric neuropsychology was defined as "the elucidation of brain-behavior relationships in the developing human organism" (Rourke, Bakker, Fisk, & Strang, 1983, p. 3). Even with this universally accepted definition, comprehensive conceptualizations of pediatric neuropsychological functioning have mostly been the result of downward extensions of conceptualizations of adult neuropsychological functioning. Despite this trend, several useful models of pediatric neuropsychological functioning have been set forth.

Historically, conceptualizations related to pediatric neuropsychological functioning have recognized the existence of several broad, distinct domains of neurocognitive functioning (Baron, 2004; Koziol & Budding, 2011). These domains have traditionally included language, attention, executive functioning, learning and memory, sensorimotor, speed of processing, and those that are visual, perceptual, and spatial. Most researchers and clinicians in pediatric neuropsychology agree children and adolescents should be assessed within each of these domains in an effort to generate useful academic, behavioral, and social/emotional recommendations for intervention. At the forefront of the development and inclusion of these domains within comprehensive conceptualizations of neuropsychological functioning was Aleksandr Luria (Lajiness-O'Neill et al., 2011).

Luria (1973) suggested that the brain is organized into three major units that operate in a hierarchical fashion. These units were believed to be connected to specific structures or regions within the brain. The first unit, referred to as Unit I, controlled basic physiological arousal and attentional processes. In line with the hierarchical nature of the units, deficient functioning in Unit I resulted in deficient functioning across the other units. Unit II was responsible for taking in environmental or sensory information and packaging that information in a useful way. Finally, Unit III was conceptualized as the output or planning unit. Commonly referred to as the executor of the brain, this unit allowed for higher-order cognitive functioning to occur. Luria hypothesized the existence of three zones within this unit referred to as the primary, secondary, and tertiary zones. The output and planning associated with these zones increased in complexity as information moved from the primary to tertiary zone; thus, output associated with the tertiary zone was characterized by planning, decision-making, and logic. In contrast, the primary zone was characterized by simple motor output. Although Luria's approach to assessment was more qualitative in nature, he attempted to assess for the intactness of primary, secondary, and tertiary functions. Thus, assessing across and within broad domains of functioning such as sensorimotor, attention, language, and executive functioning was of paramount importance.

Despite the emphasis on qualitative assessment associated with Luria's (1973) approach, neuropsychology in North America has been more influenced by the standardized approach to assessment (Lajiness-O'Neill et al., 2011). This influence is largely attributable to the work of Ralph Reitan. Consistent with Lurian theory, Reitan developed the *Halstead-Reitan Neuropsychological Test Battery for Older Children* (HRNB-C; Reitan & Wolfson, 1992) and the *Reitan-Indiana Test Battery for Children* (RIT-B; Reitan & Wolfson) as a method of assessing across broad neuropsychological domains within the pediatric population (Johnson & D'Amato, 2011). However, these test batteries reflected downward extensions of their predecessor, the *Halstead-Reitan Neuropsychological Test Battery* (Reitan & Wolfson, 1993), developed for use with adults (Johnson & D'Amato). Nonetheless, the HRNB-C and RIT-B have been found to assess within sensorimotor, memory, attention, executive functioning, and visual-spatial domains. In response to the popularity of the standardized approach to assessment, the *Luria-Nebraska Neuropsychological Battery: Children's Revision* (LNNB-C; Golden, 1987) was developed (Golden, 2011). The purpose of this battery was to formally standardize Luria's approach to neuropsychological assessment for clinical use with the pediatric population. As with the HRNB-C and RIT-B, the LNNB-C represents a downward extension of its adult counterpart, the *Luria-Nebraska Neuropsychological Battery* (Golden, 1978). However, the LNNB-C has been found to assess across customary neuropsychological domains within the pediatric population (Golden, 2011).

Although consistent with traditional neuropsychological theory, the previously mentioned batteries were not devised specifically for use with the pediatric population. The *NEPSY: A Developmental Neuropsychological Assessment* (Korkman, Kirk, & Kemp, 1998) was the first comprehensive neuropsychological battery containing content that was developmentally appropriate for use with the pediatric population (Davis & Thompson, 2011). Largely based on Lurian theory, this battery allowed for assessment across broad neuropsychological domains including attention, executive functioning, language, sensorimotor, visuospatial, and learning and memory. Now in its second edition (Korkman, Kirk, & Kemp, 2007), this battery continues to assess pediatric neuropsychological functioning across typical broad, neurocognitive domains. The structure of each of the aforementioned test batteries is reflective of the traditional and predominant conceptualization of pediatric neuropsychological functioning which includes an emphasis upon the existence and impact of several broad and separable domains.

More recently, a comparatively novel approach to the conceptualization of pediatric neuropsychological functioning has emerged from the subfield of school neuropsychology (Miller, 2013). School neuropsychology can be viewed as an area of specialization within the broader field of school psychology given the focus of clinical practice becomes more specific (Miller, 2010a). Thus, individuals practicing school neuropsychology possess an adequate working knowledge of school psychology and neuropsychology such that this knowledge is effectively applied to practice (Witsken, Stoeckel, & D’Amato, 2008). Currently, this area of interest has been described as the application of neuropsychological knowledge to assist in the understanding of behavioral difficulties with school-age children. This knowledge should also assist in the ability to link methods of instructional delivery to brain-based techniques. In addition, principles of neuropsychology should serve to illuminate students' individualized styles of learning in line with their individual patterns of cognitive strengths and weaknesses.

Support for the integration of school psychology and neuropsychology dates back to the late 1960s; for example, Gaddes authored a book entitled *A Neuropsychological Approach to Learning Disorders* in 1968 which emphasized the need for integration between these fields (Hynd, Quackenbush, & Obrzut, 1980). However, the term school neuropsychology was formally coined by Hynd and Obrzut (1981) who are considered the first authors to definitively describe the benefits of integrating the fields of school psychology and neuropsychology. These authors described a school neuropsychologist as a professional capable of generating recommendations that reflect differential assessment of cognitive abilities, engaging in screening procedures that identify students with neurologically-based learning differences, and consulting with other psychologists such that differential diagnosis is facilitated. These authors proposed a model of functioning for school neuropsychologists within the public school system. They suggested two areas of specialization within the field consisting of school neuropsychometrists and school neuropsychologists. School neuropsychometrists would function at the masters- or specialist-level and focus on assessing brain-behavior relationships; and, school neuropsychologists would function at the doctoral level and "determine program eligibility, design appropriate curricula, and consult with teachers" (Hynd & Obrzut, p. 48).

Since this proposal by Hynd and Obrzut (1981), numerous developments related to the specialization of school neuropsychology have occurred. Although not consistent with Hynd and Obrzut's proposed model of professional functioning, guidelines for certification related to the practice of school neuropsychology have been developed (Miller, 2010b). These guidelines are provided by the American Board of School Neuropsychology (ABSNP) which was established in 1999. This board issues a "peer-reviewed credential that certifies entry-level competency in school neuropsychology" (Miller, 2010b, p. 28). Those interested in receiving this credential can obtain holistic training in school neuropsychology through the School Neuropsychology Post-Graduate Certification Program. Encompassed within this training is exposure to a comprehensive model of assessment within the area(s) of pediatric or school neuropsychology. Initially referred to as the School Neuropsychology Conceptual Model (SNP; Miller, 2007), this conceptualization of pediatric neuropsychological functioning was largely consistent with traditional conceptualizations. Thus, this model purported to assess across several broad areas of neuropsychological functioning including sensorimotor functions, attention, visuospatial functions, language functions, learning and memory, executive functions, and speed and efficiency of cognitive processing. Also in line with traditional conceptualizations, these domains were considered separable and discrete.

This model was recently reconceptualized resulting in a comparatively novel proposal related to pediatric neuropsychological functioning (Miller, 2013). The

Integrated School Neuropsychological (SNP)/Cattell-Horn-Carroll (CHC) model is still characterized by the need to assess across broad neuropsychological domains; however, the nature of these domains differs qualitatively from those noted in more traditional conceptualizations of pediatric neuropsychological functioning. The Integrated SNP/CHC model suggests that cognitive processes act to influence acquired knowledge; however, both of these domains are impacted by cognitive facilitators/inhibitors. Additionally, basic sensorimotor capabilities act to influence the two broad domains of cognitive processes and acquired knowledge. Finally, each of these domains exists within a specific social/emotional and cultural environment that would likely act to influence these processes (see Figure 1.1). In this way, the Integrated SNP/CHC model hypothesizes the existence of four broad neuropsychological domains within which children may be assessed. These domains include basic sensorimotor functions, facilitators and inhibitors for cognitive processes and acquired knowledge skills, basic cognitive processes, and acquired knowledge.

The sensorimotor domain of the Integrated SNP/CHC model is largely consistent with traditional neuropsychological conceptualizations of sensorimotor functions (Miller, 2013); however, the cognitive facilitators/inhibitors domain represents a significant shift from customary neuropsychological models. This domain encompasses specific aspects of attention, processing speed (PS), and working memory (WM; Miller). The Integrated SNP/CHC model hypothesizes that these three processes act in concert to support or constrain cognitive processes and acquired knowledge. More traditional models of neuropsychological functioning conceptualize PS as representing its own domain or factor; however, PS exists under the broader rubric of cognitive facilitators/inhibitors within the Integrated SNP/CHC model. In addition, typical neuropsychological models

Figure 1.1 Integrated School Neuropsychological (SNP)/Cattell-Horn-Carroll (CHC) Model

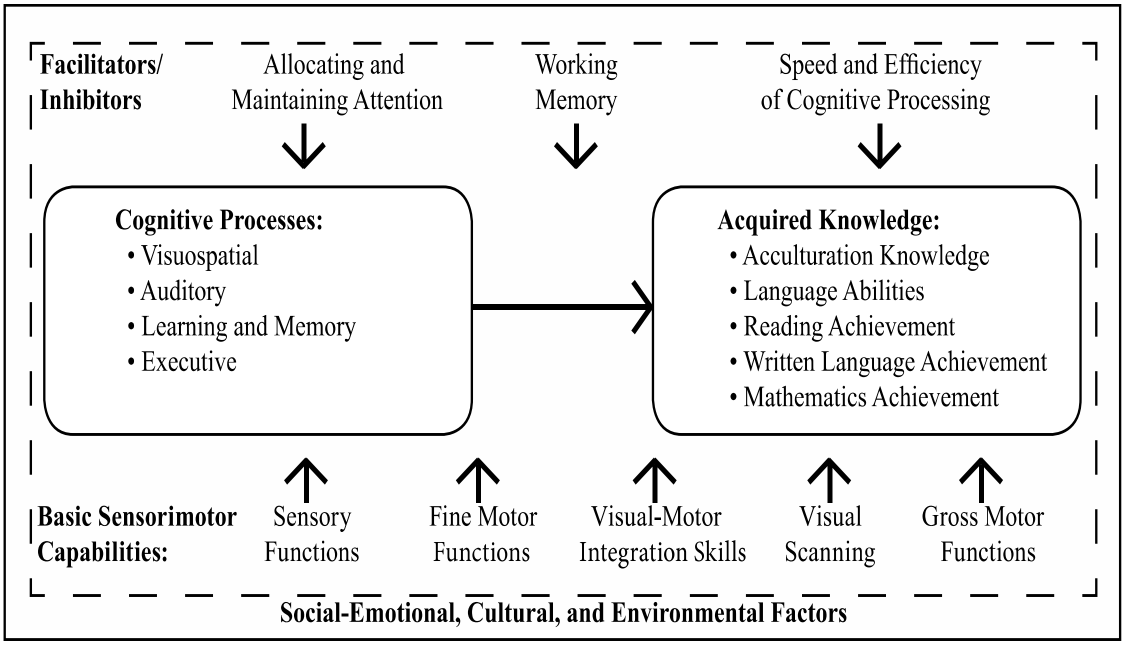

Figure 1.1. Schematic of the Integrated SNP/CHC model (Miller, 2013)

cluster all attentional and memory processes under two broad factors including attention and learning and memory, respectively. In contrast, the Integrated SNP/CHC model suggests that aspects of attention and memory function as cognitive facilitators/inhibitors. Specifically, allocation and maintenance of attention and working memory are included within this domain.

The broad domain of cognitive processes in the Integrated SNP/CHC model includes visuospatial functions, auditory functions, executive functions, and learning and memory (Miller, 2013). This conceptualization also represents a step away from traditional neuropsychological models in that each of these subdomains was typically represented as a distinct and separable broad aspect of functioning with the exception of auditory processes. Auditory processes have typically been considered an aspect of sensorimotor functions. Finally, the acquired knowledge and skills domain encompasses acculturation knowledge, language functions, and academic achievement. Again, traditional broad domains including language functions have been reconceptualized within the Integrated SNP/CHC model as a subdomain existing within an overarching domain. This model considers acculturation knowledge to be consistent with semantic memory; however, this has typically been considered an aspect or subdomain of learning and memory in more traditional models of neuropsychological functioning. Based upon this information, the Integrated SNP/CHC model represents a novel approach to the conceptualization and assessment of pediatric neuropsychological functioning.

Given the innovative nature of the model, it becomes important to evaluate the utility and validity of the Integrated SNP/CHC model (Brown, 2006; Kline, 2005). Validation of an original model of pediatric neuropsychological functioning allows for the responsible and ethical use of the model among clinicians seeking to thoroughly assess and intervene with children experiencing academic, behavioral, and social/emotional dysfunction. Intervention is largely driven by assessment and the accurate interpretation of assessment results; thus, intervention can only be as effective as the assessment from which it arises (Sattler & Hoge, 2006). In this way, the validation of new models of pediatric neuropsychological functioning can facilitate accurate assessment, interpretation, and intervention. Given the complexity of the Integrated SNP/CHC model, it seems prudent to attempt to validate this model in a systematic way; thus, specific aspects of the model can be initially evaluated in isolation. One strikingly unique component of the model in comparison to traditional neuropsychological models that lends itself well to validation is the cognitive facilitators/inhibitors domain.

Purpose, Rationale, and Significance of the Proposed Study

The purpose of the current study was to first examine the relationship between attention, PS, and WM. The relationship between PS and WM has been investigated extensively (Fry & Hale, 2000; Kail, 2007; Nettelbeck & Burns, 2010). In addition, the relationship between WM and attention has received much focus in the literature (Cowan, 2010a; Oberauer & Bialkova, 2009). However, the relationship between all three constructs is rarely investigated; thus, examination of this relationship represented initial research in this area. Additionally, examination of the relationship between attention, PS, and WM evaluates the efficacy of the broad domain of cognitive facilitators/inhibitors within the Integrated SNP/CHC model. This serves as validation of and preliminary research associated with an aspect of this model.

In order to investigate the relationship between attention, PS, and WM, a confirmatory factor analysis (CFA) was conducted. CFA is conducted within structural equation modeling (SEM), which allows for the expected factor structure of a specific set of data to be pre-determined based upon previous research and theory (Brown, 2006). Thus, theoretical models can be used to specify in the forefront relationships between observable and latent variables associated with the target theoretical models. This allows for comparison across theoretical models with regard to utility and efficacy as demonstrated by a specific data set.

This study was also being conducted in order to determine whether attention, PS, and WM act to support or constrain basic cognitive processes. A goal of this research was to determine whether these three constructs actually act as cognitive facilitators/inhibitors as suggested by the Integrated SNP/CHC model (Miller, 2013). This represents premier research in the further validation of the cognitive facilitation/inhibition domain of this model. In order to determine the collective impact of attention, PS, and WM upon basic cognitive processes, a structural regression (SR) model was executed. This statistical procedure is also considered an aspect of SEM; however, it builds upon CFA such that relationships between factors can be specified (Fabrigar & Wegener, 2009; Kline, 2005). CFA allows for only the specification of relationships between variables; thus, SR modeling provides information related to both the measurement and structural model associated with the Integrated SNP/CHC model. This allows for evaluation of the utility and efficacy of the cognitive facilitators/inhibitors domain associated with this model as demonstrated by a specific data set.

Research Questions

Based upon a review of the literature which establishes a rationale for this study, the following research questions were addressed:

1. Is the relationship between attention, PS, and WM best described by:
    a. A theoretical model wherein attention, PS, and WM produce three separate and distinguishable factors, or

b. The Integrated SNP/CHC model (Miller, 2013) wherein attention, PS, and WM are hypothesized to represent one construct referred to as cognitive facilitators/inhibitors?

2. Is the impact of attention, PS, and WM upon cognitive processes described well by:

    a. The integrated SNP/CHC model wherein attention, PS, and WM function together to facilitate or inhibit cognitive processes in a consistent, predictable manner?

CHAPTER II

REVIEW OF THE LITERATURE

The investigation of the relationship between attention, processing speed (PS), and working memory (WM) and the impact of these constructs upon cognitive processes requires foundational knowledge with regard to each of these constructs in isolation; further, current information regarding the nature of the relationship between these cognitive abilities would be necessary. This chapter first provides a broad overview of attention, PS, and WM focusing upon defining and describing these constructs. In doing so, conceptualizations of each will be introduced followed by research related to neurological substrates supporting these cognitive abilities. The developmental trajectories for each will also be presented. Next, research associated with the relationship between these constructs and their collective impact on cognitive processes will be discussed. Following this, the Integrated School Neuropsychological (SNP)/Cattell-Horn-Carroll (CHC) model will be introduced (Miller, 2013). Finally, the purpose and rationale of the current study will be reviewed.

Overview of Attention

Despite extensive research within the area, a standard or universal definition for attention has not been developed (Goldstein, Jansen, & Naglieri, 2011). Investigation of attention has been described as a "complex field of study" given the majority of research has indicated attention is not a unitary construct (Goldstein et al., p. 252). The complexity of this construct has been recognized since the late 1800s when William James characterized attention as bimodal in nature. Since that time, numerous theorists have developed definitions of attention; for example, Titchener (1924) described attention as a "pattern of consciousness arranged into focus and margin, foreground and background, and center and periphery" (Goldstein et al., 2011, p. 253). The vast majority of definitions set forth by theorists investigating attention has reflected the complexity and multimodal nature of the construct. This complexity likely contributes to the difficulty in establishing a universally accepted definition for attention.

Conceptualizations of Attention

A number of models of attention have been developed based predominantly upon the results of factor analytic studies utilizing assessment measures believed to tap into attention. Most typically, these conceptualizations discuss aspects or subdomains of attention including selective or focused attention, sustained attention, shifting attention, divided attention, and attentional capacity (Baron, 2004; Miller, 2013). Selective or focused attention refers to the ability to maintain attention to a task despite the presence of distractors. Within the field of neuropsychology, this term encompasses the ability to both focus attention on a task and to execute a response (i.e., focus/execute) as a result of that focused attention. Sustained attention can simply be described as cognitive vigilance or the ability to attend to a task for lengthy periods of time. The ability to maintain cognitive flexibility and shift smoothly across varying cognitive tasks refers to shifting or alternating attention. In contrast, divided attention represents the ability to simultaneously respond to multiple tasks. Although not as consistently noted in the literature, attentional capacity involves cognitive load. This subdomain of attention refers to the amount of incoming information an individual can successfully manage through use of attention.

Although not based on factor analytic studies, Posner and Peterson (1990) hypothesized the existence of three systems that support attention including orienting, selection, and alerting. These systems are posited to correlate with various neuroanatomical structures creating specific networks. The selection system or network can be viewed as the conscious attention system given it controls where attention is focused; more recently, this network has been referred to as the executive network. The orienting network is responsible for directing spatial attention and moderating sustained attention; and, the alerting network is consistent with sustained attention allowing for the maintenance of attention over time. Thus, the orienting network directs attention while the alerting network sustains attention. A neuropsychological model was developed by Mirsky, Anthony, Duncan, Ahearn, and Kellum (1991) through use of factor analysis which conceptualized attention as consisting of four subdomains including focused execution of attention (i.e., focus/execute), sustained attention, the encoding of information, and shifting of attention. Further research with Mirsky et al.'s model indicated that five factors were more appropriate; thus, the ability to consistently maintain attentional effort (i.e., stabilize) represents an additional subdomain (Baron, 2004). Sohlberg and Mateer (1992) identified a model of attention somewhat consistent with that of Mirsky et al. based upon work with individuals with traumatic brain injury (TBI). They noted five factors consisting of focusing, sustaining, selecting, alternating, and dividing; however, this model has received little attention in the literature (Goldstein et al., 2011). Other researchers have described a three-factor model of attention consisting of visual-motor scanning and shifting, immediate attention, and sustained effort (Picano, Klusman, Hornbestel, & Moulton, 1992).

The Integrated SNP/CHC model represents a comprehensive theory of neuropsychological functioning that encompasses attention (Miller, 2013). Within this model, attention is considered the cornerstone upon which higher-order cognitive processes are built such as learning and memory and executive processes. This model organizes constructs hierarchically into three categories including broad, second-order, and third-order classifications. Attention is broadly classified as a cognitive facilitator/inhibitor within this model; however, the focus here is only on the allocation and maintenance of attentional resources. Cognitive facilitators/inhibitors are those cognitive abilities that act to support or constrain basic cognitive processes. The second-order classifications making up attention include selective/focused, sustained attention, and attentional capacity. This second-order conceptualization of attention is somewhat consistent with the five-factor model identified by Mirsky et al. (1991); however, Mirsky et al.'s model does not include a factor suggestive of attentional capacity. This is likely related to the fact that tasks examining attentional capacity were not included in the factor analysis conducted by Mirksy and colleagues (Miller). Attentional capacity was included in the Integrated SNP/CHC model given it "has a direct relationship with the cognitive capacity or load required on memory tasks" (Miller, p. 4). The Integrated SNP/CHC model and the Mirsky et al. model also differ with regard to the categorization of shifting attention. Shifting attention is considered a subdomain of attention within the Mirsky et al. model whereas this ability is classified as an executive process in the Integrated SNP/CHC model.

The third-order classifications of attention within the Integrated SNP/CHC model focus on auditory and visual aspects of selective/focused and sustained attention (Miller, 2013); thus, the ability to focus and maintain attention may differ based upon the nature of incoming information. Third-order classifications associated with attentional capacity include memory for words or numbers, sentences, and stories. Although this classification involves memory, the focus here would be upon manipulation of contextual information; for example, memory for isolated information such as words and numbers involves minimal or no contextual information. In contrast, the ability to immediately recall a sentence or details of a story involves the use of some context. Thus, memory for material wherein the amount of contextual information with which one is presented is systematically changed can provide information related to attentional capacity. The various theories of attention reviewed here differ somewhat with regard to the subdomains identified and used to describe attention; however, each is similar in that the complex nature of the construct is emphasized.

Neurological Substrates

Given the multifaceted nature of attention, it has been suggested that multiple areas of the brain support various subdomains of attention (Baron, 2004; Goldstein et al., 2011). It seems intuitive that attention cannot be mediated by any one neuroanatomical structure or region given the complexity of the construct. The relatively early models of attention, such as that developed by Posner and Peterson (1990), were based upon the premise of direct relationships between aspects of attention and neuroanatomical regions. In line with Posner and Peterson's model, investigation of neurological substrates has largely focused upon the role of neural networks in mediating attention; however, the role of specific neuroanatomical structures has also been investigated. Despite preliminary evidence of the influence of certain neuroanatomical regions in supporting various subdomains of attention (Baron), definitive identification of key neural regions is lacking; however, many neuroanatomical substrates have been recognized (Goldstein et al.; Posner, Sheese, Odludas, & Tang, 2006).

Subdomains of attention have been hypothesized to be supported by various cortico-striatal-thalamic-cortical (CSTC) loops (Blumenfeld, 2011; Stahl, 2008). These loops are responsible for connecting areas of the prefrontal cortex to subcortical regions of the brain. In this way, information is sent to lower-order structures within the brain; however, higher-order structures receive feedback regarding how this information was processed. Specifically, areas of the prefrontal cortex will send information to the striatal complex followed by the thalamus. The thalamus then projects back to the original area of the prefrontal cortex allowing for feedback. Numerous theorists investigating attention have placed emphasis upon the importance of CSTC loops or neural networks in the mediation of attentional processes (Miller, 2013; Posner & Peterson, 1990; Posner et al., 2006). Miller points out the importance of frontal-subcortical pathways or networks that connect the reticular activating system to higher cortical regions such as the prefrontal and anterior cingulate cortices. Posner and Peterson conceptualized the three systems included in their model as networks; thus, the anterior cingulate and supplementary motor areas have been hypothesized to support the executive network. The orienting network is believed to be supported by the posterior parietal lobe, superior colliculus, and lateral pulvinar nucleus of the posteriolateral thalamus. The anterior and prefrontal regions of the right hemisphere are believed to be supportive of the alerting system.

Other subdomains of attention, such as selective and sustained attention, may also be supported by CSTC loops (Blumenfeld, 2011; Stahl, 2008). Selective attention may be modulated via a CSTC loop referred to as the selective attention circuit. This circuit originates in the dorsal anterior cingulate cortex and projects to the lower striatum followed by the thalamus. This structure, in turn, projects back to the dorsal anterior cingulate cortex. Symptoms of inattention such as distraction, forgetfulness, and negligence of detail are indicative of deficient or inefficient activation of this circuit. In contrast, the CSTC loop responsible for regulating sustained attention originates in the dorsolateral prefrontal cortex. This area of the prefrontal cortex projects to the rostral or top portion of the caudate followed by the thalamus. Finally, information is projected back to the dorsolateral prefrontal cortex allowing for feedback. Deficient or inefficient activation of this loop results in general difficulty sustaining mental effort.

Although the importance of neurocircuitry has been emphasized, various neuroanatomical regions have received focus as well. Areas of the prefrontal cortex such as the dorsolateral prefrontal cortex have been found to play a role in attentional processes outside of their influence upon CSTC loops (Blumenfeld, 2011; Stahl, 2008). The prefrontal cortex can be conceptualized as existing along an arousal spectrum wherein activation of the structure can be deficient, adequate, or excessive. Activation of the prefrontal cortex is associated with the firing of dopaminergic and noradrenergic neurons; thus, deficient dopaminergic and noradrenergic firing results in hypoactivation of the prefrontal cortex. In contrast, excessive dopaminergic and noradrenergic firing leads to hyperactivation of this structure. Ironically, both hypo- and hyperactivation of the prefrontal cortex can lead to symptoms of inattention.

Another neuroanatomical region implicated in attention in its own right is the anterior cingulate cortex (Blumenfeld, 2011; Stahl, 2008). Although usually considered part of the prefrontal cortex, symptoms of inattention arising from this region typically are not the result of hypo- or hyperactivation; rather, these symptoms are more related to inactivation of the anterior cingulate cortex. Appropriate activation of this region is mediated by dopaminergic and noradrenergic neurons. Given a failure to increase firing when confronted with tasks of selective attention, the anterior cingulate cortex remains at baseline rather than reaching normal or appropriate activation. This inactivity within the anterior cingulate cortex results in symptoms of inattention. It deserves mention that discussion of the neuroanatomical regions implicated in attention underscores the role of neurophysiological processes in regulating attentional processes.

Developmental Trajectory

Although mature attentional processes exhibit a somewhat protracted course of development, various aspects of attention are apparent in early infancy (Goldstein et al., 2011). A number of models of attention discuss the development of these processes and most agree that this process begins neonatally. Despite the emphasis on divergent subdomains of attention across these models, each focuses on the differential development of those subdomains; thus, aspects of attention "come on-line" or are available for use at a neurological level at various times throughout development. The ability to deliberately direct attention comes on-line to some extent during infancy (Blondis, Snow, Stein, & Roizen, 1991). This is preceded by an improvement in the capacity to control eye, hand, and body movements; thus, as attentional control becomes less stimulus-bound, the infant can engage in basic directed or selective attention. In contrast, the alerting network associated with the Posner and Peterson (1990) model of attention is hypothesized to develop within the first year of life (Rueda et al., 2004); thus, a minimal capacity for sustained attention may also be apparent during infancy.

During the toddler and preschool years, attention can be described as exploratory in nature (Goldstein et al., 2011). Although children within this age range are better able to direct and sustain attention given improvements in motor control, attentional selection and focus remains tied to the external environment; thus, attention will be directed and maintained upon interesting environmental stimuli. The orienting network of the Posner and Peterson (1990) model may come on-line during the preschool years; however, this network was found to remain unchanged between the age of six and adulthood (Rueda et al., 2004). In addition, the executive network may also be available for use during the preschool years. Interestingly, this network was also found to remain unchanged between the age of seven and adulthood; however, this may be related to the relative simplicity of the tasks in which people have been asked to engage when examining these networks. In general, children are able to respond to environmental stimuli with regard to attention in a more systematic way during the preschool years; thus, impulsive behaviors in response to environmental stimuli eventually give way during middle childhood to behaviors that are goal-directed and task-oriented.

By middle childhood, most typically-developing children are able to adequately utilize selective and sustained attention (Goldstein et al., 2011). In other words, children within this age range are able to selectively attend to environmental stimuli based upon need and interest. They are able to successfully ignore extraneous stimuli such that problem solving and social functioning is facilitated. The ability to engage in these and other attentional processes despite differing environmental expectations continues to improve throughout the lifespan given that additional cognitive processes, such as executive functioning, continue to develop and expand. In summary, aspects of attentional processes are apparent within the first year of life. These aspects continue to improve throughout childhood as additional subdomains of attention begin to emerge. The development and maturation of additional cognitive processes accounts for differences between attentional processes noted in children versus adults. It is also important to note that the developmental trajectory of attention may be impacted by the social environments to which a child is exposed and his or her neurobiological makeup (Berger, Kofman, Livney, & Henik, 2007); thus, this trajectory would be true for children who are average or typically-developing.

Overview of Processing Speed

Although PS has been considered an important cognitive process since the late 1800s, the field of psychology continues to lack a universally accepted definition for this construct (Ball & Vance, 2008; DeLuca, 2008). The formal measurement and recording of speed of processing dates back to Sir Francis Galton's anthropometric laboratory established in the 1800s (O'Brien & Tulsky, 2008). Despite receiving extensive attention in the literature since that time, PS has been described as an imprecise term with numerous meanings (Ball & Vance; DeLuca). Most typically, this construct has been defined operationally or methodologically resulting in the lack of a conceptual definition. Likely related to the difficulty in establishing a common definition is the multidimensional nature of PS; thus, this construct can seemingly be defined in multiple ways. Early researchers such as James McKeen Cattell noted the presence of around seven forms of what he referred to as mental speed. More recently, PS has been found to be composed of both simple and complex components (Chiaravalloti, Christodoulou, Demaree, & DeLuca, 2003); however, this characteristic of PS is rarely appreciated in the literature or in clinical settings.

Conceptualizations of Processing Speed

Comprehensive conceptualizations or working models of PS are typically not included within broader theories of cognitive processes (DeLuca, 2008). Although this construct is discussed within theories of intelligence, this discussion is typically atheoretical and based upon a methodological or operational definition of PS. Thus, few comprehensive models of PS exist which is likely related to the previously discussed lack of a consistent definition for this construct; however, some useful conceptualizations have recently been set forth.

Early researchers such as Galton and Wundt utilized reaction time as the sole measure of PS (O'Brien & Tulsky, 2008). Consistent with their reductionist ideals, this conceptualization emphasized the early viewpoint that PS was unitary in nature. Later researchers continued to utilize reaction time as a method of investigating PS; however, research demonstrated that reaction time was correlated to a statistically significant degree with both timed and untimed cognitive tasks (Vernon & Kantor, 1986). This research represented a preliminary step in the later recognition of the complex nature of PS; nonetheless, the predominant conceptualization of this construct remained simplistic and unitary. Jensen (1981) later developed the Choice Reaction Time paradigm as a method of describing the observed relationship between PS and other cognitive abilities (O'Brien & Tulsky). This paradigm suggested reaction time was a combination of decision time and movement time. Decision time was defined as the time required to react to stimuli whereas movement time reflected the time required to physically respond to stimuli. Although this paradigm was criticized in the literature, it represents an early model of PS that emphasized the multidimensional nature of the construct. However, in response to the Choice Reaction Time paradigm, the concept of inspection time was developed (O'Brien & Tulsky). This has been defined as "the duration of exposure to a stimulus necessary to make a simple visual discrimination with certain [(e.g., 97%)] accuracy" (O'Brien & Tulsky, p. 11). This ability has been considered a more pure measure of mental speed in comparison to choice reaction time; thus, many researchers continued to view PS as simply consisting of one component.

More recently, continued investigation and increasingly sophisticated research techniques have led to the development of two comprehensive, multidimensional models of PS (Miller, 2013; Schneider & McGrew, 2012). The CHC model of cognitive abilities proposes that these abilities are arranged into three hierarchical classifications referred to as strata; thus, stratum III reflects general abilities, stratum II refers to broad abilities, and stratum I denotes narrow abilities (McGrew & Evans, 2004; Schneider & McGrew). This model of cognitive functioning contains a cognitive speed of processing hierarchy wherein a general cognitive speed factor is hypothesized to exist at stratum III. The stratum II or broad abilities believed to make up cognitive speed include PS, reaction and decision speed, and psychomotor speed. Thus, PS represents one aspect of cognitive speed in this model; however, this construct is hypothesized to be composed of narrow or stratum I abilities reflecting the multidimensional nature of PS. These abilities include perceptual speed, rate of test taking, number facility, reading speed, and writing speed. Perceptual speed refers to the rate at which visual stimuli can be scanned, while rate of test taking refers to the rate at which simple, cognitive tests can be completed. The final three narrow abilities associated with PS in the CHC model are hypothesized to assist in the quick completion of basic academic skills.

The Integrated SNP/CHC model utilizes a similar hierarchical categorization of cognitive abilities wherein PS is broadly classified as a cognitive facilitator/inhibitor (Miller, 2013). The second-order classifications associated with PS include performance fluency, retrieval fluency, acquired knowledge fluency, and fluency and accuracy. Performance fluency refers to the ability to rapidly complete a simple cognitive task and is made up of six third-order classifications. These classifications include psychomotor fluency, perceptual fluency, figural fluency, naming fluency, rate of test taking fluency, and oral motor fluency. The second-order classification of retrieval fluency is defined as the rate at which information can be pulled from long-term memory. This ability is composed of two third-order classifications including word fluency and semantic fluency.

Acquired knowledge fluency represents an additional second-order classification of PS in the Integrated SNP/CHC model and can be described as the ability to quickly and efficiently complete academic tasks (Miller, 2013). It is supported by four third-order abilities such as reading fluency including both phonological and morphological decoding, writing fluency, and mathematics fluency. The final second-order classification making up PS is fluency and accuracy. This second-order classification refers to the ability to complete a cognitive task in both a timely and accurate manner. There are no third-order classifications hypothesized to exist in support of fluency and accuracy. As demonstrated here, the conceptualization associated with PS has become more multifarious over time such that this construct is currently viewed as a complex, multifaceted ability that supports numerous aspects of speeded cognitive tasks.

Neurological Substrates

Consistent with the multidimensional nature of PS, it is likely that no single neural substrate can support this ability (DeLuca, 2008; Salthouse & Madden, 2008). Rather, a complex neural network connecting multiple areas of the brain is likely responsible for supporting PS. Although neurological mechanisms are not well understood, research has focused upon the impact of neural circuitry and aspects of neural wiring (Mahurin, 2008; Posthuma & de Gues, 2008). Other research has focused upon the role of regional brain volume and neurophysiology in supporting PS (Salthouse & Madden).

Based on research with individuals with subcortical disorders (i.e., multiple sclerosis, Tourette's syndrome), which commonly result in slowed PS, it appears that CSTC loops may be involved in the moderation of this cognitive process (Blumenfeld, 2011; Mahurin, 2008; Stahl, 2008). Given PS can encompass motoric speed (i.e., psychomotor fluency), it is important to emphasize the role of motor CSTC loops. Certain CSTC loops are connected to various nuclei within the basal ganglia which are a collection of subcortical nuclei important for motor control; however, these structures can also regulate attention and emotion (Blumenfeld; Carter, 2009). Neural circuits of relevance for motoric PS include the skeletomotor pathway which connects the primary and supplementary motor areas to the basal ganglia (Blumenfeld; Mahurin; Stahl). These structures then project to the thalamus which provides feedback to the primary and supplementary motor areas. Disruption to this loop may result in psychomotor slowing or agitation; thus, this loop likely plays a role in psychomotor speed and fluency.

The oculomotor loop is an additional motoric CSTC circuit likely important for the efficient completion of speeded cognitive tasks (Blumenfeld, 2011; Mahurin, 2008). This circuit is responsible for controlling saccadic and smooth pursuit eye movements; thus, disruption of this circuit will result in difficulty with visual scanning and tracking. The oculomotor loop projects from the frontal eye fields to the basal ganglia followed by the thalamus. This structure then projects back to the frontal eye fields where feedback is provided. It is also important to mention the role of the basal ganglia in supporting motor PS outside of its influence upon CSTC loops. Individuals with subcortical lesions primarily impacting the basal ganglia have been found to exhibit impaired performance on measures of PS; in addition, more severe lesions were correlated with poorer performance (O'Brien et al., 2002).

Speed of information processing may also be supported by structural aspects of neural mechanisms (Mahurin, 2008; Posthuma & de Gues, 2008). Central nerve conduction velocity refers to the speed with which an action potential travels along the neuron in the central nervous system. Neurons represent the primary communication cells within the brain; and, action potentials are the mechanism by which these cells communicate. Thus, central nerve conduction velocity refers to the speed of communication within the brain. Increased central nerve conduction velocity would theoretically result in increased PS (Posthuma & de Gues). The speed of nerve conduction has been found to be a function of nerve diameter and myelination. Myelin refers to a sheath or coating of proteins that encapsulates the axons of neurons giving them their characteristic white appearance (Kolb & Whishaw, 2009). This myelination is responsible for efficiently conducting action potentials; thus, white matter tracts facilitate communication within the brain. Messages are sent via saltatory conduction as the signal jumps from gaps in the myelin sheath along the axon known as nodes of Ranvier. This type of conduction, which is facilitated by myelination, is responsible in part for the ability to quickly react to various stimuli.

The general integrity of white matter throughout the brain has been found to be supportive of PS in its own right apart from other structural aspects of the brain (Bendlin et al., 2010; Felmingham, Baguley, & Green, 2004; Salthouse & Madden, 2008). Research has demonstrated that individuals with impaired white matter tracts including elderly adults, those with demyelinating disorders (i.e., multiple sclerosis), and those with TBIs characterized by axonal shearing, commonly exhibit impaired PS. The structural integrity of white matter tracts can be impacted by tearing or disintegration (i.e., volumetric loss) both of which impede the conduction of the action potential along the axon. Impediments to this process result in slower information processing speed; however, further research in this area is needed. Additional structural aspects of the brain that may impact PS include the number of ion channels present within a neuron and the general efficiency of synaptic transmission (Posthuma & de Gues, 2008). Much less information is known about these neurological mechanisms and their relationship to PS; however, it is likely that individual differences in these mechanisms are genetically determined.

Although preliminary, research has suggested that regional brain volume may play a role in PS (Salthouse & Madden, 2008). Most research has focused upon age-related volumetric loss in the prefrontal region of the brain. This has been noted for both prefrontal gray- and white-matter; however, these substances have been found to decline at different rates among the aging population. Research has also indicated a relationship between decreased PS and volumetric loss within other regions including the parietal cortex, cerebellum, caudate, and hippocampus. Other neurobiological variables that may be associated with PS are related to neurotransmitter activity (DeLuca, 2008; Salthouse & Madden). The number of dopamine D_2 receptor sites within areas of the brain, particularly the caudate and putamen, may be supportive of PS; thus, those with fewer receptors have been found to exhibit slower PS. In summary, much information regarding the neural mechanisms involved in PS has been gleaned; however, a significant amount of additional research is required in order to better understand the neural substrates for this construct.

Developmental Trajectory

The ability to complete various cognitive tasks in a timely and accurate manner has been found to increase substantially with age (Kail, 1991). Presumably, these tasks have tapped multiple processes across studies including cognitive, perceptual, and linguistic abilities (Kail & Miller, 2006). This has led to some debate as to whether the ability to rapidly complete diverse tasks represents improvements in task-specific abilities or an underlying improvement in a more global mechanism. The majority of research has suggested that the ability to complete diverse cognitive tasks in a quick and efficient manner is more related to underlying improvements in a global, biologically-driven mechanism such as PS (Kail & Ferrer, 2007; Kail, 2008).

The developmental trajectory associated with PS has been found to produce a nonlinear, U-shaped curve (Kail, 2008). Given this trajectory, PS is comparatively slow during infancy and throughout the first few years of life (Rose, Feldman, & Jankowski, 2002); however, moderate increases in PS have been noted even within the first 12 months. Consistent with a nonlinear progression, speeded information processing has been found to improve significantly during early and middle childhood (Kail, 1991, 2008). This exponential improvement is likely supported by practice, experience, and developmental changes impacting the brain.

The ability to quickly process information improves among the pediatric population when they are allowed to practice (Kail, 2008); thus, initial responding is slow and laborious. As children become more familiar with a task, retrieval of relevant information becomes increasingly automatic; hence, PS increases. Speeded performance may also be the result of increases in expertise. As children gain more experience with various cognitive tasks thereby acquiring expertise, they are able to utilize more pathways in the brain in order to access task-relevant information. Neurological changes associated with development likely also support increases in PS. In line with the concept of synaptic pruning, the number and nature of neural connections change with age such that information processing becomes more efficient (Kolb & Whishaw, 2009). Age-related changes in myelination have also been found to result in increased PS (Kail). Finally, volumetric changes in gray- and white-matter such that these substances are more similar to that noted in young adults have been associated with increased PS.

Following middle childhood, PS continues to improve; however, the rate of improvement becomes slower (Kail, 1991, 2008). Moderate improvements continue throughout late childhood and early adolescence. As children reach middle or late adolescence, their PS ability is similar to that noted in young adults. This asymptote in skill likely represents neurological maturation; however, some improvements in PS may be supported by additional practice and expertise within a specific area. This developmental trajectory is relevant for children who are neurotypical given research suggests that children who have sustained acquired or traumatic injuries to the central nervous system exhibit a disrupted pattern of development with regard to PS.

Overview of Working Memory

Numerous theorists have developed definitions for WM and although the wording may vary, the gist of the definitions remains consistent (Maricle, Miller, & Mortimer, 2011). In general, WM involves the active, mental manipulation of information in order to complete some cognitive task. This cognitive ability is critical for overall cognition and specific cognitive and academic functions (Conklin, Salorio, & Slomine, 2008). The WM system is hypothesized to unite the short- and long-term memory systems, and to include aspects of both storage and control (Maricle et al.). Thus, WM is at times considered to represent an aspect of the memory system; however, there are many researchers who consider WM to be an aspect of executive functioning (i.e., Barkley, 2012; McCloskey & Perkins, 2012). Despite having a relatively consistent definition in the literature, multiple conceptualizations of WM have been proposed.

Conceptualizations of Working Memory

The term WM was initially used in 1960 in an essay discussing how activities or tasks are planned and executed (Miller, Galanter, & Pribram). Since that time, several more comprehensive conceptualizations of WM have been set forth (Cowan, 2010a). Atkinson and Shiffrin (1968) proposed a model of WM which suggested that this ability assisted in the shuttling of information to and from long-term memory. In this model, information moved into the WM system from sensory memory; thus, various aspects of memory were viewed as more static in nature (Maricle at al., 2011). The Atkinson and Shiffrin model was considered predominant for a number of years; however, little research is currently conducted on this model. Nonetheless, following this early conceptualization of WM, understanding and descriptions of this ability have become more sophisticated.

A comprehensive model of WM that has dominated the literature related to memory is that developed by Baddeley and Hitch (1994). Considered a multicomponent model of WM, this model hypothesizes the inclusion of several systems that act in concert to support WM (Fry & Hale, 2000; Maricle et al., 2011). These components include the central executive, phonological loop, visuospatial sketchpad, and episodic buffer. The central executive allocates resources such as attention and processing to both the phonological loop and visuospatial sketchpad; thus, this component can be viewed as the boss of the WM system. The phonological loop and visuospatial sketchpad are viewed as slave systems to the central executive that process different types of sensory information. The phonological loop is responsible for the processing of verbal information. Incoming verbal information is susceptible to loss over time or due to interference unless the information is continuously rehearsed and transferred to long-term memory.

The visuospatial sketchpad encodes information that is presented nonverbally (Fry & Hale, 2000; Maricle et al., 2011). This system operates analogously to the phonological loop in that encoded information may be lost due to time or interference unless transferred to long-term memory; however, this subsystem utilizes information related to form and location of an item in space. The role of the episodic buffer is to combine information from the phonological loop and visuospatial sketchpad. This subsystem forms a multimodal code or combination of information from different sensory modalities; in addition, incoming sensory information is combined with previous long-term memories to impact WM. Research has supported the presence of various slave or subsystems well-aligned with the phonological loop and visuospatial sketchpad (Cabeza & Nyberg, 2000).

An additional influential model of WM includes Cowan's embedded process theory which was proposed as an alternative to Baddeley's (1994) multicomponent model of WM (Cowan, 2010a). This model of WM incorporates aspects of Baddeley's model such as the phonological loop, visuospatial sketchpad, and central executive; however, these systems have been reconceptualized as a method of correcting issues that may be associated with Baddeley's model. Cowan's model of WM suggests that the phonological loop and visuospatial sketchpad simply represent a temporary activation of information already included in long-term memory stores. This information is considered multimodal and can include sensory, phonological, orthographic, and semantic features. The role of the central executive is to search long-term memory stores as a method of gaining information regarding incoming stimuli. Although less emphasized in the mainstream literature related to memory, Cowan's theory has resulted in a number of additional embedded process theories of WM.

The Integrated SNP/CHC model also encompasses the construct of WM and provides a comprehensive conceptualization of this ability related to assessment (Miller, 2013). This construct is broadly classified as a cognitive facilitator/inhibitor in that it theoretically acts to support or constrain basic cognitive processes described in the Integrated SNP/CHC model. The second-order classification associated with WM as a cognitive facilitator/inhibitor simply includes general WM. Conceptually consistent with the Baddeley and Hitch (1994) model of WM, the Integrated SNP/CHC model hypothesizes the existence of two third-order classifications of WM including verbal and visual WM (Miller, 2013). Thus, verbal WM can be viewed as consistent with the phonological loop while visual WM is similar to the visuospatial sketchpad. The implication of such a third-order classification is that the ability to actively mentally manipulate information may differ depending upon whether incoming information is visual or auditory in nature.

Neurological Substrates

An area of the brain that has been implicated in mediating WM includes the dorsolateral prefrontal cortex (Curtis & D'Esposito, 2006; Stahl, 2008). This important region of the brain is located within the prefrontal cortex and is believed to play a role in a number of higher-order cognitive functions. However, WM is not mediated by this region alone; rather, the influence of CSTC loops, neurophysiology, and genetic material interact to ultimately impact WM.

Research supporting the role of the dorsolateral prefrontal cortex in facilitating WM has been conducted with populations known to exhibit impaired WM (i.e., those with TBI and schizophrenia) predominantly utilizing the *n*-back task (Conklin et al., 2008; Stahl, 2008). The *n*-back test is typically a computerized cognitive task that requires the examinee to view a series of numbers and engage in specific recall of those numbers. The 0-back variant of the task requires the examinee to recall the number that was just revealed, whereas the 1-back variant requires the examinee to recall the number that was revealed before the number currently depicted. Additional variants, such as the 2- or 3-back tasks, become increasingly difficult with regard to recall. The goal of the task is to cause the examinee to engage in active, mental manipulation of information in order to successfully complete the cognitive task; thus, it is believed this task taps WM. Neuroimaging conducted on individuals completing the *n*-back task demonstrates the role of the dorsolateral prefrontal cortex in supporting successful completion of the task. Those who are better able to complete the task demonstrate more efficient activation of this region of the prefrontal cortex.

Within the CSTC loop supporting WM, the dorsolateral prefrontal cortex can be viewed as the cortical engine that drives the loop; thus, this area of the brain is more important for supporting WM in comparison to other structures involved in the loop (Blumenfeld, 2011; Stahl, 2008). The dorsolateral prefrontal cortex projects to the rostral portion of the caudate which then projects to the thalamus. This structure projects back to the dorsal lateral prefrontal cortex allowing for feedback associated with the completion of cognitive tasks. Deficient or inefficient activation of this loop may result in generally inefficient information processing; thus, WM may be impacted. This loop is predominantly activated through use of dopaminergic neurons. Increased firing of these neurons results in hyperactivation of the dorsolateral prefrontal cortex, whereas decreased firing results in hypoactivation of this region. Hyperactivation of the dorsolateral prefrontal cortex results in the recruitment of more neuronal resources; in contrast, hypoactivation results in decreased engagement and sustainment of the dorsolateral prefrontal cortex. When activation of this region is inappropriate, information processing becomes inefficient despite direction (i.e., hyper versus hypo) of that activation.

The ability of the brain to appropriately utilize dopamine within the dorsolateral prefrontal cortex depends to a significant extent upon genetic makeup (Blumenfeld, 2011; Stahl, 2008). Given the relationship between this region of the brain and dopamine, this has clear implications for WM. In order for dopamine to function properly within the brain, it must be metabolized through use of an enzyme referred to as catechol-O-methyl transferase (COMT). This enzyme is responsible for breaking down or metabolizing dopamine within synapses of the dorsolateral prefrontal cortex; thus, low COMT activity results in increased levels of dopamine. Although everyone possesses two copies of the gene responsible for the production of COMT, some individuals produce a variant of the gene that significantly reduces enzymatic activity. Individuals with two copies of this gene exhibit low levels of COMT; thus, WM capacity is improved due to comparatively higher cortical levels of dopamine. Neuroimaging studies have demonstrated more efficient activity in the dorsolateral prefrontal cortex among those with two copies of the low-COMT gene while completing the *n*-back task. In contrast, those with one or two copies of the high-COMT gene experienced significant difficulty with the *n*-back task.

Areas of the brain that may support subdomains of WM warrant mention given the clear distinction between verbal and visual aspects of this construct within predominant models of WM (i.e., Baddeley & Hitch, 1994). Studies involving neuroimaging suggest that tasks of WM involving visual stimuli typically activate the right inferior temporal lobe (Curtis & D'Esposito, 2006). In a similar vein, tasks of WM that can be considered more spatial in nature have been found to activate diffuse frontal parietal networks. In contrast, WM tasks that are more verbal in nature tend to activate frontal premotor and inferior parietal regions. Although much information is available regarding the neurological mechanisms supporting WM, it is clear that additional research in this area is needed.

Developmental Trajectory

As with numerous other cognitive constructs, WM has been found to improve significantly with age (Cowan, 2010a; Gilchrist, Cowan, & Naveh-Benjamin, 2009). With regard to developmental studies, this cognitive ability is typically tapped via examination of WM capacity; thus, the number of separate units, or chunks, of information that can be recalled is assessed. When individuals become neurologically mature, they can typically recall between three and five chunks of information; however, there has been some debate as to whether improvements in WM capacity are more related to the number of chunks recalled or the relative size of each chunk (Gilchrist et al.). The majority of research has suggested that the overall number of chunks recalled is more related to increased WM capacity given minimal change in the average size of these chunks throughout the lifespan. However, numerous researchers maintain that the size of chunks of information continues to change with age thereby impacting WM capacity. Regardless of this distinction, it is clear that changes to this capacity occur across the lifespan (Cowan, 2010a). Although few studies exist that examine the development of WM, some information regarding the developmental trajectory of this construct is available.

Evidence of WM has been observed within the first year of life (Reznick, Morrow, Goldman, & Snyder, 2004). Longitudinal research utilizing the delayed-response task has demonstrated significant improvement in WM throughout the latter half of that first year. The delayed-response task requires an infant to locate via gaze a hidden item following a delay and distraction. Through use of this task, research has demonstrated that WM may come on-line during the sixth month of life. In these studies, WM capacity has not been evaluated, but rather the general presence of WM. In addition, this type of study clearly relates to nonverbal (i.e., visual or spatial) WM; thus, the age at which verbal WM becomes available may differ. It is also important to note that there is some debate regarding whether the delayed-response task adequately taps WM rather than some other aspect or subdomain of memory. Nonetheless, preliminary research suggests infants demonstrate a general capacity for WM during the latter half of the first year of life.

During the preschool years, WM capacity has been found to include around two items (Gathercole & Alloway, 2008). Research has demonstrated that this capacity continues to increase between the ages of 5 and 11. This increase in WM capacity is likely related to general neurological development that facilitates both memory and language (Cowan, 2010b). As children age, they become more likely to utilize memory strategies such as rehearsal and grouping. The ability to quickly repeat or rehearse incoming information facilitates WM such that WM capacity is improved. Children also begin to group the information with which they are confronted into meaningful categories. This grouping can be based upon semantic, phonological, or temporal relationships; thus, strings of seemingly unrelated information can become more meaningful thereby facilitating WM capacity. As children's aptitude for language develops, WM capacity associated with the verbal subdomain of this construct is increased. In addition, improved language skills often facilitate use of memory strategies such as rehearsal given verbal repetition of information becomes more likely. Following age 11, gains in WM capacity begin to plane out (Gathercole & Alloway, 2008). Around the age of 15, adult levels of WM span have been reached.

As with other cognitive constructs, this developmental trajectory would be true for those children who are average or typically-developing. However, there is marked variability in WM capacity even among children who can be considered neurotypical (Gathercole & Alloway, 2008). Given the clear impact of genetic information upon WM, it is likely that this variability may be associated with genetic differences across children (Blumenfeld, 2011; Stahl, 2008).

Attention, Processing Speed, and Working Memory as Cognitive Facilitators/Inhibitors

Based upon the information associated with attention, PS, and WM provided above, it is clear that each of these constructs has been conceptualized as critical in the facilitation and support of higher-order cognitive processes and functional skills (Conklin et al., 2008; DeLuca, 2008; Miller, 2013). Miller has described attention as the foundation upon which all other higher-order cognitive functions rest, while WM has been noted to be pivotal for general cognition and academic functions (Conklin et al.). Speeded information processing has been considered necessary for the efficient completion of advanced cognitive functions and functional or daily living skills (DeLuca). Thus, the supportive role of each of these constructs has been recognized in the literature. In line with this recognition, several models of WM have been proposed that emphasize the supportive role of attention and PS (Cowan, 2010a; Fry & Hale, 2000; Willmot, Ponsford, Hocking, & Schonberger, 2009).

Support-Based Models of Working Memory

The models of WM that emphasize the role of either attention or PS in support of WM capacity will be referred to as support-based models. This descriptor was chosen given these models suggest that WM is substantially limited void of support from other cognitive processes (Cowan, 2010a; Fry & Hale, 2000; Willmot et al., 2009). Although some of these models have previously been discussed, they were not characterized as support-based models; rather, the general features of the models were focused upon.

Several models of WM have suggested that attention is paramount when considering individual differences in WM capacity (Cowan, 2010a; Oberauer & Bialkova, 2009). Cowan argued for the importance of attention in the functioning of WM; more specifically, focused attention was considered to play a significant role in determining which items are held in mind. Cowan's model discusses activated information which refers to information that has been pulled from long-term memory, or verbal or nonverbal incoming stimuli that an individual must utilize in order to complete a task. A certain amount of activated information is in the focus of attention which results in that information being "processed to a greater depth" than information outside the focus of attention (Cowan, 2010a, p. 453). In this way, individuals who are better able to focus attention would exhibit increased WM capacity. Other cognitive theorists such as Oberauer also have viewed the process of attention as critical for WM (Oberauer & Bialkova). However, this theorist has suggested that attention is directed more narrowly than that proposed by Cowan. The model of WM proposed by Oberauer maintains that people are capable of focusing fully on only one item at a time; thus, the focus of attention is more restricted. Nonetheless, the model continues to emphasize the role of attention in supporting WM capacity. Attention has been found to account for around 25% of the variance related to WM among adult populations (Schweizer & Moosbrugger, 2004).

In contrast, Baddeley's multicomponent model of WM has suggested that PS is key to the individual differences noted in WM capacity (Fry & Hale, 2000; Willmot et al., 2009). While this model suggests that attention is essential for the processing of information, it implies that WM capacity is a function of PS rather than attention. Focused attention is certainly required in order to bring sensory information into the central executive; however, the influence of PS is of principal importance. Baddeley's model implies that increased PS results in faster rehearsal of incoming information. The more efficient use of rehearsal within the phonological loop and visuospatial sketchpad enables sensory information to be moved into long-term memory stores more quickly. The movement of information out of the phonological loop and visuospatial sketchpad reduces the chance for loss of information by freeing up additional cognitive resources or space in the subsystems. In this way, WM is facilitated by PS. Speeded information processing has been found to account for between 25% and 64% of the variance related to WM (Fry & Hale; Kail, 2007; Nettelbeck & Burns, 2010).

Clearly, the aforementioned support-based models of WM have not focused upon the joint influence of attention, PS and WM; rather, the differential impact of attention versus PS upon WM has been a central issue. However, the presence of and empirical support for these models highlight the neurological, conceptual, and functional consistencies noted between these constructs; for example, the dorsolateral prefrontal cortex has been found to support both attention and WM (Blumenfeld, 2011; Mahurin, 2008; Stahl, 2008). Similar CSTC loops associated with this region of the brain are also supportive of both of these functions. In addition, the integrity of white matter within the brain has been linked to both PS and WM (Kinnunen et al., 2011). Further, the developmental trajectories associated with each of these cognitive functions generally coincide. Given these consistencies, it is not surprising that several models focusing upon various cognitive functions or general intelligence have emphasized the collective impact of attention, PS, and WM upon those functions and overall intelligence.

Interactional Models of Attention, Processing Speed, and Working Memory

The models emphasizing the communal impact of attention, PS, and WM will be described as interactional models given they focus on the impact of two or more of these constructs acting in concert upon a specific cognitive process or overall intelligence; thus, the interaction between these constructs is viewed as of primary importance. These models can be discussed based upon those that emphasize an interaction between two of these constructs, and those that emphasize an interaction between all three; however, it is prudent to first discuss models that may be considered foundational with regard to the later development of interactional models.

Foundational models. Baddeley's view of PS as critical for efficient information processing is in no way novel. Given the historical emphasis on the role of PS in intelligence, this construct has received specific focus with regard to its influence on general intelligence (O'Brien & Tulsky, 2008). The Fluid Intelligence Hypothesis was an early (i.e., 1980s) postulate developed in an effort to explain the predictive relationship between speeded information processing and overall intelligence. This hypothesis suggests that individuals with increased PS or more efficient cognitive processing are able to work more resourcefully with novel cognitive tasks. A highly similar model referred to as the Neural Efficiency Model has also been proposed by early theorists as a method of explaining the apparently mediating effects of PS upon intelligence. This model suggests that increased PS is valuable intellectually given the confines in storage and processing capacities of human cognitive systems. Hence, individuals who can process information more quickly are better able to complete complex cognitive tasks because they are able to capitalize upon storage and processing capabilities.

A more recent model of PS developed by Salthouse (1996) emphasizes the role of two separate systems in mediating higher-order cognition including the limited-time and simultaneity mechanisms. Salthouse posits that the limited-time mechanism regulates the amount of cognitive operations that can be completed within a finite amount of time; thus, decreased PS results in the completion of fewer cognitive tasks within a given time period. The simultaneity mechanism refers to the idea that information necessary to complete some cognitive operation may no longer be available when that cognitive operation is required. In other words, decreased PS results in the degradation of information needed to complete a cognitive task. This model has received much attention in the literature; however, research has predominantly focused upon the adult population (DeLuca, 2008).

Although not interactional, these models underscore the longstanding viewpoint that adequate PS is necessary for higher-order functioning; thus, it appears theorists have long recognized the role of PS in essentially facilitating or inhibiting higher-order functions. Speeded information processing has been found to account for between 9% and 25% of the variance related to intelligence (DeLuca, 2008), whereas WM has been found to account for between 25% and 92% of this variance (Colom, Rebollo, Palacios, Juan-Espinosa, & Kyllonen, 2004). Attention has been found to account for between 13% and 25% of the variance related to intelligence (Schweizer & Moosbrugger, 2004); however, these studies were conducted with adult samples. Given the clear consistencies between attention, PS, and WM, this has implications for attention, WM, and the development of interactional models.

Models encompassing two constructs. A primary model emphasizing the interaction between two constructs of relevance is the cascade model of cognitive development. The cascade model suggests that age-related improvements in PS trigger the concurrent age-related changes in WM (Fry & Hale, 1996; 2000). This model is consistent with the implications underlying Baddeley’s multicomponent model of WM in that PS ultimately supports WM; however, the cascade model suggests that these age-related improvements in PS and WM act in concert to influence fluid intelligence. Fluid intelligence refers to the ability to engage in problem-solving and reasoning independently of acquired knowledge. Thus, the observed improvements in cognitive abilities from childhood to adulthood may reflect a cascade such that age-related changes in PS impact WM; in turn, these processes collectively impact higher-order cognition such as fluid intelligence. In summary, the cascade model considers the interaction between PS and WM to be of primary importance in general intellectual functioning; thus, impairments in either process would result in diminished fluid intelligence.

An initial study investigating the cascade model of cognitive development by Fry and Hale (1996) examined the relationship between age, PS, WM, and fluid intelligence. Through use of path analysis, these authors found that age-related changes in PS mediated the majority of developmental improvements in WM capacity. These authors also noted that improvements in PS and WM accounted for close to half of the age-related impact on fluid intelligence. A more recent study conducted by Kail (2007) mirrored the results found by Fry and Hale. Through use of structural equation modeling (SEM), the author found that age-related change in PS was linked to increased WM capacity. These processes were in turn linked to improved fluid intelligence as evidenced by an increased capacity for inductive reasoning. The author described PS and WM as representing "one factor driving developmental change in inductive reasoning" (Kail, p. 313). A study conducted by Nettelbeck and Burns (2010) provided additional support for the cascade model through use of SEM. Table 1 provides a direct comparison of the values obtained from these studies.

Models encompassing three constructs. Few interactional models exist that attempt to incorporate and explain the relationship between attention, PS and WM; however, some preliminary models have been set forth. The time-based resource-sharing (TBRS) model proposed by Barrouillet, Bernardin, and Camos (2004) represents a comprehensive conceptualization of WM. These theorists suggest that WM is impacted by both time restrictions and the need to share cognitive resources across neural systems that facilitate WM. Since information held in mind is highly susceptible to decay or

Table 1

Intercorrelations of Age, Processing Speed (PS), Working Memory (WM), and Intelligence across Studies

	Age to PS	PS to WM	WM to Intelligence
Fry & Hale (2000)	-.84	-.54	.38
Kail (2007)	.75	.77	.61
Nettelbeck & Burns (2010)	.84	.82	.87

degradation over time, the WM process inherently suffers from time constraints; thus, WM can be viewed as time-based. The cognitive resource of primary import within the TBRS model is that of attention given it is viewed as responsible for both the mental processing and maintenance of information; thus, attention must be shared between systems responsible for processing and maintaining incoming information.

However, attention represents a limited cognitive resource; therefore, when attention is turned away from memory traces (i.e., maintenance) in order for new information to be processed (i.e., processing), these traces begin to degrade over time

(Barrouillet et al., 2004). Reactivation of these memory traces would require additional attentional resources which are already taxed; however, PS plays a large role in ensuring attentional resources are maintained (Barrouillet, Gavens, Vergauwe, Gaillard, & Camos, 2009). The TBRS model posits that PS determines the time it takes for memory traces to diminish, time allowable to refresh these traces, and the individual speed of reactivation that predicts the efficiency with which these traces are refreshed. In this way, increased PS frees up additional attentional resources which ultimately assist in facilitating WM.

A series of experiments conducted with both adults and children have demonstrated the presence of a resource-sharing process and the impact of time constraints associated with this process (Barrouillet et al., 2004; Barrouillet et al., 2009); thus, the primary aspects of the model have preliminary empirical confirmation. Of particular relevance is an experiment conducted by Barrouillet et al. (2009) explicitly examining the role of PS within the TBRS model. The authors found that individual differences in the reactivation of memory traces could not be completely explained by age-related changes in PS; however, this was considered consistent with their model. Barrouillet et al. asserted that their model underscores the collective role of attention and PS in supporting WM. Based on the TBRS model, it is likely that changes in the rate of activation go beyond age-related changes in PS and are additionally influenced by age-related changes in attention. This makes sense given the developmental trajectory associated with attention wherein older children are better able to shift attention.

The Integrated SNP/CHC model is the successor of the School Neuropsychology Conceptual Model (SNP; Miller, 2007; 2013). The primary purpose of the SNP model was to provide clinicians with a comprehensive method of organizing assessment information according to neuropsychological domain. In doing so, this model attempted to simplify interpretation of assessment data and assist in the establishment of a clear connection between assessment and intervention practices that are evidence based. In addition, the model sought to provide clinicians with a standardized method of assessing children with medically-complex diagnoses within the educational setting; thus, this model can be considered highly assessment oriented.

The SNP model consisted of seven broad neuropsychological domains within which children could be assessed (Miller, 2007). These domains included sensorimotor functions, attention, visual-spatial functions, language functions, learning and memory, executive functions, and speed and efficiency of cognitive processing. The SNP model utilized a hierarchical classification wherein overarching neuropsychological domains were considered broad classifications made up of second- and third-order classifications. These second- and third-order classifications represented specific aspects or subdomains of the broad neuropsychological construct with which they were associated; thus, the processes assessed became more specific as one moved along the classification hierarchy. The theoretical underpinnings of the SNP model included Lurian theory, the process-oriented and cross-battery approaches to assessment, and CHC theory. These perspectives influenced both the classification scheme utilized and the assessment instruments included within the model.

The assessment instruments used to tap the broad domains included in the SNP model were initially determined through examination of previously published correlational and factorial data across numerous instruments (Miller, 2007). Assessment instruments containing subtests that were found to reliably and validly tap into a neurocognitive domain were included within that domain. These subtests were further categorized based upon the aspect of the broader neuropsychological domain they purportedly assessed; in this way, initial broad, second-, and third-order classifications were created. After initial inclusion within the SNP model, factorial studies focusing specifically upon validation of this model were conducted (Canas, Sevadjian, Miller, & Maricle, 2011; Cioffi, Rowden, Miller, & Maricle, 2011; Fournier, Phillips, Miller, & Maricle, 2011; Miller, Bradford, & Maricle, 2011; Phillips, Fournier, Miller, & Maricle, 2011; Rowden, Cioffi, Miller, & Maricle, 2011; Sevadjian, Canas, Miller, & Maricle, 2011). This resulted in additional fine-tuning of the both the classifications associated with the SNP model and subtests included within those classifications. Despite ample support for the utility of aspects of the model, additional research led to further modifications.

The Integrated SNP/CHC model represents further refinement of the original goals associated with the development of the SNP model (Miller, 2013). The Integrated SNP/CHC model attempts to further integrate CHC theory with neuropsychological and Lurian perspectives although the theoretical underpinnings driving the model remain the same. A major change to the Integrated SNP/CHC model includes the reduction of the broad neuropsychological domains encompassed within the SNP model. Broad domains within the Integrated SNP/CHC model include basic sensorimotor functions, facilitators and inhibitors for cognitive processes and acquired knowledge skills, basic cognitive processes, and acquired knowledge. Thus, the conceptualization of broad neuropsychological domains of functioning has moved from more specific to more general. The SNP model characterized specific neurocognitive constructs as broad neuropsychological domains, whereas the Integrated SNP/CHC model conceptualizes specific neurocognitive constructs as existing within broad domains of neuropsychological functioning. In this way, domains that were once considered broad classifications now represent second- or third-order classifications.

Of particular relevance to this study is the broad domain encompassing facilitators and inhibitors for cognitive processes and acquired knowledge skills (Miller, 2013). The term facilitator-inhibitors has been used in the past predominantly in association with the cognitive performance model (Mather & Gregg, 2001; Woodcock, 1998). This model served as a method to interpret CHC abilities given it suggested these abilities were not autonomous; rather, they could be broken down into additional functional categories. Facilitator-inhibitors were considered but one category or factor influencing overall cognitive performance. According to the cognitive performance model, the other factors influencing cognitive performance were verbal abilities, thinking abilities, and cognitive efficiency. These factors were considered to represent cognitive functions, whereas the facilitator-inhibitors factor was considered to represent noncognitive influences on overall cognitive performance. Noncognitive influences encompassed personality attributes and external factors such as social environment and family support. The impact upon neuropsychological functioning of facilitator-inhibitors conceptualized in a similar way to that of the cognitive performance model has also been noted (Dean & Davis, 2008). In contrast to the conceptualization of facilitator-inhibitors as representative of noncognitive influences, the Integrated SNP/CHC model considers cognitive facilitators/inhibitors to represent three separate, but interrelated, cognitive factors (Miller, 2013).

The cognitive facilitators/inhibitors domain of the Integrated SNP/CHC model is made up of three broad classifications including attention, PS, and WM (Miller, 2013). These three cognitive processes are hypothesized to act in concert to either support or constrain basic cognitive processes and acquired knowledge skills. Basic cognitive processes are considered visuospatial functions, auditory functions, and executive functions, and learning and memory. The acquired knowledge skills include acculturation knowledge, language abilities, and reading, written language, and mathematics achievement. Based on a schematic provided by Miller (see Figure 1.1), it appears that both cognitive facilitators/inhibitors and basic cognitive processes influence acquired knowledge skills; further, all of these domains are hypothesized to be influenced by basic sensorimotor capabilities.

The cognitive facilitators/inhibitors domain can be assessed through use of numerous achievement, psychological, and neuropsychological batteries (Miller, 2013). Similarly to its predecessor, the classification of subtests within the Integrated SNP/CHC model was based upon previous research and theory within the area of intelligence assessment; thus, assessment continues to drive the model. Consistent with the theoretical underpinnings associated with the Integrated SNP/CHC model, subtests across various assessment instruments have been hypothesized to measure attention, PS, and WM as cognitive facilitators/inhibitors. Given the preliminary and novel nature of the model, research attempting to discern whether these three constructs actually function as cognitive facilitators/inhibitors of cognitive processes and acquired knowledge is not available; thus, the current study represents premier research with this aspect of the Integrated SNP/CHC model.

Summary

The primary purpose of the current study was to examine the relationship between attention, PS, and WM. This chapter illustrated several consistencies between these three constructs related to the comprehensive conceptualizations, neurological mechanisms, and developmental trajectories associated with each. This chapter also demonstrated that numerous theorists have recognized the conceptual and functional overlap between these constructs (Baddeley & Hitch, 1994; Barrouillet et al., 2004; Cowan, 2010a; Fry & Hale, 2000; Miller, 2013); however, their precise relationship continues to be debated given differences in and limitations of research methodology. An additional purpose of this study was to examine the collective impact of attention, PS, and WM upon basic cognitive processes. This chapter demonstrated that attention, PS, and WM have consistently been conceptualized as supportive of higher-order cognitive functions across time (DeLuca, 2008; Fry & Hale; O'Brien & Tulsky, 2008; Salthouse, 1996). Despite these conceptualizations, research examining the collective impact of each of these processes upon higher-order cognitive functions is lacking. The literature examining the relationship between PS and WM and their differential impact upon general intelligence is extensive (Fry & Hale); however, this research rarely examines the simultaneous influence of attention.

A better understanding of the relationship between these constructs could facilitate the development and use of instructional practices with the pediatric population that capitalize upon this relationship; in addition, more appropriate academic and behavioral interventions could be devised for use in the educational, treatment, and home settings. A more accurate understanding of the joint impact of attention, PS, and WM upon cognitive processes can also do much in the way to facilitate more appropriate instructional practices and behavioral and academic interventions with the pediatric population. Given the limited nature of research associated with both the relationship between and communal impact of attention, PS, and WM upon higher-order cognitive functions, preliminary investigation in this area was clearly warranted. Finally, investigation of the relationship between and joint impact of these constructs would assist in validating aspects of the Integrated SNP/CHC model (Miller, 2013) including the existence and function of the broad domain of cognitive facilitators/inhibitors. Validation of this aspect of the model would allow for responsible use of the model such that interpretation, diagnosis, and intervention are facilitated.

The majority of studies examining the relationship between one or more of these constructs have been conducted with adults or neurotypically-functioning pediatric samples; thus, the current study takes preliminary steps in illuminating this relationship with a highly under-studied population. Not only is this population highly under-studied, but it is also highly relevant. Children with clinical diagnoses are those who are most likely to exhibit impairments in various cognitive processes thereby necessitating academic and behavioral intervention. The relationship between attention, PS, and WM was examined by investigating the validity and utility of relevant aspects of the Integrated SNP/CHC model through use of statistical analyses.

CHAPTER III

METHODS

This chapter presents a research study designed to determine whether specific neurocognitive abilities function together to facilitate or inhibit basic cognition; more specifically, the primary purpose was to determine whether neurocognitive abilities including attention, processing speed (PS), and working memory (WM) support basic neurocognitive processes including visuospatial, auditory, memory, and executive processes as suggested in Miller's (2013) Integrated School Neuropsychological (SNP)/Cattell-Horn-Carroll (CHC) model. This chapter also outlines information regarding participants, procedures, measures, and data analysis techniques associated with the study.

Participants

The data utilized in this study were archival and culled from neuropsychological case studies submitted as part of the Kids, Incorporated (Inc.) School Neuropsychology Post-Graduate Certification Program. The case studies making up the broad data set from which the sample was drawn represent comprehensive neuropsychological evaluations conducted by student-clinicians. These evaluations were conducted with children and adolescents exhibiting academic, cognitive, and/or behavioral concerns; thus, participants associated with the study were comprised of individuals between the ages of 8 and 16 with clinical diagnoses. This age range was selected based upon subtest floor and ceiling limitations associated with various measures. Clinical diagnoses within the sample include attention-deficit/hyperactivity disorder (AD/HD), specific learning disabilities (LD), autism spectrum disorders (ASD), speech/language disorders, emotional disability (ED), and general neurological impairments and medical conditions including traumatic/acquired brain injuries, tumors, and seizures. The sample was comprised of 591 neuropsychological case studies.

Procedure

Case studies submitted to the Kids, Inc. certification program must contain documentation of informed consent for evaluation and notice for the potential for assessment information to be used for research purposes. Any case study with a consent form indicating the information associated with the case should not be used for research purposes was excluded from the broad data set. This data set was reviewed to determine which cases were appropriate for this study. Case studies containing subtest scores associated with measures of cognitive facilitators/inhibitors and cognitive processes were utilized. A number of these scores were imputed statistically given variations in assessment batteries administered across student-clinicians within the certification program.

Imputation is a commonly used statistical method of addressing missing data wherein plausible values are substituted for a missing data point (Schlomer, Bauman, & Card, 2010). There are numerous types of imputation techniques; however, these techniques can be grouped into two broad categories. Those techniques that are stochastic utilize random observations or data points whereas those that are nonstochastic do not. Multiple imputation (MI) is a stochastic imputation method wherein several data sets approximating the original data set are imputed. Statistical analyses are conducted on each data set resulting in multiple parameter estimates. These estimates are averaged together across data sets thereby producing less biased parameter estimates. The average parameter estimates ultimately utilized are based on an analysis of each plausible data set and the spread of these estimates across data sets; thus, the imputed data is considered highly plausible. The MI technique was utilized with the data set used in the current study as a method of imputing missing data. Based upon the use of archival data and the inability to manipulate independent variables, a non-experimental, correlational research design was implemented in the current study (Gravetter & Forzano, 2009).

Measures

The following measures were selected based on the Integrated SNP/CHC model (Miller, 2013). This model provides a comprehensive framework by which to administer assessments and organize assessment data thereby facilitating clinical interpretation, diagnosis, and intervention. The Integrated SNP/CHC model suggests that four broad neurocognitive domains including sensorimotor functions, cognitive facilitators/inhibitors, basic cognitive processes, and acquired knowledge interact to influence general neuropsychological functioning; however, the current study focused only on cognitive facilitators/inhibitors and basic cognitive processes. Information germane to these two domains was obtained through use of various batteries of general intellectual ability, achievement, and neuropsychological functioning.

Within these batteries, specific subtests were selected for use in the current study. Selection of these subtests was based upon the Integrated SNP/CHC model (Miller, 2013); however, given the complexity of the model, many subtests associated with assessment of cognitive facilitation/inhibition and cognitive processes were not utilized. Determinations regarding which subtests to retain within these domains were based on the nature of the data set, reliability and validity of the subtest, and the aspect of the domain the subtest purportedly measures.

Reliability and Validity

Reliability refers to the consistency and stability of the score an assessment instrument produces (Gravetter & Forzano, 2009). One method of gaining information regarding reliability is through use of the split-half technique. This technique produces a reliability coefficient based upon the correlation between each half of a test; thus, a measure can be divided into equivalent halves and a reliability coefficient calculated between these two halves. Reliability coefficients between .65 and .70 and above have been considered as representative of adequate reliability (Cohen & Swerdlik, 2005). Another method of determining the reliability of a measure is through use of the test-retest reliability estimate (Cohen & Swerdlik; Gravetter & Forzano). This estimate provides information about the correlation between scores produced by an assessment when completed by the same individual over time. This type of reliability is important for assessment instruments purporting to measure a construct believed to be relatively stable across time.

An estimation of the standard error of measurement (SE_M) can also provide information related to reliability (Cohen & Swerdlik, 2005; Gravetter & Forzano, 2009). The SE_M is an indication of the ability of a measure to precisely assess a construct; thus, it provides an estimate of the amount of measurement error present when assessing that construct. Measurement error can be considered a source of error variance and refers to the idea that a construct cannot be measured cleanly without also tapping random, irrelevant sources of variance. The presence of a significant amount of measurement error can cloud the interpretation associated with a measure. The SE_M is used to calculate confidence intervals or the range of scores surrounding an obtained score (Cohen & Swerdlik). Given the presence of measurement error, an individual's true score would be likely to exist within this range. The relationship between the reliability and the SE_M of a measure is inverse; thus, as reliability increases, SE_M decreases. In this way, the confidence intervals surrounding more precise, reliable measures are smaller.

Although the reliability of assessment instruments is important, validity is paramount within the realm of psychological assessment. A valid instrument is able to accurately assess the construct it claims to assess (Cohen & Swerdlik, 2005; Gravetter & Forzano, 2009). Validity often encompasses reliability in that all valid instruments are reliable; however, reliable instruments are not necessarily valid. Thus, the two must be evaluated separately. The general validity of an instrument is typically evaluated based upon content, criterion-related, and construct validity; however, predominant among these is construct validity given other aspects of validity are subsumed here. Construct validity refers to the ability of a measure to explain performance on that measure through use of the construct the measure purportedly assesses; thus, performance on a measure should be consistent with what is hypothesized to be true about the construct. This type of validity can be evaluated by examining the internal structure of a measure which assists in determining whether the measure conforms to the construct of interest.

The multitrait-multimethod matrix allows for examination of internal structure and produces Pearson correlation coefficients (Mertler & Vannatta, 2010). Those correlations above .30 within this matrix are considered substantial or highly correlated. In addition, these intercorrelations provide information associated with convergent and discriminant validity among subtests and the constructs they purport to measure. An additional method of examining internal structure is factor analysis (Cohen & Swerdlik, 2005; Gravetter & Forzano, 2009). This statistical procedure provides information about the underlying structure of a measure or group of measures; thus, the ability of a subtest to actually tap into the construct of interest is evaluated. Factor analytic studies can include those that are exploratory and those that are confirmatory. Assumptions regarding the internal structure of a measure are based upon statistical properties of that measure in confirmatory studies; however, research and theory guide assumptions about internal structure when conducting confirmatory studies.

Evidence of construct validity can also be gleaned by examining and comparing performance between various groups of individuals (Cohen & Swerdlik, 2005; Gravetter & Forzano, 2009). If a construct is adequately tapped through use of a measure, then differences in performance on the measure between various groups should be explained by the construct. Thus, the performance of children with exceptionalities can be compared to those who are neurotypical as a method of establishing validity. Children with exceptionalities are those who exhibit significant intellectual strengths and those with clinical diagnoses such as AD/HD, LD, and intellectual disability (ID).

Intellectual Measures

Subtests and indexes associated with several broad measures of intellectual functioning were utilized in the current study. These subtests and indexes will be discussed in detail below.

Wechsler Intelligence Scale for Children, Fourth Edition **(WISC-IV; Wechsler, 2003).** The WISC-IV is a widely used measure of cognitive functioning within the pediatric population (Flanagan & Kaufman, 2009; Wechsler). It is intended for use with children between the ages of 6 and 16. This instrument provides an indication of general cognitive ability gleaned from indexes indicating specific cognitive abilities including verbal comprehension, perceptual reasoning, WM, and PS. Indexes of specific abilities are made up of several subtests purported to measure these abilities; however, these subtests have also been found to measure additional cognitive abilities (Miller, 2007; Miller, 2013). Several subtests making up the WISC-IV were utilized in the current study given they represent measures of cognitive facilitators/inhibitors and cognitive processes (Miller, 2013). These subtests included Block Design, Cancellation, Coding, Digit Span, Letter-Number Sequencing, and Symbol Search.

Each subtest in the current study from the WISC-IV has demonstrated adequate validity as evidenced through use of the aforementioned procedures (Flanagan & Kaufman, 2009; Wechsler, 2003). Intercorrelations between subtests indicate that each subtest is highly and statistically significantly correlated with other subtests purported to measure the same construct. Although some subtests are also moderately correlated with other constructs, this is likely related to these subtests' intercorrelations with general intelligence. Factor analytic studies of both an exploratory and confirmatory nature demonstrate the overall validity of the underlying structure of the WISC-IV; thus, each subtest used in this study appears to tap the construct it is hypothesized to assess. In addition, evidence from studies conducted with children with exceptionalities indicates that neurotypical children commonly outperform those with exceptionalities across the subtests to be included in the study. Given the clear indication of the validity associated with each subtest, the reliability will be discussed separately.

The Block Design subtest represents a measure of perceptual reasoning on the WISC-IV in that it requires the ability to visually analyze abstract stimuli (Wechsler, 2003). This subtest is made up of 14 items requiring children to analyze and synthesize visual information through use of bi-colored blocks in a relatively quick and efficient manner. Overall, this subtest has demonstrated adequate reliability. The average internal consistency reliability coefficient associated with the Block Design subtest is .86 for the standardization sample which is neurotypical children between the ages of 6 and 16; however, this coefficient varies from .83 to .88 across these age groups (Wechsler). The internal consistency reliability of this subtest is also good for children with exceptionalities with a coefficient of .90 across clinical groups.

The average stability coefficient associated with test-retest reliability for the Block Design subtest was .81; however, these coefficients range between .73 and .88 (Wechsler, 2003). It has also been noted that children between the ages of 6 and 16 exhibit relatively large gains in performance over time on the Block Design subtest (Flanagan & Kaufman, 2009). This may be reflective of significant practice effects or the tendency to benefit from repeated exposures to test stimuli. The average SE_M for this subtest is 1.13; however, this statistic ranges between 1.04 and 1.24 (Wechsler). Taken together, this information suggests that the Block Design subtest is a reliable measure of perceptual reasoning; however, this subtest is considered a measure of visuospatial processes within the Integrated SNP/CHC model (Miller, 2013).

The Cancellation subtest provides a measure of PS on the WISC-IV (Wechsler, 2003). It is a supplemental subtest that requires the quick and efficient completion of a simple cognitive task. This subtest requires the rapid visual scanning of a cluttered array of stimuli in order to locate a target stimulus. Based upon internal consistency, test-retest estimates, and the SE_M statistic, it has demonstrated adequate reliability. The average internal consistency reliability coefficient associated with the Cancellation subtest is .79; however, it ranges between .73 and .84. The average stability coefficient associated with this subtest is .78 indicating adequate test-retest reliability; however, this coefficient ranges from .69 to .86. Children between the ages of 8 and 16 exhibit relatively large gains over time in performance on the Cancellation subtest (Flanagan & Kaufman, 2009). The SE_M associated with this subtest is 1.38 ranging from 1.20 to 1.56 across age groups (Wechsler). The Cancellation subtest is utilized as a measure of PS within the Integrated SNP/CHC model; thus, it also functions as a cognitive facilitator/inhibitor within this model (Miller, 2013).

The Coding subtest on the WISC-IV is also considered a measure of PS in that it requires the quick and efficient completion of a simple cognitive task (Weschsler, 2003). This subtest entails the rapid copying of simple geometric figures. The average internal consistency reliability coefficient associated with the Coding subtest is .85 indicating good internal consistency with a range between .72 and .89. The average stability coefficient for this subtest is .81 indicating good test-retest reliability; however, it ranges between .74 and .87. Significant practice effects have been observed on the Coding subtest among children between the ages of 6 and 7 and 12 to 16 (Flanagan & Kaufman, 2009). The average SE_M on this subtest is 1.20 and ranges between .99 and 1.59 (Wechsler). Overall, this information indicates that the Coding subtest represents a reliable measure of PS. This subtest is also considered a measure of PS within the Integrated SNP/CHC model (Miller, 2013); as such, this subtest is considered a cognitive facilitator/inhibitor.

The Digit Span subtest is considered a measure of WM on the WISC-IV given it requires the mental manipulation of incoming information (Wechsler, 2003). This subtest contains two components wherein the examinee is asked to repeat a string of numbers exactly as they are dictated (Digit Span Forward) followed by a task requiring the examinee to repeat a string of numbers backward (Digit Span Backward). These two components are aggregated to produce an overall score. In general, this subtest has been found to reliably measure WM. The internal consistency for the Digit Span Backward component is adequate with an average reliability coefficient of .80 ranging from .68 to .86. This component has also demonstrated good internal consistency among children with exceptionalities with an average coefficient of .84. The average stability coefficient for the Digit Span Backward aspect of Digit Span is .67 indicating adequate test-retest reliability; however, this coefficient ranges between .63 to .80. The average SE_M is 1.37 with a range of 1.04 to 1.70. Within the Integrated SNP/CHC model, the components of the Digit Span subtest are utilized rather than the overall score (Miller, 2013). The Digit Span Backward task represents a measure of WM within this model; thus, it also represents a cognitive facilitator/inhibitor. The Digit Span Forward task is utilized as a measure of both attention and learning and memory processes; however, this component was not utilized in the current study.

The Letter-Number Sequencing subtest on the WISC-IV is designed to measure WM (Wechsler, 2003). This task requires the child to numerically order numbers and alphabetically arrange letters presented together in an intermixed fashion. The average internal consistency coefficient associated with this subtest is .90, and ranges between .85 and .92 indicating good internal consistency. The internal consistency of this subtest is also good for children with exceptionalities with an average coefficient of .93 across clinical groups. The average stability coefficient is .75 indicating adequate test-retest reliability. This coefficient ranges between .64 and .81 suggesting performance over time is variable for some age groups; specifically, those between the ages of 6 and 7 were found to exhibit significant practice effects (Flanagan & Kaufman, 2009). The average SE_M is .97 ranging from .85 to 1.16 across age groups (Wechsler). Overall, this indicates this subtest possesses acceptable reliability. The Letter-Number Sequencing subtest is considered a measure of WM in the Integrated SNP/CHC model; therefore, this subtest represents a cognitive facilitator/inhibitor (Miller, 2013).

The Symbol Search subtest represents a measure of PS on the WISC-IV given it requires the quick and efficient completion of a simple cognitive task (Wechsler, 2003). The examinee is required to rapidly inspect rows of shapes and decide whether two match exactly. The average internal consistency reliability coefficient for this subtest is .79; however, this coefficient ranges between .78 and .82. This subtest demonstrates generally adequate test-retest reliability with an average stability coefficient of .68 and a range of .57 to .80. Children between the ages of 6 and 11 have exhibited significant practice effects on this subtest (Flanagan & Kaufman, 2009). The average SE_M associated with this subtest is 1.36 with a range of 1.27 to 1.41 (Wechsler). In general, this information suggests that this subtest possesses adequate reliability. The Symbol Search subtest is utilized as a measure of PS within the Integrated SNP/CHC model resulting in the categorization of this subtest as a cognitive facilitator/inhibitor (Miller, 2013).

***Woodcock-Johnson Tests of Cognitive Abilities, Third Edition Normative Update* (WJ-III Cog; McGrew, Schrank, & Woodcock, 2007).** The WJ-III Cog is a collection of subtests designed to assess aspects of cognitive functioning among individuals between the ages of 2 and 95 (McGrew et al.; Schrank, Miller, Wendling, & Woodcock, 2010). Although overall cognitive ability can be assessed through use of this battery, it is most typically utilized to assess within and across various cognitive factors as a method of establishing patterns of cognitive strengths and weaknesses. The cognitive factors included in this battery are drawn from those comprising the CHC model of human cognitive abilities. A number of these subtests were also considered measures of cognitive facilitators/inhibitors or cognitive processes within the Integrated SNP/CHC model and were therefore utilized in the current study (Miller, 2013). These subtests included Analysis/Synthesis, Auditory Working Memory, Concept Formation, Incomplete Words, Memory for Words, Numbers Reversed, Pair Cancellation, Retrieval Fluency, Sound Blending, Spatial Relations, and Visual Matching.

Each of these subtests possesses adequate validity (McGrew et al., 2007; Schrank et al., 2010). In addition to the use of intercorrelations, factor analysis, and comparison of performance between children with exceptionalities and those who are neurotypical, growth curves are utilized as a method of establishing construct validity for the WJ-III Cog. Growth curves require the use of cross-sectional data in order to depict changes in performance on various tests across age groups. Intercorrelations across the subtests utilized indicate that each is highly and statistically significantly correlated with other subtests purported to measure the same construct. Factor analyses utilizing both exploratory and confirmatory procedures indicate the validity of the underlying structure of the WJ-III Cog; thus, each subtest included in this study appears to adequately tap the construct it is believed to measure. Children who are neurotypical tend to outperform children with exceptionalities across various cognitive abilities further establishing construct validity associated with these subtests. Growth curves associated with the subtests of interest demonstrate differential patterns of development suggesting these tests are tapping distinct cognitive constructs. Given the presence of adequate validity for the subtests to be used in the current study, reliability will be discussed for each subtest.

The Analysis/Synthesis subtest is considered a measure of fluid reasoning and requires the use of deductive logic (Schrank et al., 2010). The examinee is asked to solve a series of increasingly complex puzzles through use of sequential reasoning. The internal consistency reliability coefficient for this test ranges between .87 and .94 for the pediatric standardization sample which is neurotypical children between the ages of 4 and 18 (McGrew et al., 2007). The stability coefficient for those re-tested one to two years following initial testing is .70 for those between the ages of 2 and 7, and .69 for those between the ages of 8 and 18. The SE_M associated with the Analysis/Synthesis subtest ranges between 3.67 and 5.41. Taken together, this indicates this subtest demonstrates adequate reliability when used with the pediatric population. Within the Integrated SNP/CHC model, the Analysis/Synthesis subtest is considered a measure of executive processes (Miller, 2013).

The Auditory Working Memory subtest is conceptualized as a measure of short-term memory on the WJ-III Cog; however, it can also be utilized as a measure of WM or divided attention (Schrank et al., 2010). The child is asked to listen to a series of aurally presented numbers and items and then appropriately rearrange this information. This subtest has demonstrated adequate reliability among the pediatric population. The internal consistency coefficients range between .84 and .96 (McGrew et al., 2007). Stability coefficients associated with test-retest reliability were not reported for the Auditory Working Memory subtest; however, the SE_M ranges between 3.00 and 6.71. This subtest is conceptualized as a measure of WM within the Integrated SNP/CHC model; therefore, it is considered a measure of cognitive facilitation/inhibition (Miller, 2013).

The WJ-III Cog utilizes the Concept Formation subtest as a measure of fluid reasoning (Schrank et al., 2010). This subtest requires the examinee to engage in inductive reasoning as a method of solving visually-presented problems; thus, a broad rule is applied in order to solve specific problems. The internal consistency coefficients associated with this subtest range between .75 and .96 (McGrew et al., 2007). The stability coefficients are .82 and .76 for those re-tested one to two years following initial testing between the ages of 2 to 7 and 8 to 18, respectively. The SE_M associated with this subtest ranges between 3.00 and 6.09. Overall, this information suggests the Concept Formation subtest possesses adequate reliability. This subtest is utilized as a measure of executive processes within the Integrated SNP/CHC model (Miller, 2013).

The Incomplete Words subtest represents a measure of auditory processing on the WJ-III Cog (Schrank et al., 2010). This task requires the examinee to produce phonemes that are missing from aurally presented words. The internal consistency coefficients associated with this task range between .74 and .92 indicating adequate split-half reliability (McGrew et al., 2007). The stability coefficients are .76 for those between the ages of 2 and 7, and .62 for those between the ages of 8 and 18 when retested between one and two years following initial testing. The SE_M ranges between 4.24 and 7.65. In general, this information suggests the Incomplete Words subtest demonstrates adequate reliability. This subtest is utilized as a measure of auditory processes in the Integrated SNP/CHC model (Miller, 2013).

The Memory for Words subtest is considered a measure of short-term memory on the WJ-III Cog (Schrank et al., 2010). The examinee is required to repeat exactly a string of aurally presented words. This subtest has demonstrated adequate reliability when used with the pediatric population. The internal consistency coefficients range between .72 and .94 (McGrew et al., 2007). The stability coefficients are .80 and .89 with children retested between one and two years following initial assessment for those who were 2 to 7 and 8 to 18 years of age, respectively. The SE_M associated with this subtest ranges between 3.67 and 7.94. The Memory for Words subtest is considered a measure of attention within the Integrated SNP/CHC model; therefore, this measure is considered an indication of cognitive facilitation/inhibition (Miller, 2013).

The Numbers Reversed subtest is utilized as a measure of short-term memory; however, the WJ-III Cog also conceptualizes this test as a measure of WM or attentional capacity (Schrank et al., 2010). This subtest requires the child to repeat in reverse order a string of progressively lengthy numbers. The internal consistency coefficients for this subtest range between .84 and .93 (McGrew et al., 2007). Stability coefficients were not reported; however, the SE_M ranges between 3.97 and 6.00. Taken together, this information indicates this subtest possesses adequate reliability. Within the Integrated SNP/CHC model, this subtest is considered a measure of WM; therefore, it is also considered a cognitive facilitator/inhibitor (Miller, 2013).

The WJ-III Cog considers the Pair Cancellation subtest a measure of PS; however, it also provides information related to executive functioning and sustained attention (Schrank et al., 2010). This is a timed task requiring the examinee to identify a target pattern of objects among a visually-complex array of stimuli. This subtest has demonstrated adequate reliability among the pediatric population. The internal consistency coefficients range between .95 and .98 (McGrew et al., 2007). The stability coefficients are .83 and .78 for those between the ages of 7 to 11 and 14 to 17, respectively. The SE_M associated with this subtest ranges between 2.08 and 3.49. The Pair Cancellation subtest is utilized as a measure of attention in the Integrated SNP/CHC model; thus, it represents a measure of cognitive facilitation/inhibition (Miller, 2013).

The Retrieval Fluency subtest represents a measure of long-term retrieval on the WJ-III Cog (Schrank et al., 2010). This subtest is also timed and requires the child to verbalize semantically-related words. The internal consistency coefficients associated with this subtest range between .70 and .87 (McGrew et al., 2007). The stability coefficients are .83 for those between the ages of 7 and 11, and .85 for those between the ages of 14 and 17. The SE_M ranges between 5.41 and 8.22 within the pediatric age groups. Overall, this indicates the general reliability associated with this subtest is acceptable. This task is considered a measure of PS within the Integrated SNP/CHC model; thus, it is classified as a cognitive facilitator/inhibitor (Miller, 2013).

The WJ-III Cog considers the Sound Blending subtest to be a measure of auditory processing (Schrank et al., 2010). The examinee is required to blend a series of aurally presented phonemes or graphemes into a legitimate word. This task has demonstrated adequate reliability among the pediatric population (McGrew et al., 2007). Internal consistency reliability is good with coefficients ranging from .81 to .93. The stability coefficients were not reported; however, the SE_M ranges between 3.97 and 5.78. This subtest is utilized as a measure of auditory processes within the Integrated SNP/CHC model (Miller, 2013).

The Spatial Relations subtest is utilized as a measure of visual-spatial thinking on the WJ-III Cog in that it requires the child to visualize various parts of a target shape (Schrank et al., 2010). The internal consistency of this task is adequate in that the reliability coefficients range between .68 and .92 (McGrew et al., 2007). Although stability coefficients are not available, the SE_M ranges between 4.24 and 8.49. Taken together, the Spatial Relations subtest represents a reliable measure of visual-spatial thinking. It is utilized as a measure of visuospatial processes within the Integrated SNP/CHC model (Miller, 2013).

The WJ-III Cog considers the Visual Matching subtest to represent PS in that it requires the examinee to quickly discriminate between visual symbols (Schrank et al., 2010). This timed subtest has demonstrated adequate reliability when utilized with the pediatric population. The internal consistency reliability coefficients for this task range between .79 and .91 (McGrew et al., 2007). The stability coefficients for those between the ages of 7 to 11 and 14 to 17 are .87 and .75, respectively, indicating adequate test-retest reliability. The SE_M ranges between 4.49 and 6.95 within the pediatric age groups. The Visual Matching subtest is also utilized as a measure of PS within the Integrated SNP/CHC model; as such, it is considered a cognitive facilitator/inhibitor (Miller, 2013).

Achievement Measures

Several subtests from one measure of academic achievement were utilized in the current study. These subtests will be discussed in detail below.

***Woodcock-Johnson Tests of Achievement, Third Edition Normative Update* (WJ-III Ach; Mather, Wendling, & Woodcock, 2001).** The WJ-III Ach can be considered the achievement counterpart to the WJ-III Cog in that these instruments were normed together; however, the WJ-III Ach is designed to assess aspects of academic functioning (Mather et al.). Collectively, these two instruments represent a comprehensive battery of individually administered tests. The WJ-III Ach is a collection of various academic tasks that can be administered to individuals between the ages of 2 and 95. A number of tests included in the WJ-III Ach are utilized in the Integrated SNP/CHC model as measures of cognitive facilitators/inhibitors and cognitive processes (Miller, 2013); however, only one of these tests was utilized for the current study. This included Sound Awareness.

Based upon evidence of concurrent validity including intercorrelations, factor analysis, and growth curves, the Sound Awareness subtest has demonstrated adequate validity (McGrew et al., 2007). Intercorrelations between this subtest and other tests believed to measure phonemic awareness are substantial and statistically significant. Factor analyses of both an exploratory and confirmatory nature indicate the underlying structure of the WJ-III Ach is consistent with the theory driving this measure; thus, the Sound Awareness subtest appears to adequately tap phonemic awareness. Growth curves associated with various reading clusters, the curricular area of which Sound Awareness is a part, indicate that these clusters produce differential developmental trajectories in comparison to other curricular areas. This suggests that each reading cluster represents a distinct aspect of reading and general academic achievement.

This subtest also possesses adequate reliability when used with the pediatric population (McGrew et al., 2007). As previously mentioned, the Sound Awareness subtest is considered a measure of phonemic awareness on the WJ-III Ach. This task consists of several components including Rhyming, Deletion, Substitution, and Reversal. Collectively, the child is asked to provide words that rhyme with aurally presented words, and remove, substitute, or reverse various parts of a word in order to produce a new word. The internal consistency coefficient ranges between .69 and .93 for children who are neurotypical between the ages of 4 and 18. The stability coefficient associated with this task was not reported; however, the SE_M ranges between 3.97 and 8.35. This task represents a measure of auditory processes within the Integrated SNP/CHC model (Miller, 2013).

Neuropsychological Measures

Subtests, indexes, and composite scores associated with several measures used to assess neurocognitive functioning were utilized in the current study. These subtests, indexes, and composite scores will be discussed in detail below.

***Delis-Kaplan Executive Function System* (D-KEFS; Delis, Kaplan, & Kramer, 2001).** The D-KEFS provides a comprehensive evaluation within the neurocognitive domain of executive functioning (Delis et al.; Golden & Hines, 2011). Executive functioning refers to a number of cognitive processes that allow an individual to enact independent and purposeful behaviors (Maricle, Johnson, & Avirett, 2010). The subtests included in this battery represent frequently assessed aspects of frontal lobe functioning which is theorized to be supportive of general executive functioning (Golden & Hines, 2011). This battery is appropriate for use with individuals between the ages of 8 and 89 (Delis et al.). A number of subtests included in this battery were utilized in the current study given they represent measures of cognitive processes within the Integrated SNP/CHC model (Miller, 2013). These subtests included Color-Word Interference, Design Fluency, Trail Making Test, and Verbal Fluency.

The specific subtests utilized in the current study have demonstrated evidence of validity (Delis et al., 2001); however, it is important to note that the validity evidence associated with these tasks was established historically with modified versions. Validity studies have indicated that these tasks are able to distinguish between those with brain injuries resulting in frontal lobe dysfunction and those who are neurotypical. It is also important to note that the majority of studies examining validity were conducted within the adult population; thus, validity evidence within the pediatric population is lacking (Maricle et al., 2010). Nonetheless, intercorrelation data indicate that various scores within the subtests of interest demonstrate minimal to moderate correlations with other tests believed to measure the same construct for children between the ages of 8 and 19 who are neurotypical which represents the pediatric standardization sample (Delis et al.). This suggests that the various aspects of these tasks may represent a unitary construct. Factor analyses associated with the pediatric standardization sample were not conducted. The reliability associated with each subtest included in the proposed study will be discussed.

The Color-Word Interference task is considered a measure of executive functioning on the D-KEFS and is made up of four conditions (Delis et al., 2001). It is hypothesized that the specific aspect of executive functioning this task taps is verbally-mediated attentional shifting (Miller, 2013). The presence of multiple conditions is believed to assist the clinician in gaining a more precise understanding of executive dysfuntion. Collectively, this task requires the child to simply name colors (Condition 1), read the printed labels for colors (Condition 2), name the color of the ink in which a color label is printed (Condition 3), and appropriately switch between reading the printed label of a color and naming the color ink in which that color label is printed (Condition 4). The composite score associated with this task has demonstrated adequate internal consistency with coefficients ranging between .62 and .75 across the pediatric standardization sample (Delis et al). The average stability coefficients for each condition are adequate to good ranging between .77 and .90. The SE_M ranges between 1.45 and 1.85 for the composite score. Overall, this information suggests the Color-Word Interference task possesses adequate reliability. The specific score from this task that was utilized in the proposed study is that associated with Condition 4 which is considered a measure of executive processes in the Integrated SNP/CHC model (Miller).

The Design Fluency task is utilized as a measure of executive functioning on the D-KEFS and consists of three conditions (Delis et al., 2001); more specifically, this task may provide a measure of attentional shifting within the visual modality (Miller, 2013). These conditions require the examinee to connect a random array of dots while holding a set of rules in mind. The child must first connect solid dots presented alone (Condition 1), then connect empty dots presented along with solid dots (Condition 2), and finally alternate between connecting solid and empty dots presented together (Condition 3). The average stability coefficients associated with each condition range between .13 and .66. This reflects poor test-retest reliability particularly in association with Condition 3. The SE_M ranges between 1.94 and 2.47 for each condition; however, because calculation of this statistic was based upon the entire standardization sample, it is difficult to know the measurement error associated with this task for the pediatric population. The score associated with Condition 3 was utilized in the current study and represents a measure of executive processes (Miller).

The Trail Making Test is considered a measure of executive functioning on the D-KEFS; however, it may represent a measure of visual attentional shifting within the broader domain of executive functioning (Miller, 2013). This task consists of five conditions requiring the examinee to quickly visually scan for target stimuli (Condition 1), quickly and correctly order numbers (Condition 2), quickly and correctly order letters (Condition 3), alternate between quickly and correctly ordering numbers and letters (Condition 4), and quickly and accurately trace a line (Condition 5). The internal consistency reliability coefficients range between .57 and .79 for the composite score (Delis et al., 2001). The average stability coefficient ranges between .20 and .82 for each condition indicating poor test-retest reliability particularly with Condition 4. The SE_M associated with this task ranges between 1.38 and 1.96. Condition 4 scores were utilized in the current study and are considered a measure of executive processes within the Integrated SNP/CHC model (Miller).

The Verbal Fluency subtest is considered a general measure of executive functioning on the D-KEFS and may provide a specific measure of verbal attentional shifting (Miller, 2013). This subtest consists of three conditions requiring the child to quickly produce phonetically similar words (Condition 1), quickly produce semantically similar words (Condition 2), and quickly alternate between producing words associated with two different categories (Condition 3). The internal consistency reliability coefficients for this task range between .37 and .81. The average stability coefficient for each condition ranges between .53 and .70 indicating poor to adequate test-retest reliability. The SE_M for each condition ranges between 1.31 and 2.25. The score that was utilized in the current study is that associated with Condition 3 which is considered a measure of executive processes within the Integrated SNP/CHC model (Miller).

***NEPSY: A Developmental Neuropsychological Assessment, Second Edition* (NEPSY-II; Korkman et al., 2007).** The NEPSY-II is a comprehensive pediatric neuropsychological battery that assesses across multiple, broad neurocognitive domains (Davis & Thompson, 2011; Kemp & Korkman, 2010). These include traditional neuropsychological domains such as attention, executive functioning, language, memory and learning, sensorimotor, visuospatial, and social perception. The development of this battery was strongly influenced by Lurian theory and is intended for use with children between the ages of 3 and 16. A number of the subtests included in this battery are utilized in the Integrated SNP/CHC model as measures of cognitive facilitators/inhibitors and cognitive processes (Miller, 2013); therefore, a number of these subtests were included in the current study. These subtests were Arrows, Auditory Attention and Response Set, Geometric Puzzles, Inhibition, Memory for Designs, Memory for Names, Narrative Memory, Phonological Processing, and Picture Puzzles.

In general, the NEPSY-II has demonstrated adequate validity among the pediatric population (Davis & Thompson, 2011). Substantial and statistically significant intercorrelations between subtests included in various domains indicate the underlying structure of the NEPSY-II is consistent with the theory driving this measure (Korkman et al., 2007). Although a number of low or poor correlations are present within some domains, this pattern is expected particularly when using a Lurian approach given disparate abilities are present even within exclusive neurocognitive domains; thus, the NEPSY-II appears to possess adequate construct validity. Factor analyses were not reported; however, the NEPSY-II has demonstrated adequate concurrent validity given it is statistically significantly correlated with a number of intellectual, achievement, and neuropsychological measures. In addition, studies with children with exceptionalities provide further indications of validity. Given the overall measure appears to possess adequate validity, it is likely that the subtests making up this measure also possess adequate validity. Estimates of reliability will be discussed separately for each subtest included in the current study.

The Arrows subtest is considered a measure of visuospatial processing on the NEPSY-II (Kemp & Korkman, 2010). This task requires the examinee to utilize visual skills to make a judgment about the orientation of a line in space. The internal consistency reliability coefficients for this task range between .64 and .92 for children who are neurotypical between the ages of 3 and 16 which is the standardization sample (Korkman et al., 2007). The stability coefficients range between .51 and .83; and, the SE_M ranges between .85 and 1.80. Taken together, this information suggests that the

Arrows subtest possesses adequate reliability. The total score was utilized in the current study and represents a measure of visuospatial processes (Miller, 2013).

The Auditory Attention and Response Set subtest is utilized as a measure of both attention and executive functioning on the NEPSY-II (Kemp & Korkman, 2010). This subtest can be considered to include two components consisting of the attentional measure (i.e., Auditory Attention) and the measure of executive functioning (i.e., Response Set). This task requires the examinee to first exhibit a motor response when he or she has heard a target word; and, then to inhibit that response and replace it with a non-dominant response when confronted with the same target word. The internal consistency reliability coefficients for the Auditory Attention portion of this task range between .71 and .91 (Korkman et al., 2007). These coefficients range between .83 and .93 for the Response Set portion. Stability coefficients for the Auditory Attention component range between .59 and .73; and, these coefficients range between .53 and .84 for the Response Set component. The SE_M associated with the Auditory Attention portion of the subtest ranges between 1.53 and 1.90. Those associated with the Response Set portion range between 1.16 and 2.01. In the current study, the Auditory Attention combined score was utilized as a measure of attention, while the Response Set combined score is considered to be a measure of executive processes as outlined in the Integrated SNP/CHC model (Miller, 2013).

The NEPSY-II considers the Geometric Puzzles subtest to represent a measure of visuospatial processing (Kemp & Korkman, 2010). The child is required to identify matching complex shapes that may have been rotated. The internal consistency coefficients associated with this task range between .67 and .82 indicating adequate split-half reliability (Korkman et al., 2007). Test-retest reliability is adequate as well with stability coefficients ranging between .63 and .89. The SE_M ranges between 1.27 and 1.72. Overall, this indicates the Geometric Puzzles subtest possesses adequate reliability. The total score associated with this task was utilized for this study. This subtest is considered a measure of visuospatial processes within the Integrated SNP/CHC model (Miller, 2013).

The Inhibition task on the NEPSY-II is considered a measure of executive functioning (Kemp & Korkman, 2010). This subtest consists of three components requiring the child to name simple stimuli (Naming), inhibit the naming of that stimuli (Inhibition), and alternate between these response types (Switching). In general, this subtest has demonstrated adequate reliability. The internal consistency reliability coefficients range between .85 and .89 (Korkman et al., 2007). The stability coefficients range between .75 and .93; and, the SE_M ranges between 1.31 and 1.80. The Switching component of the Inhibition subtest was included in the current study and is considered a measure of executive processes (Miller, 2013).

The NEPSY-II considers the Memory for Designs task to represent a measure of memory (Kemp & Korkman., 2010). Specifically, spatial memory for novel designs is assessed by requiring the examinee to immediately recall a series of designs. Split-half reliability is good with coefficients ranging between .82 and .92 (Korkman et al., 2007). Test-retest reliability is also adequate with stability coefficients ranging between .56 and .83. The SE_M associated with this task ranges between .85 and 1.27. In general, the reliability of this subtest appears to be acceptable. The total score from the Memory for Designs subtest was utilized in the current study as a measure of memory processes (Miller, 2013).

The Memory for Names subtest is utilized as a measure of memory on the NEPSY-II (Kemp & Korkman, 2010). This task essentially measures associative memory in that the child is required to pair a specific name with a picture of a specific face. The internal consistency of this measure is poor to adequate with reliability coefficients ranging between .50 and .78; in addition, test-retest reliability is poor to adequate with stability coefficients ranging between .46 and .73 (Korkman et al., 2007). The SE_M associated with this task ranges between 1.41 and 2.12. The total score for the Memory for Names subtest was utilized in the current study as a measure of memory processes (Miller, 2013).

Narrative Memory is a subtest included on the NEPSY-II that is purported to measure memory (Kemp & Korkman, 2010). The examinee is asked to listen to a story and then repeat as many details from that story as can be recalled. This task has three conditions that can be characterized as immediate recall, delayed recall, and cued recall or recognition. Internal consistency reliability coefficients associated with this task range between .56 and .75 (Korkman et al., 2007). Test-retest reliability is slightly better with coefficients ranging between .61 and .76. The SE_M associated with this task ranges between 1.50 and 1.99. The free recall total score for the Narrative Memory subtest was included in the current study as a measure of memory processes.

The Phonological Processing subtest is considered a measure of language on the NEPSY-II and requires the child to identify, omit, and substitute various phonemes associated with aurally presented words (Kemp & Korkman, 2010). Split-half reliability is adequate with internal consistency coefficients ranging between .62 and .92 (Korkman et al., 2007). Test-retest reliability ranges between .60 and .88 indicating generally adequate stability. The SE_M associated with this task ranges between .85 and 1.85; thus, general reliability is acceptable. The total score associated with this task was utilized in the current study which provides a measure of auditory processes (Miller, 2013).

The final subtest that will be utilized from the NEPSY-II is the Picture Puzzles task. This subtest represents a measure of visuospatial processing and requires the examinee to identify constituent parts of a larger picture (Kemp & Korkman, 2010). The internal consistency coefficients associated with this task range between .76 and .88. Test-retest reliability is good with stability coefficients ranging between .71 and .91. The SE_M ranges between 1.04 and 1.47; thus, general reliability is adequate. In line with the Integrated SNP/CHC model, the total score was included in the current study as a measure of visuospatial processes (Miller, 2013).

Wide Range Assessment of Memory and Learning, Second Edition **(WRAML2; Sheslow & Adams, 2003).** The WRAML2 is an assessment instrument that allows for broad evaluation of aspects of memory and learning (Adams & Reynolds, 2009; Sheslow & Adams). Immediate, delayed, working, and associative memory can be assessed in both visual and verbal modalities through use of this battery. It is appropriate for use with individuals between the ages of 5 and 90. Several of the subtests comprising this battery are included in the Integrated SNP/CHC model as potential measures of cognitive facilitators/inhibitors and cognitive processes (Miller, 2013); therefore, many of these subtests were used in the current study. These subtests included Design Memory, Finger Windows, Number/Letter, Sound-Symbol, Story Memory, Symbolic Working Memory, and Verbal Working Memory.

Studies involving the pediatric standardization sample have demonstrated the presence of adequate construct validity with regard to the overall WRAML2 (Maricle, et al., 2011; Sheslow & Adams, 2003). These studies are based upon subtest intercorrelations and factor analyses. Each of the subtests included in the current study exhibits substantial and statistically significant correlations with other subtests on the WRAML2 purported to measure the same construct. In addition, factor analytic studies of both an exploratory and confirmatory nature indicate the underlying factor structure of the WRAML2 is consistent with the theory driving this measure; thus, the subtests included in the current study appear to be adequately tapping the constructs they are hypothesized to assess. With regard to concurrent validity, the WRAML2 has demonstrated substantial correlations with other comprehensive measures of memory and learning. Given these results and their indications of the general validity of the WRAML2, it is likely that the subtests making up this battery are valid measures of the constructs they are believed to assess; thus, reliability for each task will be addressed.

The Design Memory subtest is part of the core battery and considered to measure immediate visual memory on the WRAML2 (Adams & Reynolds, 2009). The examinee is confronted with a complex visual design and asked to reproduce that design. The reliability coefficients for this task range between .82 and .91 for those who are neurotpyical between the ages of 5 and 17 which represents the pediatric standardization sample (Sheslow & Adams, 2003). The stability coefficient is .59 indicating poor test-retest reliability; however, this statistic was derived using the overall standardization sample. Thus, it is difficult to know the nature of test-retest reliability within the pediatric standardization sample. The SE_M ranges between .90 and 1.30 across the pediatric standardization sample. In general, this task has demonstrated adequate reliability. This task is considered a measure of memory processes within the Integrated SNP/CHC model (Miller, 2013).

Finger Windows is included in the WRAML2 as core subtest and measure of short-term, visual memory (Adams & Reynolds, 2009). The examinee is asked to motorically imitate a visual sequence or pattern of movements produced by the examiner. Overall, the reliability associated with this task is acceptable (Sheslow & Adams, 2003). Split-half reliability is adequate with coefficients ranging between .76 and .86; in addition, test-retest reliability is adequate with a coefficient of .69. The SE_M ranges between 1.10 and 1.50. This task was utilized in the current study as a measure of attention; therefore, it is considered a cognitive facilitator/inhibitor (Miller, 2013).

The Number/Letter subtest is a core subtest and measure of immediate verbal memory on the WRAML2 (Adams & Reynolds, 2009). This task requires the child to simply repeat a string of orally presented numbers and letters. The internal consistency coefficients for this task range between .79 and .88 (Sheslow & Adams, 2003). The stability coefficient is .67 indicating adequate test-retest reliability. The SE_M for this task ranges between 1.10 and 1.40. Taken together, the Number/Letter subtest represents a reliable measure of immediate memory. This subtest is utilized as a measure of attention within the Integrated SNP/CHC model; thus, it represents a cognitive facilitator/inhibitor (Miller, 2013).

Sound-Symbol is an optional subtest on the WRAML2 that provides a measure of associative memory (Adams & Reynolds, 2009). The examinee must pair a novel design with a novel sound; thus, the design and sound represent paired associates. This task has demonstrated good internal consistency with coefficients ranging between .88 and .89; however, test-retest reliability is poor with a stability coefficient of .55 (Sheslow & Adams, 2003). The SE_M ranges between 1.70 and 1.80. The Sound-Symbol subtest was utilized in the current study as a measure of memory processes (Miller, 2013).

The Story Memory subtest is considered a core task on the WRAML2 that provides a measure of immediate auditory memory (Adams & Reynolds, 2009). The examinee is asked to repeat an orally presented story including as many details as possible. This task has demonstrated acceptable general reliability (Sheslow & Adams, 2003). Internal consistency is good with coefficients ranging between .88 and .95; however, test-retest reliability is adequate with a stability coefficient of .68. The SE_M for this task ranges between .70 and 1.0. This task is considered a measure of memory processes within the Integrated SNP/CHC model (Miller, 2013).

The Symbolic Working Memory subtest represents an optional subtest on the WRAML2 designed to assess visual/verbal WM (Adams & Reynolds, 2009). This task requires the child to sequence in numerical and alphabetical order a string of numbers and letters by pointing to the appropriate numbers and letters. Split-half reliability is good with coefficients ranging between .85 and .89; in addition, test-retest reliability is adequate with a coefficient of .73 (Sheslow & Adams, 2003). The SE_M ranges between 1.00 and 1.20. Scores on this task were included in the current study as measures of WM; thus, they represent measures of cognitive facilitators/inhibitors (Miller, 2013).

The Verbal Working Memory subtest is also optional and provides a measure of verbal WM on the WRAML2 (Adams & Reynolds, 2009). The examinee must order a string of intermixed words consisting of animals and nonanimals by repeating animals first followed by nonanimals. Older examinees are additionally required to order the animals and/or nonanimals by size. This task has demonstrated acceptable overall reliability in that internal consistency is good with coefficients ranging between .85 and .89. Test-retest reliability is adequate with a stability coefficient of .77. The SE_M for this task ranges between 1.20 and 1.30. This task was utilized as a measure of WM in the current study and therefore represents a cognitive facilitator/inhibitor (Miller, 2013). See Table 2 for summative information regarding batteries and subtests utilized in the current study.

Data Analysis

Descriptive Statistics

As a preliminary procedure, descriptive statistics were computed for demographic data and across scores associated with each measure using the Statistical Package for the Social Sciences (SPSS) version 19. Means, standard deviations, and ranges for

Table 2

Subtest Classification According to the Integrated SNP/CHC Model (Miller, 2013)

		Cognitive F/I			Cognitive Processes			
Battery	Subtest	Att	PS	WM	VS	Aud	Mem	EF
WISC-IV	Block Design				X			
WISC-IV	Cancellation		X					
WISC-IV	Digit Span Backward			X				
WISC-IV	LNS			X				
WISC-IV	Symbol Search			X				
WJ-III Cog	Analysis/Synthesis							X
WJ-III Cog	AWM			X				
WJ-III Cog	Concept Formation							X
WJ-III Cog	Incomplete Words					X		
WJ-III Cog	Memory for Words	X						
WJ-III Cog	Numbers Reversed			X				
WJ-III Cog	Pair Cancellation	X						
WJ-III Cog	Retrieval Fluency		X					
WJ-III Cog	Sound Blending					X		
WJ-III Cog	Spatial Relations				X			
WJ-III Cog	Visual Matching		X					
WJ-III Ach	Sound Awareness					X		
D-KEFS	CWI-4							X

Table 2, Cont

		Cognitive F/I			Cognitive Processes			
Battery	Subtest	Att	PS	WM	VS	Aud	Mem	EF
D-KEFS	DF-3							X
D-KEFS	TMT-4							X
D-KEFS	VF-3							X
NEPSY-II	Arrows				X			
NEPSY-II	Auditory Attention	X						
NEPSY-II	Response Set							X
NEPSY-II	Geometric Puzzles				X			
NEPSY-II	Inhibition Switching							X
NEPSY-II	Memory for Designs						X	
NEPSY-II	Memory for Names						X	
NEPSY-II	Narrative Memory						X	
NEPSY-II	Phonological Processing					X		
NEPSY-II	Picture Puzzles				X			
WRAML2	Design Memory						X	
WRAML2	Finger Windows	X						
WRAML2	Number/Letter	X						
WRAML2	Sound-Symbol						X	
WRAML2	Story Memory						X	

Table 2, Cont

		Cognitive F/I			Cognitive Processes			
Battery	Subtest	Att	PS	WM	VS	Aud	Mem	EF
WRAML2	SWM			X				
WRAML2	VWM			X				

Note. Integrated SNP/CHC model = Integrated School Neuropsychological/Cattell-Horn-Carroll Model; Cognitive F/I = Cognitive Facilitators/Inhibitors; Att = Attention; PS = Processing Speed; WM = Working Memory; VS = Visuospatial; Aud = Auditory; Mem = Memory; EF = Executive Functioning; LNS = Letter-Number Sequencing; AWM = Auditory Working Memory; CWI-4 = Color-Word Interference Condition 4; DF-3 = Design Fluency Condition 3; TMT-4 = Trail Making Test Condition 4; VF-3 = Verbal Fluency Condition 3; SWM = Symbolic Working Memory; VWM = Verbal Working Memory.

demographics and all scores were calculated. The normality and linearity of subtest scores were also investigated and will be described in the following chapter.

Bivariate Correlations

The SPSS was also used to conduct bivariate correlations between scores on each subtest included in the study. A correlation matrix presenting correlation coefficients, significance levels, means, and standard deviations for all scores was generated and examined. This analysis assisted in evaluating for the presence of multicollinearity among subtest scores (McDonald & Ho, 2002; Weston & Gore, 2006). Variables characterized by multicollinearity are highly correlated such that they are redundant when included in statistical analyses (Weston & Gore). This condition is problematic for a number of statistical operations; however, multicollinearity was not observed within the correlation matrix.

Primary Analyses

In order to determine whether cognitive facilitators/inhibitors support basic cognitive processes, two structural equation modeling (SEM) techniques were utilized. The phrase SEM refers to a family of statistical procedures that essentially allows researchers to examine the behavior and utility of pre-specified models (Kline, 2005; Weston & Gore, 2006). The goal in SEM is to provide a parsimonious, theory-based description of the relationships between variables within these models. The SEM techniques that were utilized in the current study include confirmatory factor analysis and structural regression modeling.

Confirmatory factor analysis (CFA). Under the broader rubric of latent variable SEM, CFA represents the measurement model (Brown, 2006; Keith, 2006). This refers to the interrelationships between unobservable or latent variables and observable variables. In general, CFA is a factor analytic procedure used to gain an understanding of the underlying structure associated with a set of variables (Mertler & Vannatta, 2010). The purpose of factor analysis is to determine whether measures purporting to assess the same construct are doing so; thus, factor analysis can be considered a reduction method. Observable, measurable variables tapping the same construct are grouped thereby reducing the number of variables. Factor analytic procedures produce factor loadings or correlations between observable variables and latent variables or constructs (Mertler & Vannatta). These correlations are interpreted as Pearson correlation coefficients ranging from -1.00 to +1.00 reflecting perfect negative and positive correlations, respectively.

Factor analyses also produce communalities which indicate the amount of variability within an observable variable that is explained by the latent variable or construct.

There are two basic types of factor analyses frequently used in the social sciences based upon the common factor model distinguishable by their intended function (Brown, 2006; Mertler & Vannatta, 2010). Exploratory factor analysis (EFA) allows for the initial description and summarization of a set of variables by grouping those that are correlated (Mertler & Vannatta). This technique is commonly used during initial stages of research when minimal information regarding the underlying structure of a given measure is available. Essentially, the underlying factor structure is explored and subsequently described through use of statistical information, theory, and previous research (Keith, 2006). In contrast, CFA is typically conducted as a method of evaluating a theory associated with the latent constructs that may be driving the underlying structure of a measure (Mertler & Vannatta); thus, theory and research are used to determine in advance which variables represent which latent constructs (Keith). Given the focus on assessing a priori hypotheses, CFA has been used extensively in evaluating the validity of test instruments and psychological constructs (Brown). CFA is particularly desirable given it allows for the ability to specify method effects. Method effects occur when the correlation between observable variables is more related to the measurement approach rather than the overarching latent variables. By allowing statistically for measurement error and error theory, CFA handles method effects much better than other SEM techniques.

In the current study, CFAs were conducted to determine whether measures of attention, PS and WM collectively could be considered cognitive facilitators/inhibitors, and to produce factors associated with basic cognitive processes. In conducting CFAs, several steps must be undertaken including model specification, model fitting, model evaluation, and model modification (McDonald & Ho, 2002). In model specification, the initial model or assumed underlying structure of a measure or group of measures is graphically indicated (Keith, 2006). These models are comprised of latent and observable variables. Latent variables or factors are synonymous with the presumed underlying constructs believed to be associated with the measure, while observable variables or indicators refer to the actual measurements (i.e., subtest scores) that are obtained. Causal assumptions or relationships between factors and indicators are explicitly noted through use of a diagram depicting single- or double-headed arrows referred to as paths. Double-headed arrows are noted between factors and signify the presence of a correlation; in contrast, single-headed arrows exist between factors and indicators signifying the presence of a direct effect. The nature of these paths makes clear the presumed underlying structure of a measure or group of measures. This diagram also indicates that measurement error is associated with each indicator.

After specifying the model, several steps must be taken in order to clearly identify the model (Brown, 2006; Keith, 2006). The latent variables included in the model do not possess a scale; thus, they may be scaled by fixing at 1.0 the path from a factor to one indicator associated with that factor, or by fixing the variance of the factor at 1.0. In the current study, the models were identified by fixing marker indicators or paths given this method of scaling is more common and more consistent with SEM (Keith). The ratio of indicator variances and covariances to factor loadings and variances/covariances were evaluated. Models with fewer pieces of input information than freely estimated model parameters are referred to as underidentified and cannot be estimated through use of SEM techniques; in contrast, models with equal numbers of input information and freely estimated parameters are considered just-identified (Brown). In this situation, measures of goodness-of-fit cannot be utilized. Models with a greater number of input information than freely estimated parameters are referred to as overidentified meaning the model can be estimated and goodness-of-fit statistics can be utilized. The models in the current study were overidentified given the factors associated with the models were correlated with at least one other factor and characterized by numerous indicators; in addition, error between these indicators was largely uncorrelated.

Various factor-extraction techniques are utilized across factor analytic procedures to determine the factors that exist within a measure or group of measures (Brown, 2006; Mertler & Vannatta, 2010). The most commonly used extraction procedure in CFA is maximum likelihood (ML; Brown). This method of extraction attempts to discern parameter values that make the current data most likely via an iterative process. Essentially, the model is repeatedly refined until convergence is reached. This indicates that further parameter estimates cannot be improved upon. This method of extraction is useful given it produces standard errors associated with each parameter in the model. This allows for the evaluation of both significance and precision of these parameters. The ML method was utilized in extracting factors for the current study.

The significance and utility of the models produced was evaluated in part by examining goodness-of-fit indices (Brown, 2006; Keith, 2006). A goodness-of-fit index provides a measure of how well the pre-specified model fits the observed data. Several indices have been developed that exist within three broad categories including indices of absolute fit, indices of fit adjusting for model parsimony, and indices of comparative or incremental fit (Brown). It has been recommended that at least one index from each category be reported (Brown; Jackson, Gillaspy, & Purc-Stephenson, 2009). The index of absolute fit that was utilized in this study is the standardized root mean square residual (SRMR) given it is preferred over other indices of absolute fit including chi-square (χ^2) and root mean square residual (RMR; Brown; Hooper, Coughlan, & Mullen, 2008). The χ^2 statistic is highly sensitive to sample size while the RMR is considered difficult to interpret given it is not standardized. Essentially, the SRMR is a measure of the average difference between observed correlations and correlations predicted by the model. SRMR values of 0.0 indicate a perfect fit; thus, smaller numbers indicate better fit. Values close to .08 and below have been considered to indicate reasonably good fit. Although most emphasis was placed upon the SRMR in assessing absolute fit of the model, the model χ^2 was reported as well given it represents a necessary component of other goodness-of-fit indices (Kline, 2005).

The index emphasizing parsimony correction that was utilized is the root mean square error of approximation (RMSEA; Brown, 2006). Parsimony refers to embracing the simplest hypothesis in the formulation of a theory or interpretation of data; thus, more parsimonious models are valued. Models produced by CFAs with fewer degrees of freedom are considered more parsimonious. Essentially, the RMSEA penalizes models based upon poor parsimony. This index is also desirable given a confidence interval can be calculated around its value. Values of RMSEA close to .06 and below have been considered to indicate a parsimonious model with reasonably good fit (Brown; McDonald & Ho, 2002). A confidence interval with a lower limit close to 0 and an upper limit below.08 further indicates good fit (Hooper et al.). The index of comparative fit that was utilized in this study is the comparative fit index (CFI). The CFI compares the fit of the observed data to the null hypothesis which states that no relationships exist among factors and indicators (Brown). CFI scores range from 0.0 to 1.0 with values of .95 and above considered indicative of good fit (Brown; McDonald & Ho). These indices were interpreted collectively and in association with other aspects of the model such as localized strain and parameter estimates.

Goodness-of-fit statistics provide information on only global fit of the model; however, they do not provide an indication of good fit across aspects of the model (Brown, 2006). In other words, goodness-of-fit indices cannot provide information about relationships between specific indicators within the model. At times, goodness-of-fit indices may indicate good fit on a global scale between the model and the data, while local aspects of the model do not fit well. This situation becomes more likely as models increase in complexity. Because the models associated with the current study were complex in that they were characterized by numerous indicators, additional interpretations of model fit were made. The models were evaluated for localized areas of strain or focal areas of misfit (Brown). This was achieved through use of residual statistics.

Residual statistics provide information associated with the difference between variances and covariances of indicators in the observed data and variances/covariances of indicators in the predicted model (Brown, 2006). These residuals can be standardized and interpreted similarly to *z* scores wherein zero would suggest perfect fit for the indicator in question. As the residual value deviates from zero, poorer fit would be suggested; thus, standardized residuals with an absolute value close to 1.96, which reflects a statistically significant *z* score at the .05 alpha level, are often considered to be indicative of poor fit. However, the current study utilized the critical standardized residual value of 2.58, which reflects a statistically significant *z* score at the .01 alpha level, given standardized residuals are highly sensitive to sample size. Larger sample sizes typically result in larger standardized residuals (Brown); thus, a larger cutoff value was utilized in the current study given the large sample size.

Specific aspects of parameter estimates were also used to evaluate the significance and utility of the models produced. These aspects include direction, magnitude, and significance of parameter estimates such as factor loadings, variances, and covariances, and indicator errors (Brown, 2006). Initially, the models were evaluated as to whether general parameter estimates make sense statistically and functionally. Statistically, all parameter estimates should fall within an acceptable range for that parameter; thus, standardized factor correlations should not exceed 1.0 and factor and indicator error variances should not be negative. Functionally, the direction of parameter estimates should be aligned with prediction, theory, and research. In addition, parameter estimates should all reach statistical significance indicating they are all necessary parameters within the model. Standard errors of parameter estimates were also evaluated to determine whether their magnitude was suitable. Standard errors provide information regarding the ability of the model to approximate actual population parameters; thus, the model should hold for other samples within the population of interest. Overly small or large standard errors may indicate problems with parameter estimates associated with sample size or non-normal data. In addition, the magnitude or practical significance of parameter estimates were evaluated by examining the effect size associated with each.

Finally, the potential for modifying the models was considered. Modification indices provide information about the likely impact of changes (i.e., modifications) to the original model (Brown, 2006). These indices focus specifically on fixed or constrained parameters in the initial model and how changes to these parameters impact goodness-of-fit indices such as χ^2. These indices may suggest that a specific fixed or constrained parameter be instead freely estimated in order to improve overall model fit. Modification indices with a value of 3.84 or greater, which reflects a statistically significant χ^2 value with one degree of freedom at the .05 alpha level, suggest that global fit could be improved if a specific fixed or constrained parameter were freely estimated. These indices are also highly sensitive to sample size; thus, expected parameter change (EPC) values were evaluated as well. These values indicate the magnitude and direction of change correcting for sample size if a parameter were freely estimated.

Although global fit of the models is important, respecifications or modifications to the model should not be attempted unless these modifications are supported by theory and previous research (Brown, 2006; McDonald & Ho, 2002). Consideration of modification indices proceeded in a stepwise fashion wherein the largest modification index and EPC value were examined first in association with research and theory. Modifications that were nonsensical or inconsistent with research and theory resulted in examination of the next largest modification index and EPC values. The original models were also modified via removal of statistically nonsignificant parameters (Brown). Unnecessary parameters can be detected through use of the univariate Wald test. This statistic can be viewed as the converse of the modification index in that it provides an indication of improvement in overall model fit when a freely estimated parameter was instead fixed or constrained. The Wald test can be calculated for each parameter by squaring the z score associated with that parameter.

Traditionally, indicators with factor loadings of .30 and above are retained as salient factor loadings within CFA models (Brown, 2006; Mertler & Vannatta, 2010). Factor loadings at this level are considered to suggest that a measure is reasonably representative of a construct. In contrast, factor loadings between factors of .80 and higher are considered to reflect poor discriminant validity; thus, factors exhibiting this degree of correlation could be interpreted as representing the same construct. For all CFAs, indicators with loadings of .30 and above were retained. Factors found to be highly correlated (i.e., loadings greater than .80) were considered representative of the same construct and reconceptualized; however, in the initial CFA directed at measures of cognitive facilitation/inhibition, loadings between factors above .80 are desirable since this would indicate attention, PS, and WM represent one general factor. All analyses associated with the CFAs were conducted in the Linear Structural Relationships (LISREL; Joreskog & Sorbom, 1993) 8.8 computer program.

Structural regression (SR) modeling. The primary purpose of conducting a CFA is to identify the measurement model associated with a set of variables (Fabrigar & Wegener, 2009; Weston & Gore, 2006). However, the measurement model cannot describe directional relationships between factors. The SR modeling technique allows for factors to be specified as either antecedents or consequences of other factors. This type of specification refers to the path or structural model of a set of variables; thus, SR modeling encompasses both the measurement and structural models (Kline, 2005). Given the purpose of the current study was to determine whether cognitive facilitators/inhibitors support cognitive processes, both of which are represented as factors, identification of the structural model was essential. Because CFAs and SR models are both SEM procedures, the process of identifying the structural model again consisted of four basic steps including model specification, fitting, evaluation, and modification (Fabrigar & Wegener; Kline).

As with CFA, model specification in SR modeling should be directed by theory and previous research (Fabrigar & Wegener, 2009; Weston & Gore, 2006). The model specification process requires that endogenous and exogenous factors be explicitly identified. Endogenous factors are those with a presumed antecedent or cause explicitly represented in the model (Kline, 2005). In contrast, exogenous factors are those lacking a presumed antecedent; thus, their causes are not represented in the model. The diagram associated with SR modeling differs from that associated with CFA in that single-headed arrows are depicted between factors (Fabrigar & Wegener). Diagrams associated with CFA utilize double-headed arrows between factors representing the lack of a directional relationship. Within SR modeling, factors receiving single-headed arrows from other factors are considered endogenous. This directional path signifies the presumed antecedent or cause of the endogenous factor. Factors that do not receive a single-headed arrow or those lacking a directional path are considered exogenous; thus, their antecedents are not specified. For the current study, cognitive facilitators/inhibitors theoretically represent an exogenous factor that exerts influence upon cognitive processes or the endogenous factor(s). Diagrams associated with SR models also specify that measurement error or disturbance is associated with endogenous factors (Kline).

Model specification also encompasses model identification (Fabrigar & Wegener, 2009; Kline, 2005). This requires that the exogenous and endogenous factors associated with the model be scaled given these latent variables do not inherently possess a scale (Fabrigar & Wegener; Weston & Gore, 2006). As with CFA, the models were specified by fixing at 1.0 the path from a factor to one indicator associated with that factor. These parameters are referred to as fixed; however, free and constrained parameters were also specified. Free parameters are those that are free to vary in that their values are estimated from the data (Fabrigar & Wegener). Constrained parameters are also estimated from the data; however, they must maintain a specific relationship to other parameters in the model.

In line with the two-step rule, model identification in SR modeling also depends upon the nature of the measurement and structural models such that both must be identified (Kline, 2005). In order to determine whether the measurement model is identified, the initial SR models were respecified as a CFA model. Although CFAs evaluating measurement models were previously conducted, these measurement models were associated with the nature of cognitive facilitators/inhibitors and cognitive processes separately rather than together. Therefore, a CFA containing these factors and all their indicators was conducted. This CFA was specified and identified as outlined above. Following identification of the measurement model, the structural model was identified. Two types of structural models exist including those that are recursive and nonrecursive (Kline; McDonald & Ho, 2002). Recursive models are characterized by unidirectional paths and uncorrelated disturbances between endogenous factors; in contrast, nonrecursive models contain feedback loops and/or correlated disturbances. Thus, structural models that are nonrecursive may exhibit bidirectional relationships between endogenous factors. Recursive structural models are always considered to be identified and typically result in models that are overidentified (Kline); thus, the presence of a recursive model indicates the structural model is identified. Nonrecursive models are more complex and may potentially be identified by adding exogenous factors to those models that are just-identified or underidentified. The SR models in the current study can be described as recursive models.

The process of identifying the measurement component followed by the structural component of a SR model is consistent with the two-step modeling procedure and reflective of the two-step rule of model identification (Kline, 2005). The two-step modeling procedure simply requires that both components of the SR model be identified in the forefront (Anderson & Gerbing, 1988). In this way, model misspecification can be localized to the measurement model, structural model, or both. In the current study, both the measurement and structural models associated with the SR models were identified. Within the measurement models, factors were correlated with at least one other factor and characterized by numerous indicators; and, error between indicators was uncorrelated. The structural models were recursive given only unidirectional paths were specified between endogenous factors; in addition, disturbances associated with these factors were uncorrelated.

Following specification of the SR model, the model was fit to the data (Fabrigar & Wegener, 2009; Weston & Gore, 2006). Model fitting in SR modeling essentially represents parameter estimation and is highly similar to the process of factor extraction and model fitting in CFA. The purpose of model fitting is to determine parameter estimates for a specified model that best account for the current data (Fabrigar & Wegener). Various methods of parameter estimation exist; however, the most commonly used method of estimation is ML estimation (Fabrigar & Wegener; Kline, 2005). This method attempts to establish through an iterative process the set of parameter estimates that are most likely given the nature of the specified model and the observed data (Fabrigar & Wegener). The likelihood that a model with a certain set of parameter estimates produced the observed data is evaluated by examining the discrepancy between the model and the data. When the smallest possible discrepancy is reached, a solution will have been converged. The ML estimation method was utilized for SR model estimation in the current study.

Evaluation of the significance and utility of the SR models was achieved in part through use of indices of goodness-of-fit. As with CFA, these indices provide an indication of the overall fit of the SR models to the observed data (Fabrigar & Wegener, 2009; Kline, 2005; McDonald & Ho, 2002). Fit indices are reported with regard to absolute fit, parsimonious fit, and incremental fit (Jackson et al., 2009). The index of absolute fit utilized in the current study was the SRMR (Hooper et al., 2008; McDonald & Ho). As discussed above, this index is preferred over χ^2 and RMR; however, the χ^2 statistic was still reported. A reasonably good fit is again associated with values close to and below .08 (Hooper et al.; McDonald & Ho). The index emphasizing parsimonious fit utilized in the current study was the RMSEA. Again, values close to and below .06 are interpreted as indicating a parsimonious model with reasonably good fit. A confidence interval with a lower limit close to 0 and an upper limit below.08 further indicates good fit (Hooper et al.). The index of incremental fit interpreted in the current study was the CFI (Hooper et al.; McDonald & Ho). Values of .95 and above again represent good fit for this index.

Significance and utility of the overall SR models were also evaluated by examining local aspects of the model such as parameter estimates (Fabrigar & Wegener, 2009). These values were individually examined for evidence of misfit and general utility. Detection of localized areas of strain were again achieved via examination of the residual statistics associated with each parameter (Brown, 2006). The critical value of

2.58 was utilized in determining which indicators exhibit poor fit. Various aspects of the parameter estimates such as factor loadings, variances and covariances, and indicator error were also examined for direction, magnitude, and significance. Again, these aspects of the parameter estimates should make sense statistically and functionally. The estimates should all fall within an appropriate range such that implausible values are not present; and, the direction of these estimates should be consistent with theory, prediction, and research. In addition, each of the estimates should reach statistical significance indicating they are a necessary piece of the SR model. Standard errors of these estimates provided information related to each estimate's magnitude and practical significance.

In evaluating model fit in SR modeling, it also becomes important to consider the presence of equivalent models (Fabrigar & Wegener, 2009; Kline, 2005). Equivalent models are those that account for the observed data as well as the originally specified model; however, the interrelationships between factors and indicators differ. These models produce identical covariances and indices of goodness-of-fit; thus, they would fit equally well to any data set. In this way, equivalent models represent a competing explanation of the observed data. Numerous equivalent models can be present within a SR model; however, the existence of these models is difficult to determine. Detecting and discussing the presence of these models is important since the purpose of the SR modeling technique is to best explain the observed data. One method for detecting equivalent models is the replacement rule (Fabrigar & Wegener). This rule emphasizes the idea that the structural component of the SR model is composed of subsets or blocks of factors. Alterations can be made within a block without altering the fit of the overall model if the block meets specific criteria. Although this rule is difficult to implement, it works well when attempting to identify the presence of saturated preceding blocks and symmetric focal blocks within the SR model. Detection of these types of blocks is important since they account for most equivalent models. The replacement rule was applied in the current study in order to evaluate for the presence of equivalent models which indicated equivalent models did not exist in the context of the data.

The final potential step in SR modeling is model modification (Fabrigar & Wegener, 2009; Kline, 2005; McDonald & Ho, 2002). As with CFA, modifications to the initial model were not made unless supported by theory and previous research. Modification indices were again examined for the impact of specific changes made to the model upon the overall fit of the model. The critical value of 3.84 was again utilized along with EPC values (Brown, 2006). Removal of statistically nonsignificant parameters is also considered a method of model modification. However, modifications that are nonsensical or inconsistent with theory and previous research were not made. Following establishment of a satisfactory SR model, the analysis was completely and accurately described (Kline; McDonald & Ho). All analyses associated with SR modeling were conducted in the LISREL (Joreskog & Sorbom, 1993) 8.8 computer program.

Research Questions

Through use of these methods, the current study examined two separate, but related, research questions. These questions involved the comparison and evaluation of differing theoretical models associated with the neurocognitive abilities of interest. The specific research questions and theoretical models that were analyzed are described in detail below.

Initial Question

Initially, differing theoretical models describing the relationship between attention, PS, and WM were compared. This assisted in determining whether these neurocognitive abilities factor or function together. Specifically, the research question states:

Is the relationship between attention, PS, and WM best described by:

a. A theoretical model wherein attention, PS, and WM produce three separate and distinguishable factors?
b. The Integrated SNP/CHC model (Miller, 2013) wherein attention, PS, and WM are hypothesized to represent one construct referred to as cognitive facilitators/inhibitors?

Initially, a CFA was conducted involving subtests across measures believed to represent attention, PS, and WM. The models proposed above were examined separately with regard to overall and local fit as a method of determining which model best described the relationship between attention, PS, and WM.

Three-Factor Model. This model represents the null model (Brown, 2006) in association with the relationship between attention, PS, and WM. More specifically, this model represents the idea that no discernible relationship exists between these factors; thus, they cannot collectively be considered cognitive facilitators/inhibitors. Subtests or indicators associated with each construct or factor were forced to load on separate factors thereby producing three distinct factors including attention, PS, and WM. For the current study, determinations regarding subtest loadings were made via examination of Miller's (2013) Integrated SNP/CHC model. Although this model suggests attention, PS, and WM function together to impact cognitive processes, each is viewed as a separate category within a broader classification. The following subtests were forced to load upon the attention factor: WJ-III Cog Pair Cancellation and Memory for Words, NEPSY-II Auditory Attention, and WRAML2 Number/Letter and Finger Windows. The subtests that were forcibly loaded upon the PS factor include: WISC-IV Cancellation, Coding, and Symbol Search, and WJ-III Cog Visual Matching and Retrieval Fluency. Finally, the following subtests were forced to load upon the WM factor: WISC-IV Digit Span Backward and Letter-Number Sequencing, WJ-III Cog Auditory Working Memory and Numbers Reversed, and WRAML2 Verbal Working Memory and Symbolic Working Memory. The Three-Factor Model is depicted in Figure 3.1.

One-Factor Model. The Integrated SNP/CHC model suggests that neurocognitive functioning can be tapped by assessing across four broad domains including sensorimotor functions, cognitive facilitators/inhibitors, cognitive processes, and acquired knowledge (Miller, 2013; see Figure 1.1). These domains influence each other and are additionally influenced by social-emotional, cultural, and environmental factors. The model posits that sensorimotor functions act as the foundation upon which cognitive processes are built and impact the acquisition of knowledge. The model further suggests that cognitive processes including visuospatial, auditory, memory, and executive processes are influenced by cognitive facilitators/inhibitors. In other words, cognitive

Figure 3.1. Three-Factor Model

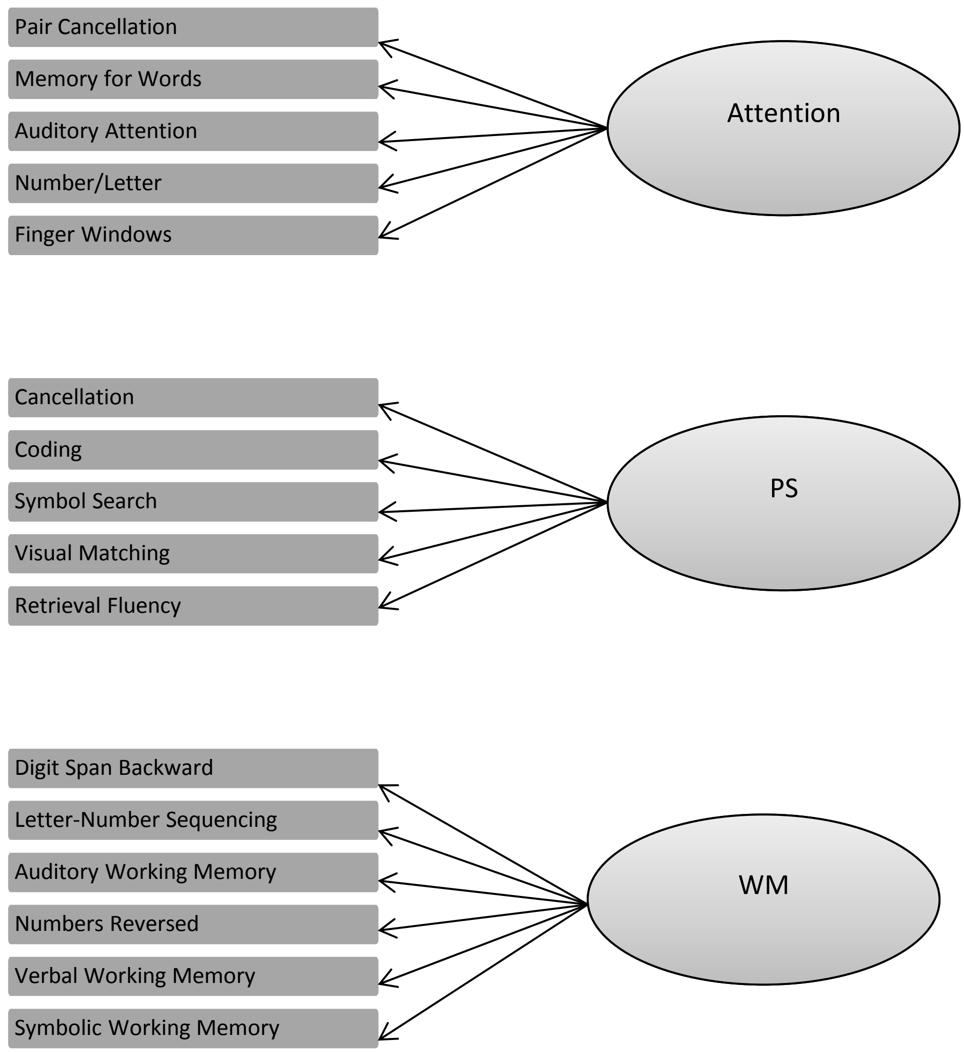

Figure 3.1 Graphic representation of the three-factor model of attention, processing speed (PS), and working memory (WM).

facilitators/inhibitors such as attention, PS, and WM act to enable or constrain cognitive processes. Thus, performance on measures believed to tap cognitive facilitators/inhibitors should influence performance on measures believed to tap cognitive processes in a consistent and predictable way. The model also states that cognitive processes act to influence acquired knowledge. This domain includes crystallized and academic knowledge and language.

The current study focused only on the relationship between attention, PS, and WM; therefore, the following subtests were forced to load together to produce one common factor: WISC-IV Cancellation, Coding, Symbol Search, Digit Span Backward, and Letter-Number Sequencing; WJ-III Cog Pair Cancellation, Memory for Words, Visual Matching, Retrieval Fluency, Auditory Working Memory, and Numbers Reversed; NEPSY-II Auditory Attention; and, WRAML-2 Number/Letter, Finger Windows, Verbal Working Memory, and Symbolic Working Memory. Determinations regarding these loadings were made via examination of Miller's (2013) Integrated SNP/CHC model. The One-Factor Model is represented in Figure 3.2.

Subsequent Question

Following examination of the relationship between attention, PS, and WM, the utility of a theoretical model describing the impact of these neurocognitive abilities upon cognitive processes including visuospatial, auditory, memory, and executive processes was evaluated. Specifically, the research question states:

Is the impact of attention, PS, and WM upon cognitive processes described well by:

a. The Integrated SNP/CHC model (Miller, 2013) wherein attention, PS, and WM function together to facilitate or inhibit cognitive processes in a consistent, predictable manner?

Figure 3.2. One-Factor Model

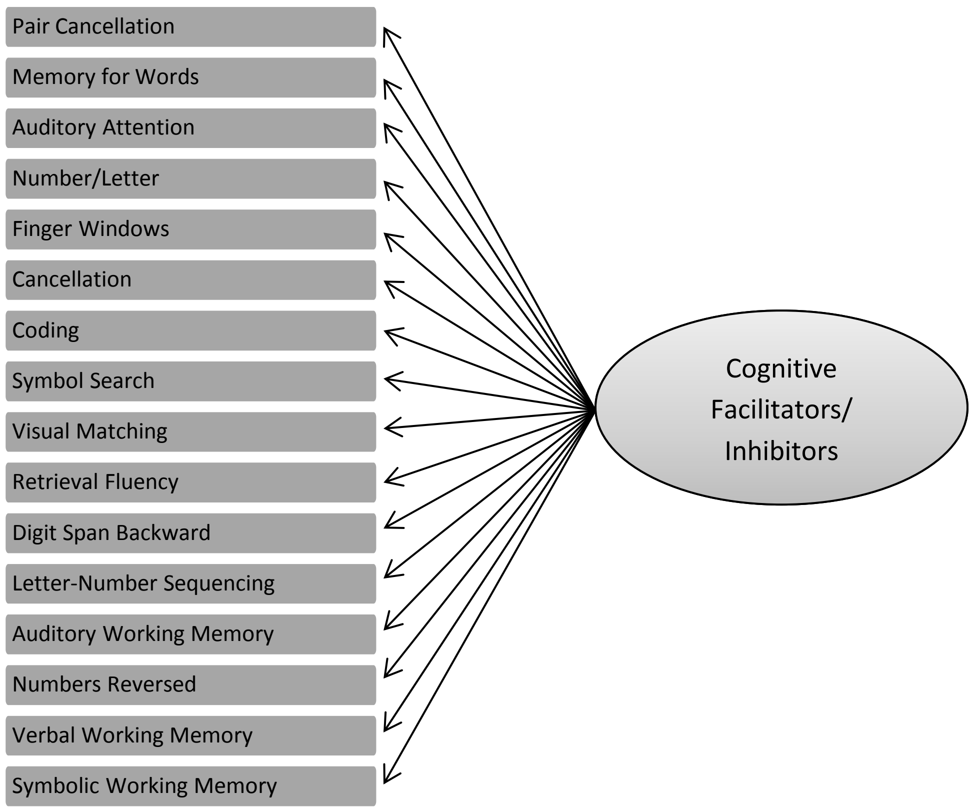

Figure 3.2 Graphic representation of the one-factor model of attention, processing speed (PS), and working memory (WM).

In order to address the subsequent research question, an additional CFA was conducted. This analysis was directed at establishing the measurement model associated with cognitive processes; thus, this procedure served to create factors associated with cognitive processes. Following this analysis, a SR model was conducted involving subtests believed to assess cognitive facilitators/inhibitors and cognitive processes. The model proposed above was examined for global and local fit in order to determine whether this model exhibited utility in explaining the impact of attention, PS, and WM upon cognitive processes.

Cognitive Facilitation/Inhibition Model. This model is most consistent with the Integrated SNP/CHC model (Miller, 2013) in that it hypothesizes that attention, PS, and WM act in concert to result in facilitation or inhibition of cognitive processes. Within this model, poor performance on measures of attention, PS, and WM should theoretically result in poor performance on measures of various cognitive processes and vice versa; thus, cognitive facilitators/inhibitors would directly influence cognitive processes. The selection of the various indicators associated with each factor was based upon examination of the Integrated SNP/CHC model (Miller). The following subtests were considered indicators of cognitive facilitation/inhibition: WISC-IV Cancellation, Coding, Symbol Search, Digit Span Backward, and Letter-Number Sequencing; WJ-III Cog Pair Cancellation, Memory for Words, Visual Matching, Retrieval Fluency, Auditory Working Memory, and Numbers Reversed; NEPSY-II Auditory Attention; and, WRAML2 Number/Letter, Finger Windows, Verbal Working Memory, and Symbolic Working Memory.

Subtests that were considered indicators of visuospatial processes included: WISC-IV Block Design, WJ-III Cog Spatial Relations, and NEPSY-II Arrows, Picture Puzzles, and Geometric Puzzles. The following subtests were utilized as indicators of auditory processes: WJ-III Ach Sound Awareness, WJ-III Cog Incomplete Words and Sound Blending, and NEPSY-II Phonological Processing. The subtests that were considered indicators of memory included the following: NEPSY-II Narrative Memory,

Memory for Designs, and Memory for Names, and WRAML2 Story Memory, Design Memory, and Sound-Symbol. Finally, indicators of executive processes included: WJ-III Cog Concept Formation and Analysis/Synthesis, D-KEFS Color-Word Interference, Verbal Fluency, Design Fluency, and Trail Making Test, and NEPSY-II Inhibition and Response Set. Figure 3.3 provides a schematic of the Cognitive Facilitation/Inhibition Model.

Summary

The previously described study was designed to determine whether specific neurocognitive abilities can be considered cognitive facilitators/inhibitors as suggested within the Integrated SNP/CHC model (Miller, 2013). In addition, this study was intended to determine whether these cognitive facilitators/inhibitors act to influence cognitive processes in a consistent and predictable manner. The literature review provided indicates a clear need to research the relationship between attention, PS, and WM and the impact of these neurocognitive abilities upon basic cognitive processes within the pediatric clinical population. This was examined by conducting SEM analyses including CFA and SR modeling.

Figure 3.3. Cognitive Facilitation/Inhibition Model

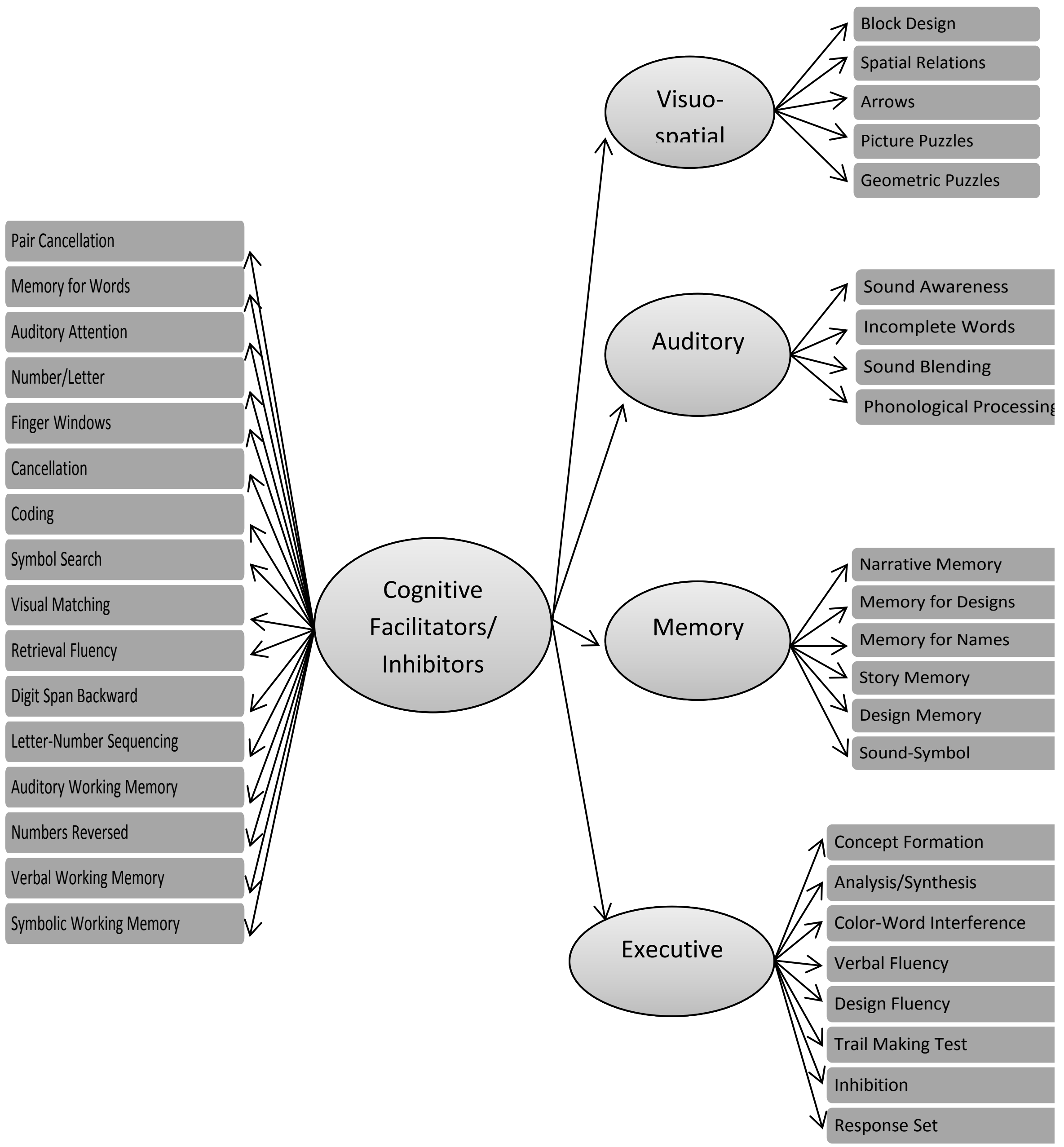

Figure 3.3 Graphic representation of the cognitive facilitation/inhibition model.

CHAPTER IV

RESULTS

The goal of this study was to examine whether certain neurocognitive processes act together to constrain or support basic cognition as suggested in the Integrated School Neuropsychological (SNP)/Cattell-Horn-Carroll (CHC) model (Miller, 2013). In more specific terms, the primary purpose was to determine whether attention, processing speed (PS), and working memory (WM) collectively act upon basic neurocognitive processes including visuospatial, auditory, memory, and executive processes. The factor structure of measures tapping attention, PS, and WM was examined by comparing a three-factor, null model to a one-factor model through use of confirmatory factor analysis (CFA). The fit of both models was examined separately and then compared to determine which model best explained the relationship between attention, PS, and WM within the context of the data. The model with the best fit was utilized in a structural regression (SR) model to determine the impact of attention, PS, and WM upon basic neurocognitive processes. The global and local fit of this model was examined as a method of evaluating the validity of one aspect of the Integrated SNP/CHC model (Miller).

Preliminary Analysis

This section discusses descriptive statistics associated with the variables, and the bivariate relationships among those variables. The alpha level for the study was set at α =

.05. Any findings with *p*-values of greater than .05 are presented as nonsignificant. The Statistical Package for the Social Sciences (SPSS) version 19 was used for all preliminary analyses.

Descriptive Statistics

Prior to primary statistical analyses, missing data points were determined to be missing not at random (MNAR). As a method of increasing the amount of data used in the primary analyses, multiple imputation (MI) was used to estimate missing data. The data were also examined for outliers. Only extreme outliers were removed given the sample was comprised of children who may be expected to produce scores outside the average range on subtests included in this study.

There were 591 participants between the ages of 8 and 16 in the current study. More than half were girls (52.3%), about one-third were Caucasian (37.7%), and just over 10% were African American (5.8%) and Hispanic/Latino (5.4%). A large number of participants did not provide information about their ethnicity (41.1%). For the purpose of analysis, participants who identified as Caucasian were compared to participants who did not identify as Caucasian due to the unequal distribution. Finally, one-fourth of the participants were diagnosed with learning disabilities (LD; 25.2%), 16.1% with attention-deficit/hyperactivity disorder (AD/HD) and 13.5% with general neurological impairments and medical conditions. About one-third of the participants did not provide their diagnostic information (33.0%; see Table 3).

Table 3

Frequencies and Percentages for Gender, Ethnicity, and Broad Diagnosis

	n	%
Gender		
Male	281	47.5
Female	308	52.1
Ethnicity		
African American	34	5.8
Hispanic/Latino	32	5.4
Caucasian	223	37.7
Other	58	9.8
Not Answered	243	41.1
Broad Diagnosis		
Learning Disability	149	25.2
Speech/Language Disability	13	2.2
Neurological Impairment & General Medical	80	13.5
AD/HD	95	16.1
Autism Spectrum Disorder	36	6.1
Emotional Disability	23	3.9
Not Answered	195	33.0

Note. Frequencies not summing to $N = 591$ and percentages not summing to 100 reflect missing data; AD/HD = attention-deficit/hyperactivity disorder.

Bivariate Relationships among Variables

Crosstab analysis using Pearson's chi-square (χ^2) and Cramer's *V* tests were conducted to examine the relationships among the demographic variables. No significant relationships were found between gender by ethnicity, age group, or broad diagnostic category (all *ps* > .05). In addition, no significant relationships were found between ethnicity by age group or broad diagnostic category (all *ps* > .05).

As seen in Table 4, the relationship between broad diagnostic category and age group was found to be significant, $\chi^2(10) = 21.27$, $p = .019$, $V = .164$. A greater proportion of participants aged 8 to 9 years had LDs and autism spectrum disorders (ASD; 44.1% and 14.4%, respectively) than did participants aged 10 to 12 years (35.6% and 6.3%, respectively) and participants aged 13 to 16 years (33.9% and 7.6%, respectively). A greater proportion of participants aged 10 to 12 years had speech/language disabilities and ASDs (4.4% and 30.0%, respectively) than did participants aged 8 to 9 years (4.2% and 17.8%, respectively) and participants aged 13 to 16 years (.8% and 22.0%, respectively). A greater proportion of participants aged 13 to 16 years had neurological impairments (28.0%) and emotional disabilities (ED; 7.6%) than did participants aged 8 to 9 years (15.3% and 4.2%, respectively) and participants aged 10 to 12 years (18.1% and 5.6%, respectively).

Table 4

Frequencies and Percentages for Broad Diagnosis by Age

	8-9 Years		10-12 Years		13-16 Years			
	n	%	*n*	%	*n*	%	χ^2	*p*
Broad Diagnosis							21.27	.019*
Learning Disability	52	44.1	57	35.6	40	33.9		
Speech/Language Disability	5	4.2	7	4.4	1	.8		
Neurological Impairment & General Medical	18	15.3	29	18.1	33	28.0		
AD/HD	21	17.8	48	30.0	26	22.0		
Autism Spectrum Disorder	17	14.4	10	6.3	9	7.6		
Emotional Disability	5	4.2	9	5.6	9	7.6		

Note. AD/HD = attention-deficit/hyperactivity disorder.
*$p < .05$.

Table 5 shows descriptive statistics with minimums, maximums, means, and standard deviations of the scores for all the subtests that were associated with the six measures used in this study. The highest mean score for the *Woodcock-Johnson Tests of Cognitive Abilities, Third Edition Normative Update* (WJ-III Cog; McGrew et al., 2007) was observed for the Sound Blending subtest (*M* = 103.57, *SD* = 14.80), while the lowest mean score was observed for Visual Matching (*M* = 85.84, *SD* = 14.34). For the *Woodcock-Johnson Tests of Achievement, Third Edition Normative Update* (WJ-III Ach; Mather et al., 2001) the mean score observed for Sound Awareness was 90.68 (*SD* =

11.83). The highest mean scores observed for the *Wide Range Assessment of Memory and Learning, Second Edition* (WRAML2; Sheslow & Adams, 2003) were seen on Symbolic Working Memory (M = 8.69, SD = 2.23) and Story Memory (M = 8.61, SD = 2.51), whereas the lowest mean scores were observed for Finger Windows (M = 7.88, SD = 2.47) and Design Memory (M = 7.93, SD = 2.63).

Table 5

Means and Standard Deviations for Subtests from the Wechsler Intelligence Scale for Children, Fourth Edition (WISC-IV), Woodcock-Johnson Tests of Cognitive Abilities, Third Edition Normative Update (WJ-III Cog), Woodcock-Johnson Tests of Achievement, Third Edition Normative Update (WJ-III Ach), Delis-Kaplan Executive Function System (D-KEFS), NEPSY: A Developmental Neuropsychological Assessment, Second Edition (NEPSY-II), and Wide Range Assessment of Memory and Learning, Second Edition (WRAML2)

	N	Mean	*SD*	Min	Max
WJ-III Cog Pair Cancellation	590	94.47	10.56	53	165
WJ-III Cog Memory for Words	591	91.90	13.11	49	141
WJ-III Cog Spatial Relations	591	97.64	10.51	37	132
WJ-III Cog Concept Formation	590	96.04	14.19	43	139
WJ-III Cog Analysis/Synthesis	591	96.92	13.67	45	151
WJ-III Cog Visual Matching	590	85.84	14.34	28	141
WJ-III Cog Retrieval Fluency	589	93.95	12.97	33	131
WJ-III Cog Incomplete Words	591	98.02	12.70	49	142
WJ-III Cog Sound Blending	590	103.57	14.80	51	166
WJ-III Ach Sound Awareness	591	90.68	11.83	57	112
WJ-III Cog Auditory Working Memory	588	94.81	14.47	37	148
WJ-III Cog Numbers Reversed	587	90.04	14.10	24	148

Table 5, cont.

	N	Mean	*SD*	Min	Max
WRAML2 Finger Windows	590	7.88	2.47	1	16
WRAML2 Number/Letter	590	8.59	2.47	1	15
WRAML2 Story Memory	585	8.61	2.51	1	18
WRAML2 Design Memory	591	7.93	2.63	1	16
WRAML2 Sound-Symbol	591	8.31	2.09	4	16
WRAML2 Symbolic Working Memory	590	8.69	2.23	1	17
WRAML2 Verbal Working Memory	591	8.45	2.35	1	17
NEPSY-II Auditory Attention	590	8.69	2.93	1	16
NEPSY-II Arrows	591	8.69	3.04	1	18
NEPSY-II Geometric Puzzles	591	5.92	3.53	1	16
NEPSY-II Picture Puzzles	591	9.02	2.62	1	16
NEPSY-II Narrative Memory Free Recall	591	10.39	2.91	2	19
NEPSY-II Memory for Designs	591	8.70	2.65	1	18
NEPSY-II Inhibition Switching	554	8.12	3.05	1	16
NEPSY-II Memory for Names	590	8.11	2.79	1	17
NEPSY-II Response Set	590	85.69	11.64	48	132
NEPSY-II Phonological Processing	591	7.76	2.67	1	16
D-KEFS Trail Making Test Condition 4	588	7.32	3.24	1	18
D-KEFS Color Word Interference Condition 4	589	7.82	2.82	1	14
D-KEFS Design Fluency Condition 3	591	97.12	10.78	61	144
D-KEFS Verbal Fluency Condition 3	589	85.94	13.41	36	150
WISC-IV Block Design	591	8.80	2.65	1	17
WISC-IV Coding	589	7.27	2.26	1	15
WISC-IV Cancellation	591	8.09	2.38	1	19
WISC-IV Digit Span Backward	591	7.75	2.05	1	16
WISC-IV Letter-Number Sequencing	591	7.71	2.53	1	16
WISC-IV Symbol Search	589	7.81	2.40	1	14

Note. Min = minimum score obtained within the sample; Max = maximum score obtained within the sample.

For the *NEPSY: A Developmental Neuropsychological Assessment, Second Edition* (NEPSY-II; Korkman et al., 2007), the highest mean score was observed for Narrative Memory Free Recall (M = 10.39, SD = 2.91), whereas the lowest mean score was observed for Geometric Puzzles (M = 5.92, SD = 3.53). The Response Set subtest was measured on a different scale and had a mean of 85.69 (SD = 11.64). With regard to the *Delis-Kaplan Executive Function System* (D-KEFS; Delis et al., 2001), Trail Making Test Condition 4 (M = 7.32, SD = 3.24) and Color Word Interference Condition 4 (M = 7.82, SD = 2.82) had similar means. The mean of Design Fluency Condition 3 (M = 97.12, SD = 10.78) was larger than was the mean of Verbal Fluency Condition 3 (M = 85.94, SD = 13.41). Finally, for the *Wechsler Intelligence Scale for Children, Fourth Edition* (WISC-IV; Wechsler, 2003), the highest mean score was observed for Block Design (M = 8.80, SD = 2.65), whereas the lowest mean score was observed for Coding (M = 7.27, SD = 2.26).

Pearson's product-moment correlations were conducted to examine the relationships among dependent variables. Tables 6 through 10 show the correlations among subtests for each measure utilized in this study. All rs with $p < .05$ are significant. A positive correlation suggests that participants who scored high on one subtest will score high on the other subtest within the measure; in contrast, a negative correlation suggests that participants who score high on one subtest will score low on the other subtest within the measure.

Tables 11 through 14 show the correlations among subtests associated with one measure and subtests from all other measures. All *r*s with $p < .05$ are significant. A positive correlation suggests that participants who score high on a subtest within a given measure will score high on a subtest for another measure. A negative correlation suggests that participants who score high on a subtest of a given measure will score low on a subtest for the other measure.

Table 6

Pearson's Product-Moment Correlation among Wechsler Intelligence Scale for Children, Fourth Edition (WISC-IV) Subtests

	WISC-IV Block Design	WISC-IV Coding	WISC-IV Cancellation	WISC-IV Digit Span Backward	WISC-IV Letter-Number Sequencing
WISC-IV Coding	.180**				
WISC-IV Cancellation	.102*	.339**			
WISC-IV Digit Span Backward	.262**	.129**	.103*		
WISC-IV Letter-Number Sequencing	.230**	.253**	.152**	.230**	
WISC-IV Symbol Search	.372**	.514**	.286**	.160**	.342**

*$p < .05$. ** $p < .01$.

Point-Biseral Correlations were conducted to examine the relationships among dependent and demographic variables. Table 15 shows correlations among the subtests of the WISC-IV, WJ-III Cog, and WJ-III Ach and the following demographic variables: gender, ethnicity, and age group. Table 16 shows correlations among the subtests of the D-KEFS, NEPSY-II, and WRAML2 and the same three demographic variables of interest. A positive correlation between subtest and gender suggests that participants who score high on a subtest are more often girls; whereas, a negative correlation suggests that participants who score low on a subtest are more often boys.

A positive correlation between subtest and ethnicity suggests that participants who score high on a subtest are more often children who were Caucasian. A negative correlation between subtest and ethnicity suggests that participants who score low on a subtest are more often children who were not Caucasian. A positive correlation between subtest and age group suggests that participants who score high on a subtest are more often in the older age group (13 to 16 years old); and, a negative correlation suggests that participants who score low on a subtest are more often in the younger age group (8 to 9 years old). The results show that the three demographic variables of gender, ethnicity, and age are significantly related to many of the subtests and should be accounted for in the model testing of the hypotheses.

A series of one-way multivariate analysis of variance (MANOVA) tests were conducted on each of the subtests used in the current study to test for differences between

Table 7

Pearson's Product-Moment Correlation among Woodcock-Johnson Tests of Cognitive Abilities, Third Edition Normative Update (WJ-III Cog) and Woodcock-Johnson Tests of Achievement, Third Edition Normative Update (WJ-III Ach) Subtests

	1	2	3	4	5	6	7	8	9	10	11
WJ-III Cog Memory for Words	.084*										
WJ-III Cog Spatial Relations	.229**	.184**									
WJ-III Cog Concept Formation	.223**	.186**	.428**								
WJ-III Cog Analysis/Synthesis	.191**	.193**	.275**	.451**							
WJ-III Cog Visual Matching	.525**	.086*	.255**	.216**	.251**						
WJ-III Cog Retrieval Fluency	.225**	.144**	.269**	.457**	.528**	.297**					
WJ-III Cog Incomplete Words	.116**	.109**	.208**	.175**	.129**	.170**	.170**				
WJ-III Cog Sound Blending	.112**	.240**	.287**	.252**	.222**	.141**	.161**	.309**			

Table 7, cont.

	1	2	3	4	5	6	7	8	9	10	11
WJ-III Cog Auditory Working Memory	.139**	.311**	.279**	.378**	.302**	.112**	.271**	.202**	.316**		
WJ-III Cog Numbers Reversed	.203**	.293**	.286**	.417**	.254**	.199**	.275**	.184**	.328**	.426**	
WJ-III Ach Sound Awareness	.021	.005	-.035	.010	.045	.022	.109**	.112**	-.014	-.003	.018

Note. 1= WJ-III Cog Pair Cancellation; 2= WJ-III Cog Memory for Words; 3= WJ-III Cog Spatial Relations; 4= WJ-III Cog Concept Formation; 5= WJ-III Cog Analysis/Synthesis; 6= WJ-III Cog Visual Matching; 7= WJ-III Cog Retrieval Fluency; 8= WJ-III Cog Incomplete Words; 9= WJ-III Cog Sound Blending; 10= WJ-III Cog Auditory Working Memory; 11= WJ-III Cog Numbers Reversed.
$^{*}p < .05$. $^{**}p < .01$.

Table 8

Pearson's Product-Moment Correlation among Delis-Kaplan Executive Function System (D-KEFS) Subtests

	D-KEFS Trail MakingTest Condition 4	D-KEFS Color Word Interference Condition 4	D-KEFS Design Fluency Condition 3
D-KEFS Color Word Interference Condition 4	.164**		
D-KEFS Design Fluency Condition 3	.136**	-.104*	
D-KEFS Verbal Fluency Condition 3	.102*	-.136**	.441**

*$p < .05$. **$p < .01$.

the diagnostic categories and the subtests. The MANOVAs were not statistically significant for the subtests associated with the WISC-IV (p = .929) or the NEPSY-II (p = .093). In addition, a one-way analysis of variance (ANOVA) testing for differences betweeen diagnostic criteria and the WJ-III Ach Sound Awareness subtest was not significant (p = .457).

Table 9

Pearson's Product-Moment Correlation among NEPSY: A Developmental Neuropsychological Assessment, Second Edition (NEPSY-II) Subtests

	1	2	3	4	5	6	7	8	9
NEPSY-II Arrows	-.035								
NEPSY-II Geometric Puzzles	.067	.108**							
NEPSY-II Picture Puzzles	.153**	.183**	.205**						
NEPSY-II Narrative Memory Free Recall	-.085*	.087*	-.034	-.030					
NEPSY-II Memory for Designs	.075	.163**	.212**	.243**	.015				
NEPSY-II Inhibition Switching	.099*	.161**	.142**	.183**	.045	.056			
NEPSY-II Memory for Names	.036	.120**	.003	.054	.201**	.079	.117**		
NEPSY-II Response Set	-.106*	-.023	-.198**	-.091*	.290**	-.161**	-.016	.314**	
NEPSY-II Phonological Processing	.100*	.044	.104*	.218**	-.175**	-.056	.091*	-.022	-.217**

Note. 1= NEPSY-II Auditory Attention; 2= NEPSY-II Arrows; 3= NEPSY-II Geometric Puzzles;4= NEPSY-II Picture Puzzles; 5= NEPSY-II Narrative Memory Free Recall; 6= NEPSY-II Memory for Designs; 7= NEPSY-II Inhibition Switching; 8= NEPSY-II Memory for Names; 9= NEPSY-II Response Set.
**p* < .05. ***p* < .01

Table 10

Pearson's Product-Moment Correlation among Wide Range Assessment of Memory and Learning, Second Edition (WRAML2) Subtests

	WRAML2 Finger Windows	WRAML2 Number/ Letter	WRAML2 Story Memory	WRAML2 Design Memory	WRAML2 Sound-Symbol	WRAML2 Symbolic Working Memory
WRAML2 Number/Letter	.286**					
WRAML2 Story Memory	.155**	.203**				
WRAML2 Design Memory	.388**	.173**	.336**			
WRAML2 Sound-Symbol	.106**	-.006	.093*	.142**		
WRAML2 Symbolic Working Memory	.106*	.216**	.257**	.136**	.131**	
WRAML2 Verbal Working Memory	.192**	.141**	.332**	.175**	.161**	.218**

*$p < .05$. **$p < .01$.

Table 11

Pearson's Product-Moment Correlation for Subtests from the Woodcock-Johnson Tests of Cognitive Abilities, Third Edition Normative Update (WJ-III Cog), Woodcock-Johnson Tests of Achievement, Third Edition Normative Update (WJ-III Ach), Delis-Kaplan Executive Function System (D-KEFS), NEPSY: A Developmental Neuropsychological Assessment, Second Edition (NEPSY-II), and Wide Range Assessment of Memory and Learning, Second Edition (WRAML2) by Wechsler Intelligence Scale for Children, Fourth Edition (WISC-IV) Subtests

	1	2	3	4	5	6
WJ-III Cog Pair Cancellation	.008	.167 **	.136 **	.043	-.032	.202 **
WJ-III Cog Memory for Words	-.005	.038	.032	.119 **	.054	.002
WJ-III Cog Spatial Relations	.067	-.017	-.016	-.029	.051	.062
WJ-III Cog Concept Formation	.031	-.016	.001	.081 *	.037	.081
WJ-III Cog Analysis/Synthesis	.051	-.042	-.001	.138 **	.008	.021
WJ-III Cog Visual Matching	.027	.127 **	.072	.077	.019	.187
WJ-III Cog Retrieval Fluency	.089 *	.042	-.003	.055	.014	.062
WJ-III Cog Incomplete Words	.040	.028	-.007	-.010	.031	.018
WJ-III Cog Sound Blending	.073	.047	.016	.039	.098 *	.072
WJ-III Cog Auditory Working Memory	.054	-.003	-.069	.057	.129 **	.018
WJ-III Cog Numbers Reversed	-.007	.024	.016	.058	.005	.101 *
WJ-III Ach Sound Awareness	.044	.042	.239 **	.020	.028	.030

Table 11, cont.

	1	2	3	4	5	6
D-KEFS Trail Making Test Condition 4	.156 **	.128 **	.102 *	.072	.124 **	.200 **
D-KEFS Color Word Interference Condition 4	.000	.094 *	.037	.015	-.053	.097 *
D-KEFS Design Fluency Condition 3	.018	.058	.044	.008	.055	.060
D-KEFS Verbal Fluency Condition 3	-.035	.167 **	.132 **	.084 *	-.087 *	.008
NEPSY-II Auditory Attention	.123 **	.032	.055	.067	.054	.109
NEPSY-II Arrows	.135 **	.037	-.063	.022	.081 *	.087
NEPSY-II Geometric Puzzles	.070	.074	-.008	.022	.021	.080
NEPSY-II Picture Puzzles	.123 **	.128 **	.087 *	-.010	.186 **	.204
NEPSY-II Narrative Memory Free Recall	.040	-.007	-.118 **	-.016	.110 **	-.036
NEPSY-II Memory for Designs	.078	-.051	.013	-.001	.015	.077
NEPSY-II Inhibition Switching	.140 **	.169 **	.014	.155 **	.201 **	.209
NEPSY-II Memory for Names	.061	-.042	-.099 *	.043	.190 **	-.055
NEPSY-II Response Set	-.124 **	-.014	-.152 **	-.014	.130 **	-.076
NEPSY-II Phonological Processing	.167 **	.146 **	.158 **	.052	.055	.187
WRAML2 Finger Windows	-.041	-.047	-.065	-.081 *	.100 *	.029
WRAML2 Number/Letter	-.023	.048	.005	-.102 *	.105 *	.020
WRAML2 Story Memory	-.039	.037	.008	.091 *	.156 **	.008
WRAML2 Design Memory	.006	-.010	-.080	-.073	.085 *	-.036

Table 11, cont.

	1	2	3	4	5	6
WRAML2 Sound-Symbol	.021	.033	.053	.148 **	.034	.086 *
WRAML2 Symbolic Working Memory	.065	.045	-.116 **	.002	.048	.089 *
WRAML2 Verbal Working Memory	-.158 **	.021	.068	.084 *	.124 **	-.113 **

Note. 1= WISC-IV Block Design;2= WISC-IV Coding;3= WISC-IV Cancellation; 4= WISC-IV Digit Span Backward;5= WISC-IV Letter-Number Sequencing; 6= WISC-IV Symbol Search.
*$p < .05$. **$p < .01$.

The one-way MANOVA on the WJ-III Cog among different diagnostic conditions revealed a significant multivariate effect, $F(55, 1744) = 1.85$, $p < .01$, $\eta^2 = .051$. Examination of the univariate effects from this analysis revealed significant differences among the following subtests: Pair Cancellation, $F(5, 386) = 2.79$, $p = .01$; Visual Matching, $F(5, 386) = 2.49$, $p < .05$; and Incomplete Words, $F(5, 386) = 2.33$, $p < .05$. As shown in Table 17, participants with ASDs scored significantly lower on the Pair Cancellation ($M = 88.75$, $SD = 13.37$), Visual Matching ($M = 80.47$, $SD = 15.37$), and Incomplete Words ($M = 92.22$, $SD = 13.23$) subtests than did participants in other diagnostic categories.

Table 12

Pearson's Product-Moment Correlation for Subtests from the Delis-Kaplan Executive Function System (D-KEFS), NEPSY: A Developmental Neuropsychological Assessment, Second Edition (NEPSY-II), and Wide Range Assessment of Memory and Learning, Second Edition by Woodcock-Johnson Tests of Cognitive Abilities, Third Edition Normative Update (WJ-III Cog) and Woodcock-Johnson Tests of Achievement, Third Edition Normative Update (WJ-III Ach) Subtests

	1	2	3	4	5	6	7	8	9	10	11	12
D-KEFS Trail Making Test Condition 4	.156 **	.035	.159 **	.149 **	.126 **	.230 **	.124 **	.047	.037	.081	.043	.076
D-KEFS Color Word Interference Condition 4	.093 *	.028	.039	.077	.078	.121 **	.103 *	.061	.069	.071	.155 **	-.028
D-KEFS Design Fluency Condition 3	.219 **	.218 **	.277 **	.332 **	.264 **	.178 **	.251 **	.213 **	.255 **	.263 **	.195 **	-.039
D-KEFS Verbal Fluency Condition 3	.117 **	.150 **	.123 **	.178 **	.063	.074	.078	.050	.078	.110 **	.144 **	-.148**
NEPSY-II Auditory Attention	.087 *	.123 **	.060	.156 **	.104 *	.197 **	.111 **	.108 **	.068	.096 *	.065	.204
NEPSY-II Arrows	.087 *	-.006	.132 **	.128 **	.170 **	.089 *	.185 **	.069	.121 **	.056	.110 **	.045
NEPSY-II Geometric Puzzles	.144 **	-.009	.057	.074	.101 *	.070	.097 *	.059	.066	.114 **	.108 **	.097*
NEPSY-II Picture Puzzles	.178 **	.040	.236 **	.178 **	.039	.114 **	.172 **	.121 **	.130 **	.171 **	.157 **	.179**
NEPSY-II Narrative Memory Free Recall	-.023	.003	.000	.072	.059	-.068	.111 **	.019	.027	.115 **	.017	.037

Table 12, cont.

	1	2	3	4	5	6	7	8	9	10	11	12
NEPSY-II Memory for Designs	.136**	.156**	.123**	.090*	.207**	.057	.164**	-.092*	-.031	.156**	.070	.283**
NEPSY-II Inhibition Switching	.118**	.034	.184**	.053	.039	.097*	.066	.127**	.092*	.102*	.030	-.105*
NEPSY-II Memory for Names	-.005	.135**	.088*	.139**	.105*	.005	.102*	.158**	.054	.196**	.135**	-.019
NEPSY-II Response Set	-.077	.008	.054	.021	-.035	-.019	-.056	-.012	-.022	.067	.062	-.187**
NEPSY-II Phonological Processing	.054	.048	.023	-.010	.052	.044	.048	.116**	.163**	.036	.156**	-.012
WRAML2 Finger Windows	.069	.066	.212**	.140**	.145**	.064	.113**	-.018	.162**	.084*	.071	-.085*
WRAML2 Number/Letter	.005	.296**	.106*	.127**	.044	.022	.031	.045	.123**	.109**	.152**	.043
WRAML2 Story Memory	.091*	.177**	.039	.072	.071	.059	.034	.130**	.143**	.107**	.136**	.079

Table 12, cont.

	1	2	3	4	5	6	7	8	9	10	11	12
WRAML2 Design Memory	.008	.070	.155 **	.058	-.067	.035	.051	.050	.121 **	.061	.096 *	-.016
WRAML2 Sound-Symbol	-.037	.006	.018	-.013	-.011	-.021	-.081 *	.012	.155 **	.011	.070	-.328**
WRAML2 Symbolic Working Memory	.032	.104 *	.101 *	-.030	-.029	.095 *	.012	-.004	.044	.040	.064	-.073
WRAML2 Verbal Working Memory	.010	.011	.062	.077	.002	.026	-.067	.049	.012	-0.024	.089 *	-.043

Note. 1= WJ-III Cog Pair Cancellation; 2= WJ-III Cog Memory for Words; 3= WJ-III Cog Spatial Relations; 4= WJ-III Cog Concept Formation; 5= WJ-III Cog Analysis/ Synthesis; 6= WJ-III Cog Visual Matching; 7= WJ-III Cog Retrieval Fluency; 8= WJ-III Cog Incomplete Words; 9= WJ-III Cog Sound Blending; 10= WJ-III Cog Auditory Working Memory; 11= WJ-III Cog Numbers Reversed; 12= WJ-III Ach Sound Awareness.
*$p < .05$. **$p < .01$.

Table 13

Pearson's Product-Moment Correlation for Subtests from the NEPSY: A Developmental Neuropsychological Assessment, Second Edition (NEPSY-II) and Wide Range Assessment of Memory and Learning, Second Edition (WRAML2) by Delis-Kaplan Executive Function System (D-KEFS) Subtests

	D-KEFS Trail Making Test Condition 4	D-KEFS Color Word Interference Condition 4	D-KEFS Design Fluency Condition 3	D-KEFS Verbal Fluency Condition 3
NEPSY-II Auditory Attention	.159 **	.029	.069	.041
NEPSY-II Arrows	.047	.070	.023	-.053
NEPSY-II Geometric Puzzles	.128 **	.102 *	.108 **	-.006
NEPSY-II Picture Puzzles	.113 **	-.063	.136 **	-.042
NEPSY-II Narrative Memory Free Recall	.012	-.114 **	.002	.002
NEPSY-II Memory for Designs	.135 **	-.029	.073	-.086 *
NEPSY-II Inhibition Switching	.114 **	.044	-.011	.017
NEPSY-II Memory for Names	-.016	-.026	.088 *	-.008
NEPSY-II Response Set	-.107 **	-.030	-.114 **	.032
NEPSY-II Phonological Processing	.055	.108 **	.134 **	.259 **
WRAML2 Finger Windows	.096 *	.063	.059	-.051
WRAML2 Number/Letter	-.007	-.001	.121 **	-.014
WRAML2 Story Memory	.066	.090 *	.102 *	.032
WRAML2 Design Memory	.076	.054	-.042	-.041
WRAML2 Sound-Symbol	-.091 *	.135 **	-.023	.141 **
WRAML2 Symbolic Working Memory	.075	.102 *	.009	-.072
WRAML2 Verbal Working Memory	.084 *	.026	.044	.091 *

**p* < .05. ***p* < .01.

Table 14

Pearson's Product-Moment Correlation for Subtests from the Wide Range Assessment of Memory and Learning, Second Edition (WRAML2) by NEPSY: A Developmental Neuropsychological Assessment, Second Edition (NEPSY-II) Subtests

	1	2	3	4	5	6	7	8	9	10
WRAML2 Finger Windows	.050	.192 **	.183 **	.137 **	.056	.151 **	.069	.066	-.004	-.035
WRAML2 Number/ Letter	.068	.064	.039	.194 **	-.064	.067	.041	.125 **	.110 **	.066
WRAML2 Story Memory	.102 *	.121 **	-.074	.082 *	.020	.078	-.007	.148 **	.061	.095 *
WRAML2 Design Memory	.043	.135 **	-.036	.140 **	.152 **	-.006	.062	.180 **	.038	.031
WRAML2 Sound-Symbol	-.106 *	.071	.077	.057	.047	-.307 **	.020	-.020	.165 **	.253 **
WRAML2 Symbolic Working Memory	.103 *	.134 **	-.014	.136 **	-.133 **	-.019	-.002	-.024	-.012	.060
WRAML2 Verbal Working Memory	-.017	.023	-.053	.104 *	-.023	-.063	-.099 *	.109 **	.096 *	.067

Note. 1= NEPSY-II Auditory Attention; 2= NEPSY-II Arrows; 3= NEPSY-II Geometric Puzzles; 4= NEPSY-II Picture Puzzles; 5= NEPSY-II Narrative Memory Free Recall; 6= NEPSY-II Memory for Designs; 7= NEPSY-II Inhibition Switching; 8= NEPSY-II Memory for Names; 9= NEPSY-II Response Set; 10= NEPSY-II Phonological Processing.
**p* < .05. ***p* < .01.

Table 15

Point-Biseral Correlations for Subtests from the Wechsler Intelligence Scale for Children, Fourth Edition (WISC-IV), Woodcock-Johnson Tests of Cognitive Abilities, Third Edition Normative Update (WJ-III Cog) and Woodcock-Johnson Tests of Achievement, Third Edition Normative Update (WJ-III Ach) by Gender, Age, and Ethnicity

	Gender	Ethnicity	Age
WISC-IV Block Design	.064	.057	-.082*
WISC-IV Coding	.081	-.017	-.014
WISC-IV Cancellation	.104*	-.054	-.071
WISC-IV Digit Span Backward	.054	.088	.065
WISC-IV Letter-Number Sequencing	.014	.057	.030
WISC-IV Symbol Search	-.003	.078	-.168**
WJ-III Cog Pair Cancellation	.013	.042	-.085*
WJ-III Cog Memory for Words	.003	.157**	.050
WJ-III Cog Spatial Relations	-.067	.227**	-.012
WJ-III Cog Concept Formation	-.012	.224**	-.055
WJ-III Cog Analysis/Synthesis	.104*	.185**	-.116**
WJ-III Cog Visual Matching	-.093*	.085	.002
WJ-III Cog Retrieval Fluency	.104*	.050	-.048
WJ-III Cog Incomplete Words	.057	.127*	.142**
WJ-III Cog Sound Blending	.048	.246**	-.209**
WJ-III Ach Sound Awareness	.293**	.074	.181**
WJ-III Cog Auditory Working Memory	.093*	.165**	-.216**
WJ-III Cog Numbers Reversed	.004	.132*	-.044

*$p < .05$. **$p < .01$.

Table 16

Point-Biseral Correlations for Subtests from the Delis-Kaplan Executive Function System (D-KEFS), NEPSY: A Developmental Neuropsychological Assessment, Second Edition (NEPSY-II) and Wide Range Assessment of Memory and Learning, Second Edition (WRAML2) by Gender, Age, and Ethnicity

	Gender	Ethnicity	Age
D-KEFS Trail Making Test Condition 4	.060	.051	.059
D-KEFS Color Word Interference Condition 4	-.118**	.021	-.051
D-KEFS Design Fluency Condition 3	.042	.121*	-.186**
D-KEFS Verbal Fluency Condition 3	.182**	-.115*	-.025
NEPSY-II Auditory Attention	-.053	.108*	.133**
NEPSY-II Arrows	.052	.088	.060
NEPSY-II Geometric Puzzles	.128**	-.136*	-.131**
NEPSY-II Picture Puzzles	.013	.117*	.009
NEPSY-II Narrative Memory Free Recall	.250**	.071	.075
NEPSY-II Memory for Designs	.066	.053	-.057
NEPSY-II Inhibition Switching	.093*	.027	.071
NEPSY-II Memory for Names	.074	.088	.169**
NEPSY-II Response Set	.054	.096	.144**
NEPSY-II Phonological Processing	-.025	-.032	-.039
WRAML2 Finger Windows	.042	.057	-.024
WRAML2 Number/Letter	-.016	.179**	.058
WRAML2 Story Memory	.014	.243**	.151**
WRAML2 Design Memory	.121**	.074	.260**
WRAML2 Sound-Symbol	.139**	-.015	-.006
WRAML2 Symbolic Working Memory	-.283**	.133*	.051
WRAML2 Verbal Working Memory	-.055	.050	.284**

*$p < .05$. **$p < .01$.

The one-way MANOVA on the D-KEFS among different diagnostic conditions revealed a significant multivariate effect, $F(20, 1274) = 1.73$, $p < .05$, $\eta^2 = .022$. Examination of the univariate effects from this analysis did not reveal significant differences on any subtests of the D-KEFS as shown in Table 18.

The one-way MANOVA on the WRAML2 among different diagnostic conditions revealed a significant multivariate effect, $F(35, 1584) = 1.69$, $p < .01$, $\eta^2 = .030$. Examination of the univariate effects from this analysis revealed significant differences on the following subtests: Sound Symbol, $F(5, 382) = 6.63$, $p < .01$ and Symbolic Working Memory, $F(5, 382) = 2.30$, $p < .05$. As shown in Table 19, participants with speech/language disabilities scored significantly lower on the Sound Symbol ($M = 7.31$, $SD = 1.70$) and Symbolic Working Memory ($M = 7.61$, $SD = 1.61$) subtests than did participants in other diagnostic categories.

Table 17

Means and Standard Deviations for Subtests from the Woodcock-Johnson Tests of Cognitive Abilities, Third Edition Normative Update (WJ-III Cog) by Broad Diagnosis

	n	Mean	*SD*	*F*	*p*
WJ-III Cog Pair Cancellation				2.79	.017*
Learning Disability	146	94.62	8.89		
Speech/Language Disability	13	98.69	5.69		
Neurological Impairment & General Medical	80	94.40	9.50		
AD/HD	94	93.41	10.09		
Autism Spectrum Disorder	36	88.75	13.37		

Table 17, cont.

	n	Mean	*SD*	*F*	*p*
Emotional Disability	23	93.65	11.91		
WJ-III Cog Memory for Words				2.02	.075
Learning Disability	146	90.42	12.29		
Speech/Language Disability	13	88.54	6.15		
Neurological Impairment & General Medical	80	92.26	12.58		
AD/HD	94	92.10	13.58		
Autism Spectrum Disorder	36	97.00	11.83		
Emotional Disability	23	94.91	14.96		
WJ-III Cog Spatial Relations				2.07	.068
Learning Disability	146	96.70	10.26		
Speech/Language Disability	13	98.08	6.24		
Neurological Impairment & General Medical	80	97.80	11.08		
AD/HD	94	99.14	9.35		
Autism Spectrum Disorder	36	96.19	10.29		
Emotional Disability	23	102.96	9.08		
WJ-III Cog Concept Formation				1.29	.269
Learning Disability	146	96.95	13.68		
Speech/Language Disability	13	93.62	14.93		
Neurological Impairment & General Medical	80	94.34	13.70		
AD/HD	94	95.67	13.41		
Autism Spectrum Disorder	36	92.36	15.91		
Emotional Disability	23	99.87	13.26		
WJ-III Cog Analysis/Synthesis				1.08	.369
Learning Disability	146	96.32	13.28		

Table 17, cont.

	n	Mean	*SD*	*F*	*p*
Speech/Language Disability	13	97.54	14.46		
Neurological Impairment & General Medical	80	95.54	11.86		
AD/HD	94	95.62	12.84		
Autism Spectrum Disorder	36	93.22	15.01		
Emotional Disability	23	101.13	16.43		
WJ-III Cog Visual Matching				2.49	.031*
Learning Disability	146	84.81	12.30		
Speech/Language Disability	13	87.77	9.36		
Neurological Impairment & General Medical	80	82.64	14.38		
AD/HD	94	87.39	16.06		
Autism Spectrum Disorder	36	80.47	15.37		
Emotional Disability	23	89.91	10.50		
WJ-III Cog Retrieval Fluency				1.42	.216
Learning Disability	146	95.29	11.88		
Speech/Language Disability	13	95.69	9.43		
Neurological Impairment & General Medical	80	93.23	12.82		
AD/HD	94	94.83	11.87		
Autism Spectrum Disorder	36	89.83	12.46		
Emotional Disability	23	93.00	11.85		
WJ-III Cog Incomplete Words				2.33	.042*
Learning Disability	146	97.67	12.30		
Speech/Language Disability	13	94.92	9.41		
Neurological Impairment & General Medical	80	98.85	13.23		
AD/HD	94	100.30	14.14		
Autism Spectrum Disorder	36	92.22	13.23		

Table 17, cont.

	n	Mean	*SD*	*F*	*p*
Emotional Disability	23	96.48	11.09		
WJ-III Cog Sound Blending				1.16	.327
Learning Disability	146	102.53	15.14		
Speech/Language Disability	13	98.69	17.34		
Neurological Impairment & General Medical	80	100.88	12.72		
AD/HD	94	103.79	13.08		
Autism Spectrum Disorder	36	105.83	17.21		
Emotional Disability	23	106.13	13.31		
WJ-III Cog Auditory Working Memory				1.82	.109
Learning Disability	146	95.44	12.78		
Speech/Language Disability	13	97.23	6.03		
Neurological Impairment & General Medical	80	95.81	13.75		
AD/HD	94	95.30	14.51		
Autism Spectrum Disorder	36	88.78	16.53		
Emotional Disability	23	97.83	15.51		
WJ-III Cog Numbers Reversed				1.30	.264
Learning Disability	146	88.73	12.13		
Speech/Language Disability	13	95.69	11.54		
Neurological Impairment & General Medical	80	88.91	14.09		
AD/HD	94	90.28	13.90		
Autism Spectrum Disorder	36	92.06	13.14		
Emotional Disability	23	93.22	16.05		

Note. AD/HD = attention-deficit/hyperactivity disorder.
$^{*}p < .05$.

Table 18

Means and Standard Deviations for Subtests from the Delis-Kaplan Executive Function System (D-KEFS) by Broad Diagnosis

	n	Mean	*SD*	*F*	*p*
D-KEFS Trail Making Test Condition 4				1.60	.160
Learning Disability	148	7.59	3.16		
Speech/Language Disability	13	7.15	3.26		
Neurological Impairment & General Medical	80	7.11	2.86		
AD/HD	94	6.84	3.30		
Autism Spectrum Disorder	36	6.97	3.09		
Emotional Disability	22	8.64	3.17		
D-KEFS Color Word Interference Condition 4				1.49	.194
Learning Disability	148	7.77	2.81		
Speech/Language Disability	13	8.08	3.43		
Neurological Impairment & General Medical	80	7.57	2.75		
AD/HD	94	8.59	2.61		
Autism Spectrum Disorder	36	7.83	2.53		
Emotional Disability	22	8.09	2.91		
D-KEFS Design Fluency Condition 3				1.68	.138
Learning Disability	148	98.14	10.54		
Speech/Language Disability	13	93.54	11.05		
Neurological Impairment & General Medical	80	94.24	11.64		
AD/HD	94	97.86	11.77		
Autism Spectrum Disorder	36	97.06	10.39		
Emotional Disability	22	96.59	10.62		

Table 18, cont.

	n	Mean	*SD*	*F*	*p*
D-KEFS Verbal Fluency Condition 3				1.18	.319
Learning Disability	148	85.59	13.54		
Speech/Language Disability	13	81.23	11.30		
Neurological Impairment & General Medical	80	85.38	15.83		
AD/HD	94	88.31	12.67		
Autism Spectrum Disorder	36	86.78	11.83		
Emotional Disability	22	89.86	17.85		

Note. AD/HD = attention-deficit/hyperactivity disorder.

Primary Analysis

The primary analyses included CFA and SR modeling within the statistical program Linear Structural Relationships (LISREL) 8.80 (Joreskog & Sorbom, 1993). For the purposes of the primary analysis of this study, the path coefficients are represented as standardized estimates. Typically, path coefficients range from .0 to 1.0; however, a path coefficient may be greater than 1.0 which typically indicates a potentially high level of multicollinearity among the observed variables. Path coefficients included throughout this chapter were reported to show the relative magnitude of each path in a comparable metric with higher values indicating stronger causal relationships among factors and variables.

Table 19

Means and Standard Deviations for Subtests from the Wide Range Assessment of Memory and Learning, Second Edition (WRAML2) by Broad Diagnosis

	n	Mean	*SD*	*F*	*p*
WRAML2 Finger Windows				1.04	.391
Learning Disability	147	7.68	2.56		
Speech/Language Disability	13	8.00	1.63		
Neurological Impairment & General Medical	78	8.04	2.33		
AD/HD	93	7.83	2.56		
Autism Spectrum Disorder	35	8.71	2.87		
Emotional Disability	22	7.77	2.25		
WRAML2 Number/Letter				.68	.641
Learning Disability	147	8.54	2.57		
Speech/Language Disability	13	7.85	1.95		
Neurological Impairment & General Medical	78	8.32	2.35		
AD/HD	93	8.42	2.60		
Autism Spectrum Disorder	35	9.09	2.66		
Emotional Disability	22	8.59	2.06		
WRAML2 Story Memory				.69	.633
Learning Disability	147	8.44	2.41		
Speech/Language Disability	13	8.92	2.02		
Neurological Impairment & General Medical	78	8.47	2.00		
AD/HD	93	8.77	2.55		
Autism Spectrum Disorder	35	9.11	3.08		
Emotional Disability	22	8.91	2.60		

Table 19, cont.

	n	Mean	*SD*	*F*	*p*
WRAML2 Design Memory				1.85	.102
Learning Disability	147	7.63	2.65		
Speech/Language Disability	13	8.85	2.12		
Neurological Impairment & General Medical	78	8.17	2.28		
AD/HD	93	8.02	2.90		
Autism Spectrum Disorder	35	8.83	2.62		
Emotional Disability	22	8.64	2.89		
WRAML2 Sound-Symbol				6.64	.000**
Learning Disability	147	8.06	2.15		
Speech/Language Disability	13	7.31	1.70		
Neurological Impairment & General Medical	78	8.74	1.73		
AD/HD	93	9.40	2.04		
Autism Spectrum Disorder	35	8.94	2.40		
Emotional Disability	22	9.23	1.88		
WRAML2 Symbolic Working Memory				2.30	.044*
Learning Disability	147	8.50	2.08		
Speech/Language Disability	13	7.62	1.61		
Neurological Impairment & General Medical	78	8.49	2.23		
AD/HD	93	9.16	2.41		
Autism Spectrum Disorder	35	8.94	2.24		
Emotional Disability	22	9.32	1.81		

Table 19, cont.

	n	Mean	*SD*	*F*	*p*
WRAML2 Verbal Working Memory				1.54	.177
Learning Disability	147	8.18	2.70		
Speech/Language Disability	13	7.69	1.65		
Neurological Impairment & General Medical	78	8.54	2.07		
AD/HD	93	8.86	2.17		
Autism Spectrum Disorder	35	8.94	2.03		
Emotional Disability	22	8.50	2.06		

Note. AD/HD = attention-deficit/hyperactivity disorder.
*$p < .05$. **$p < .01$.

Prior to running the CFA, a constraint value of 1.0 was placed on one subtest/observed variable of each latent factor. Using a constraint value of 1.0 is common in model estimations containing variables that have defined scales (Keith, 2006) which included all of the standardized measures used in this study. In this chapter, figures and tables have been used to show the final tested models. In the figures, paths representing direct causal relationships between the variables and factors are marked with single-headed arrows. In each figure, the observed variables or indicators (i.e., subtests) are represented by rectangles and unobservable, latent constructs (i.e., factors) are represented as circles. Path coefficients are attached to each arrow indicating the relative strength of the causal relationship between the individual observed variable and the latent variable.

Initial Question

The first research question asked whether the relationship between attention, PS, and WM was best described by:

a. A theoretical model wherein attention, PS, and WM produce three separate and distinguishable factors, or

b. The Integrated SNP/CHC model (Miller, 2013) wherein attention, PS, and WM are hypothesized to represent one construct referred to as cognitive facilitators/inhibitors.

The first step in testing the initial question was to conduct separate CFAs on each of the three factors proposed to measure attention, PS, and WM. Each CFA was conducted first with all hypothesized items. Next, items with standardized loadings of less than .10 were removed from the CFA. If adequate fit (root mean square error of approximation [RMSEA] < .06) was not achieved, then the error covariances were correlated among items that may be correlated as indicated by the modification indices, theory, and previous research. For all three constructs of attention, PS, and WM, adequate fit was achieved for the CFAs which will be described in the following paragraphs.

For the attention factor, the final CFA included Pair Cancellation and Memory for Words from the WJ-III Cog; Auditory Attention from the NEPSY-II; and, Finger

Windows from the WRAML2. One subtest, Number/Letter from the WRAML2, was not included because the CFA would not run when this subtest was included; more specifically, the error message indicated that the data did not fit to the CFA when this subtest was included. No error covariances were correlated for attention.

With regard to the PS factor, four of the five subtests proposed were included in the final CFA. These subtests included Cancellation, Coding, and Symbol Search from the WISC-IV; and, Visual Matching from the WJ-III Cog. Retrieval Fluency from the WJ-III Cog was eliminated due to a small standardized path coefficient (.06). The correlation of errors for Cancellation and Coding was added to improve model fit as indicated by a large modification index.

For the WM factor, six subtests were proposed for the CFA. Of these six subtests, Symbolic Working Memory from the WRAML2 was removed due to a standardized path coefficient of .08. The remaining five items were retained and included Digit Span Backward and Letter-Number Sequencing from the WISC-IV; Auditory Working Memory and Numbers Reversed from the WJ-III Cog; and, Verbal Working Memory from the WRAML2. The error covariances of two items were allowed to correlate due to large modification indices and improved fit of the CFA. The error covariance of Auditory Working Memory was correlated with Numbers Reversed, and the error covariance of Numbers Reversed was correlated with Letter-Number Sequencing.

Next, a measurement model was conducted to test the three previously described factors together to determine whether the data fit to the proposed one-factor model. However, this model did not fit the data well requiring elimination of 8 of the 16 subtests, and correlation of error covariances of four pairs of the remaining subtests to achieve adequate fit. Because this model no longer represented one factor with all of the subtests and exhibited very poor fit, it was not tested further. The proposed three-factor model was also tested to determine general and local fit to the data. This model is shown in Figure 4.1.

Given the fit associated with the three-factor model, several additional options were tested as alternates to the three-factor model. These options included combining the subtests from pairs of factors and testing a series of two-factor models. From this testing, one viable model was achieved as an alternative to the three-factor model and is shown in Figure 4.2. In this measurement model, the subtests for attention and WM were combined into one factor, and the subtests for PS comprised a separate factor. In both the three-factor and two-factor models, one subtest from the PS factor, Visual Matching, was removed due to a very strong cross loading with Cancellation (Modification index = 134.17).

As shown in Figure 4.1, the items and modifications used in the CFA were also used in the measurement model to achieve the best possible fit. The only exception was the removal of Visual Matching from the PS factor as previously described, and the addition of Number/Letter back into the attention factor. Although the CFA would not run with Number/Letter, it did run in the measurement model, had an adequate standardized path coefficient (.51), and was therefore retained for the three-factor model.

As demonstrated in Figure 4.2, all of the subtests from the CFAs for the attention factor and the WM factor were included; however, the Visual Matching subtest was excluded from the PS factor. In the two-factor model, Number/Letter was not retained in the attention/WM factor due to errors when running the model. In addition, the two-factor model only indicated one modification between Digit Span Backward and Letter-Number Sequencing. The other modifications indicated in the CFAs did not improve model fit for the two-factor model and thus were not included in the final two-factor model.

Table 20 shows the path coefficients for both the three-factor model and the two-factor model. For the most part, higher loadings in the three-factor model were also demonstrated in the two-factor model. Some paths are stronger in the three-factor model while others are stronger in the two-factor model. One item to note is Verbal Working Memory which had a loading of only .066 in the two-factor model. Model fit for the two-factor model was very similar with and without this item. Ultimately, it was decided to keep this item in the two-factor model because the loading of this item was adequate when tested in the SR model.

Figure 4.1. Three-Factor Measurement Model

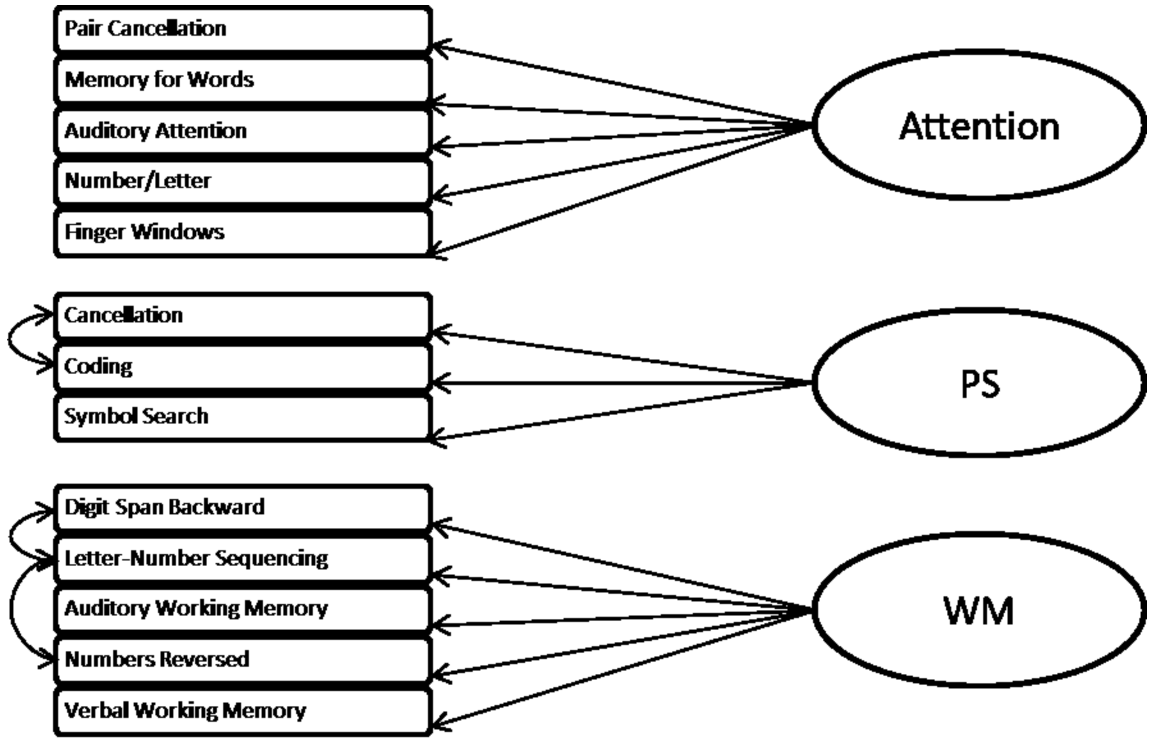

Figure 4.1. Graphic representation of the measurement model for the three-factor model of attention, processing speed (PS), and working memory (WM).

Figure 4.2. Two-Factor Measurement Model

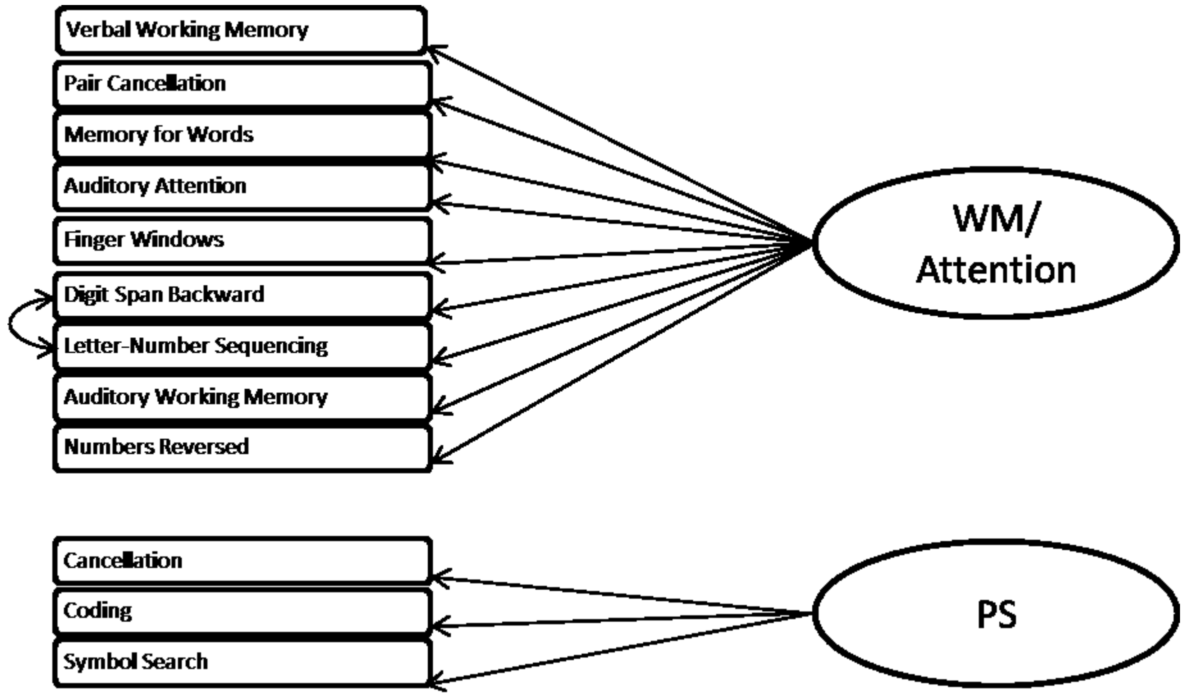

Figure 4.2. Graphic representation of the measurement model for the two-factor model tested as an alternate to the three-factor model.

Table 21 shows the fit indices for both the three-factor model and the two-factor model. The fit was very similar for the two models. Both the χ^2 and the degrees of freedom (df) were smaller for the two-factor model. The adjusted χ^2, which is χ^2 divided by df, is essentially the same for both models. The RMSEA and the comparative fit index

Table 20

Standardized Path Coefficients for the Three- and Two-Factor Models

Three Factors		Two Factors	
Attention		Working Memory/Attention	
Pair Cancellation	.172	Pair Cancellation	.261
Memory for Words	.563	Memory for Words	.467
Finger Windows	.295	Finger Windows	.135
Auditory Attention	.186	Auditory Attention	.162
Number/Letter	.505	--	--
Working Memory			
Auditory Working Memory	.515	Auditory Working Memory	.642
Numbers Reversed	.747	Numbers Reversed	.641
Verbal Working Memory	.127	Verbal Working Memory	.066
Digit Span Backward	.107	Digit Span Backward	.128
Letter-Number Sequencing	.395	Letter-Number Sequencing	.133
Processing Speed		Processing Speed	
Coding	.531	Coding	.767
Cancellation	.296	Cancellation	.436
Symbol Search	.969	Symbol Search	.671

Note. Standardized error covariances between Cancellation and Coding = .15; Digit Span Backwards and Letter-Number Sequencing = .17; and Letter-Number Sequencing and Numbers Reversed = -.29 for the three factor solution. For the two factor solution, the standardized error covariances between Digit Span Backwards and Letter-Number Sequencing = .21.

(CFI) indicate slightly better fit for the two-factor model than for the three-factor model. It should be noted that although the RMSEA is minimally adequate at < .10, ideally these numbers would be at .06 or below to indicate a parsimonious model. The standardized root mean square residual (SRMR) was below .08 for both models indicating adequate absolute fit. Incremental fit was not adequate for either model (CFI < .95). Due to similar fit for the two-factor and three-factor models, both were used in the SR models to determine which would have better fit when predicting visuospatial, auditory, memory, and executive processes factors.

Table 21

Model Fit Indices for the Three- and Two-Factor Models

	Three Factors	Two Factors
χ^2	297.11	262.70
df	59	52
Adjusted χ^2	5.04	5.05
p-value	< .001	< .001
RMSEA	.083	.075
RMSEA (C.I.)	(.074; .092)	(.065; .085)
SRMR	.077	.078
CFI	.739	.749

Note. df = degrees of freedom; C.I. = 90% confidence interval.

Subsequent Question

The second research question asked if the impact of attention, PS, and WM upon cognitive processes was described well by:

a. The Integrated SNP/CHC model (Miller, 2013) wherein attention, PS, and WM function together to facilitate or inhibit cognitive processes in a consistent, predictable manner.

The first step in testing the second research question was to conduct separate CFAs on each of the cognitive processes factors including visuospatial, auditory, memory, and executive processes. Each CFA was conducted first with all hypothesized items. Next, items with standardized loadings of less than .10 were removed from the CFA. If adequate fit (RMSEA < .06) was not achieved, then the error covariances were correlated among items that may be correlated as indicated by the modification indices, theory, and previous research. For all four constructs of visuospatial, auditory, memory, and executive processes, adequate fit was achieved for the CFAs described below.

For the visuospatial processes factor, the final CFA included all five proposed subtests including Block Design from the WISC-IV; Spatial Relations from the WJ-III Cog; and, Arrows, Picture Puzzles, and Geometric Puzzles from the NEPSY-II. No error covariances were correlated for this factor. With regard to the auditory processes factor, Phonological Processing from the NEPSY-II was removed due to errors resulting from poor fit when the subtest was included. The remaining subtests were Sound Awareness from the WJ-III Ach; and, Incomplete Words and Sound Blending from the WJ-III Cog. It was found that Sound Awareness had a low factor loading (.08); however, this subtest was retained for the CFA because the model would not run with only two subtests.

For the memory processes factor, the final subtests included Narrative Memory and Memory for Names from the NEPSY-II; and, Story Memory, Design Memory, and Sound-Symbol from the WRAML2. The age range on the Sound-Symbol subtest was restricted to include only those who are eight years of age given this subtest was normed only on those age eight and below. Memory for Designs from the NEPSY-II was removed due to the small factor loading (.01). In addition, the error covariance of Narrative Memory and Memory for Names was allowed to correlate to improve model fit.

Finally, the items for the executive processes factor actually loaded onto two factors with Concept Formation and Analysis/Synthesis from the WJ-III Cog loading on either factor. Ultimately, it was decided to eliminate Color-Word Interference from the D-KEFS; and, Response Set and Inhibition from the NEPSY-II due to low factor loadings in order to achieve adequate model fit. The final items loaded on one factor and included Concept Formation and Analysis/Synthesis; and, Verbal Fluency, Design Fluency, and Trail Making Test from the D-KEFS. The error covariance of Concept Formation and Analysis/Synthesis were allowed to correlate to improve the model fit.

Next, a measurement model was conducted testing all of the CFAs together in one model with no paths among the factors. The best-fitting measurement model included all of the subtests as stated in the previous CFA descriptions (i.e., subtests associated with the attention, PS, WM, and visuospatial, auditory, memory, and executive processes factors). Thus, this measurement model was consistent with the three-factor model; however, only the correlation between error covariances was necessary between Concept Formation and Analysis/Synthesis within the model. The fit of this measurement model was χ^2 = 1532.53, df = 383, RMSEA = .071, CFI = .734, SRMR = .074.

Given the presence of poor global fit, a measurement model was also conducted with the WM and attention factors combined, while PS remained separate, and all of the previously described cognitive processes factors; thus, this measurement model can be viewed as consistent with the two-factor model. This model also exhibited the correlation between error covariances of Concept Formation and Analysis/Synthesis. The fit of this measurement model was χ^2 = 1023.35, df = 288, RMSEA = .066, CFI = .791, SRMR = .066.

Next, the SR models were conducted with both the two-factor and three-factor models shown in Figures 4.1 and 4.2. The SR model for the three-factor model is shown in Figure 4.3, and the SR model for the two-factor model is shown in Figure 4.4. In conducting the two-factor SR model, it was found that PS did not significantly predict any of the cognitive processes (path coefficients < .10); thus, PS was removed from the model leaving only one factor. This one factor was made up of indicators or subtests associated with the attention and WM factors and will therefore be described as the attention/WM (A/WM) model.

One additional change to the A/WM model was removing Sound Awareness from the auditory processes factor. Removing this item improved the incremental fit of the model as evidenced by reducing the CFI. The three-factor SR model would not run with Sound Awareness removed; therefore, this subtest remained although the standardized path coefficient was low (.047). The path coefficients among factors are discussed in detail in the following paragraphs, but potential multicollinearity issues should be noted in the three-factor SR model where path coefficients are greater than 1.0.

The standardized path coefficients between each factor and the associated indicators are shown in Table 22 for both models. The path coefficients are shown side by side for ease of comparisons. For the most part, higher loadings in the three-factor SR model were also present in the A/WM model. Some paths are stronger in the three-factor SR model, and others are stronger in the A/WM model. All paths are greater than .10 with the exception of the Sound Awareness item in the auditory processes factor of the previously-described three-factor SR model. As already mentioned, the model would not run without the Sound Awareness item; therefore, it was left in the model.

The standardized path coefficients among the conceptual factors are shown in Figures 4.3 and 4.4 and side by side in Table 23. Several issues arise in the three-factor

SR model including weak paths from the PS to auditory processes factors, from the PS to executive processes factors, and from the attention to auditory processes factors. In addition, issues of multicollinearity are shown in the path coefficients greater than 1.0 between the WM and memory processes factors (3.616), WM and executive processes factors (1.560), and attention and memory processes factors (-3.156). Finally, unexpected negative paths between the attention and memory factors (-3.156) and the attention and executive processes factors (-.701) give further indication of problems with the three-factor SR model. In contrast, the paths for the A/WM model range from .399 to .836 in the positive direction as expected.

The fit indices were then examined for both the three-factor SR and A/WM models and are depicted in Table 24. The χ^2 and adjusted χ^2 were both smaller for the A/WM model, $\chi^2(294) = 1051.51$ and adjusted $\chi^2 = 3.58$, than for the three-factor SR model, $\chi^2(389) = 1554.69$ and adjusted $\chi^2 = 4.00$. The RMSEA was the same for both models (.066) and demonstrated minimally adequate fit, although a RMSEA < .06 would indicate better parsimonious fit. It should also be noted that the confidence interval around the RMSEA reveals slightly lower values for the upper and lower intervals of the A/WM model than for that of the three-factor SR model.

Figure 4.3. Three-Factor SR Model

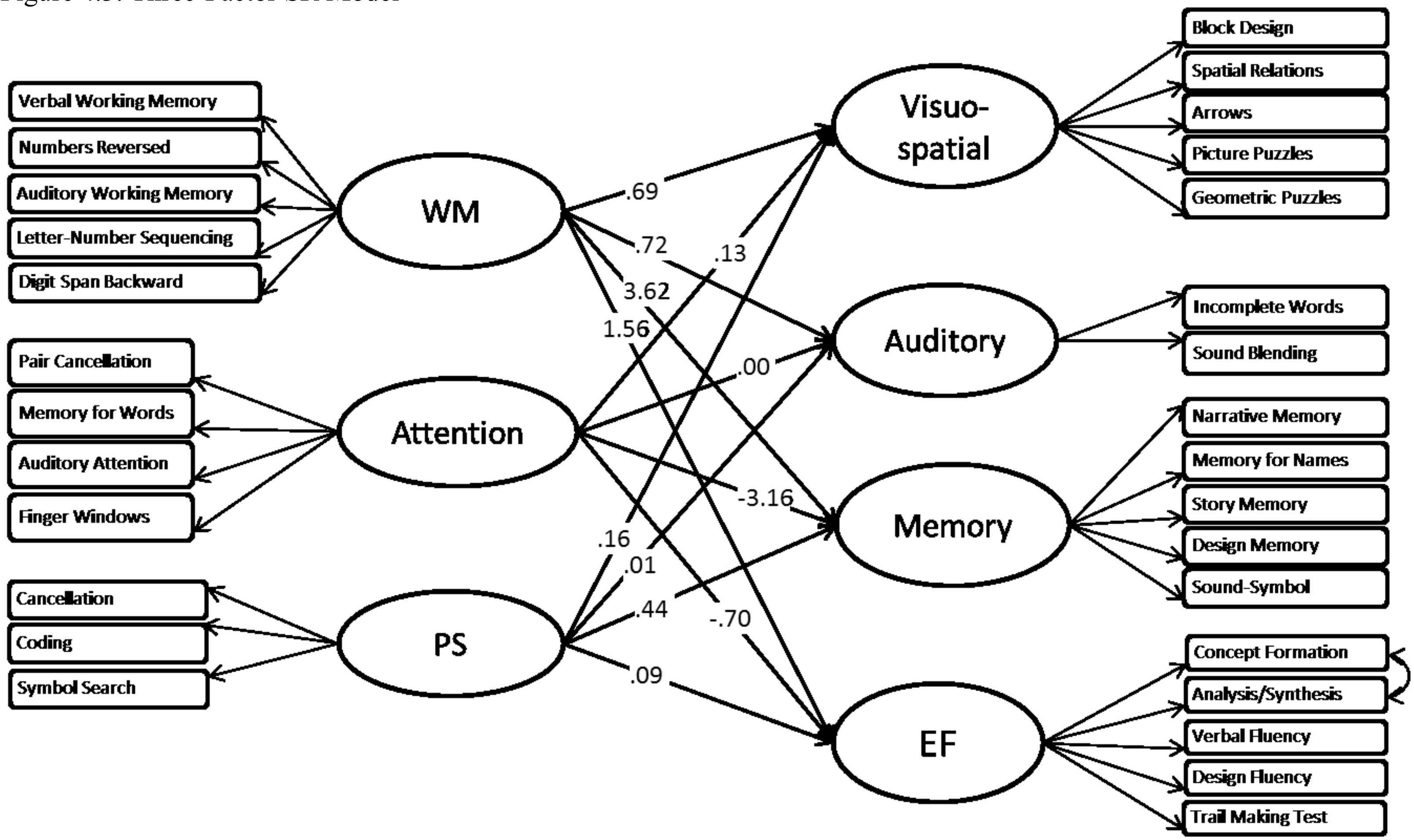

Figure 4.3. Graphic representation of the structural regression (SR) model for the three-factor model.

Figure 4.4. A/WM Model

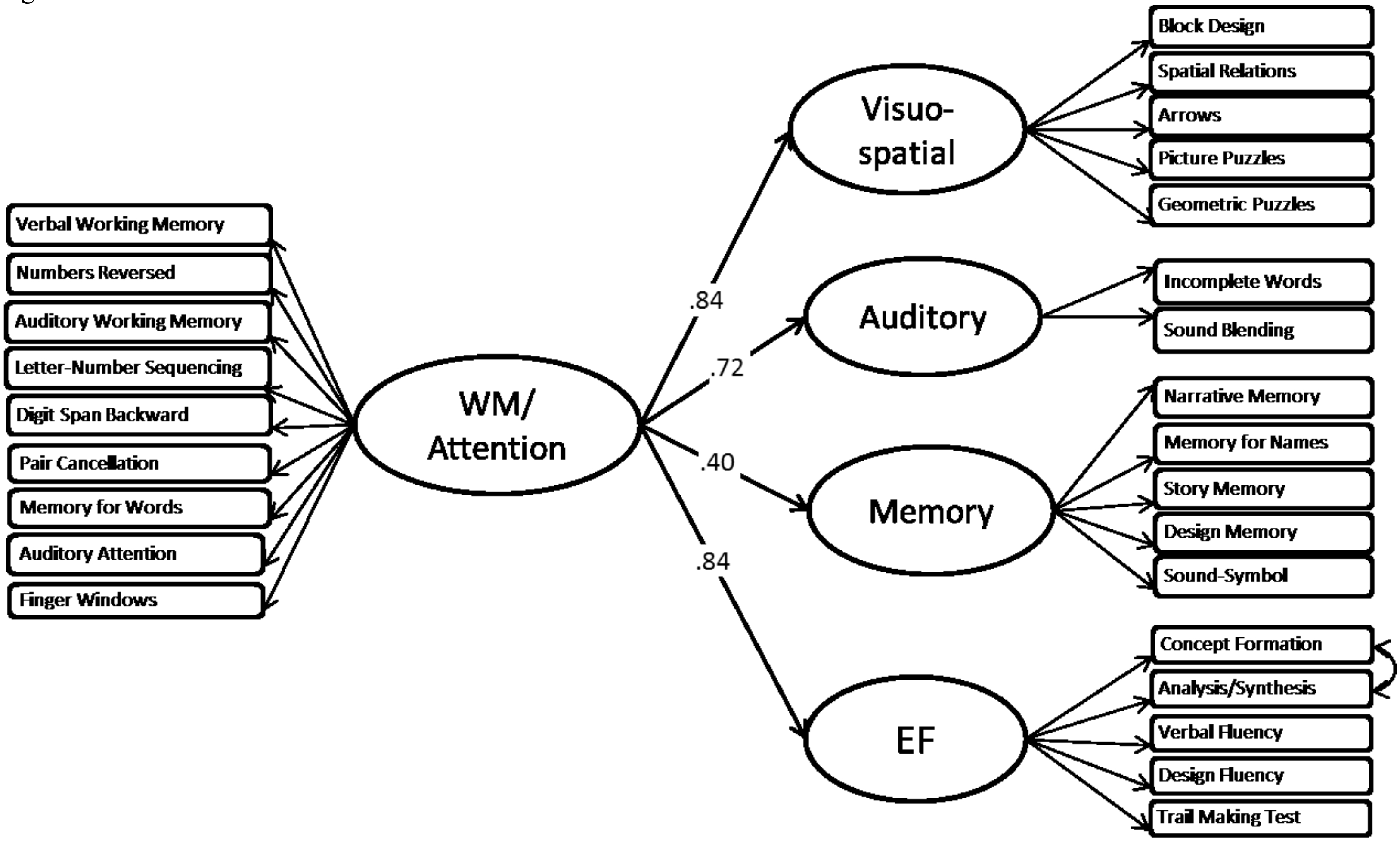

Figure 4.4. Graphic representation of the structural regression (SR) model for the attention/working memory (A/WM) model.

Table 22

Standardized Path Coefficients for Factor Indicators for the Three-Factor Structural Regression (SR) and Attention/Working Memory (A/WM) Models

Three Factor		A/WM	
Processing Speed		--	
Coding	.712	--	--
Cancellation	.432	--	--
Symbol Search	.723	--	--
Working Memory		Working Memory/Attention	
Auditory Working Memory	.600	Auditory Working Memory	.605
Numbers Reversed	.594	Numbers Reversed	.601
Verbal Working Memory	.126	Verbal Working Memory	.116
Digit Span Backward	.116	Digit Span Backward	.114
Letter-Number Sequencing	.171	Letter-Number Sequencing	.158
Attention			
Pair Cancellation	.299	Pair Cancellation	.327
Memory for Words	.338	Memory for Words	.404
Finger Windows	.296	Finger Windows	.259
Auditory Attention	.176	Auditory Attention	.193
Visuo-Spatial		Visuo-Spatial	
Spatial Relations	.586	Spatial Relations	.630
Arrows	.282	Arrows	.263
Geometric Puzzles	.217	Geometric Puzzles	.208
Picture Puzzles	.423	Picture Puzzles	.394
Block Design	.195	Block Design	.139
Auditory		Auditory	
Incomplete Words	.449	Incomplete Words	.446
Sound Blending	.687	Sound Blending	.694
Sound Awareness	.047	--	--

Table 22, cont.

Three Factor		A/WM	
Memory		Memory	
Story Memory	.503	Story Memory	.521
Design Memory	.655	Design Memory	.590
Sound Symbol	.180	Sound Symbol	.179
Narrative Memory	.187	Narrative Memory	.218
Memory for Names	.315	Memory for Names	.351
Executive Functioning		Executive Functioning	
Concept Formation	.728	Concept Formation	.743
Analysis/Synthesis	.586	Analysis/Synthesis	.575
Trail Making Test	.220	Trail Making Test	.224
Design Fluency	.483	Design Fluency	.477
Verbal Fluency	.206	Verbal Fluency	.211

Note. Standardized error covariances between Concept Formation and Analysis/Synthesis was.34 for both the three-factor SR and A/WM models.

The CFI indicates better fit for the A/WM model (.784) than for the three-factor SR model (.731) although neither meets the criterion for incremental fit (CFI > .95). The SRMR was below .08 for both models indicating adequate absolute fit; however, the SRMR was lower for the A/WM model (.067) than for the three-factor SR model (.074). In addition to problems with the three-factor SR model regarding the standardized path coefficients among factors, the fit indices for the three-factor SR model were worse for every indicator than were those for the A/WM model with the exception of the RMSEA.

Table 23

Standardized Path Coefficients between Conceptual Factors for the Three-Factor and Attention/Working Memory (A/WM) Structural Regression (SR) Models

Three Factor		A/WM	
Processing Speed		--	
Visuo-Spatial	.158	--	--
Auditory	.012	--	--
Memory	.438	--	--
Executive Functioning	.089	--	--
Working Memory		Working Memory/Attention	
Visuo-Spatial	.687	Visuo-Spatial	.836
Auditory	.724	Auditory	.724
Memory	3.616	Memory	.399
Executive Functioning	1.560	Executive Functioning	.835
Attention		--	
Visuo-Spatial	.126	--	--
Auditory	.002	--	--
Memory	-3.156	--	--
Executive Functioning	-.701	--	--

As a final step, the data were divided into demographic subsets as indicated in the preliminary analyses. The best-fitting model, the A/WM model, was tested individually on boys, girls, children who were Caucasians, children who were not Caucasians, 8- to 9-year-olds, 10- to 12-year-olds, and 13- to 16-year-olds to determine whether the data fit this model for each of these samples. The standardized path coefficients from each indicator to its respective factor are shown in Table 25. In addition, the final section in the table includes the standardized paths among the factors. The associated model fit indices are shown in Table 26.

It was found that in terms of χ^2 and adjusted χ^2, the model fit best for the group of children who were not Caucasian and for the 10- to 12-year-old group. For parsimonious fit, all the models were minimally adequate (RMSEA < .10) with the exception of the 8- to 9-year-olds and the 13- to 16-year-olds (RMSEA = .101 for both). The children who were not Caucasian had the most parsimonious fit (RMSEA = .067); however, none of

Table 24

Model Fit Indices for the Three-Factor and Attention/Working Memory (A/WM) Structural Regression (SR) Models

	Three Factor	A/WM
χ^2	1554.69	1051.51
df	389	294
Adjusted χ^2	4.00	3.58
p-value	<.001	<.001
RMSEA	.066	.066
RMSEA (C.I.)	(.068; .075)	(.062; .070)
SRMR	.074	.067
CFI	.731	.784

Note. df = degrees of freedom. C.I. = 90% Confidence Interval.

the models had an RMSEA < .06 indicating good parsimony. The incremental fit was not minimally adequate for any of the subsamples (all CFIs < .706). The 10- to 12-year-old group had the highest CFI (.706), while the 8- to 9-year-old group had the lowest CFI (.581). Finally, absolute fit was minimally adequate (SRMR < .10) for all subsamples with the exception of the 8- to 9-year-old group (SRMR = .105). While none of the models showed good absolute fit (SRMR < .08), girls had the best absolute fit (SRMR = .088).

Overall, the models for children who were not Caucasians and 10- to 12-year-olds seemed to display the best overall fit; however, the models for some of the other samples, such as girls, had better fit in some areas. The youngest and oldest age groups seemed to display the worst overall fit. However, no single model was dramatically better or worse than were the other models; and, overall, the whole sample tested together produced better fit than did the subsamples tested individually.

Summary

In summary, the relationship and structure of attention, PS, and WM was first tested. The findings revealed three-factor and two-factor models that had relatively equal fit to the data. Next, the SR model using the initial three-factor and two-factor models was attempted. The SR model using the three-factor model ran successfully, but the paths indicated several problems with the model. The two-factor SR model was changed to a model with one factor made up of attention and WM predicting the outcomes. This was done because it was determined based upon an analysis of local fit that PS did not significantly predict any of the outcomes. This A/WM model was determined to have the best fit and was tested on several demographic divisions (i.e., subsamples) of the data. Overall, findings suggest that although the data fit slightly better for some subsamples, the best fit was found for the A/WM model using the entire sample.

Table 25

Standardized Path Coefficients for Demographic Splits for the Attention/Working Memory (A/WM) Structural Regression (SR) Model

	Boys	Girls	Caucasian	Not Caucasian	Age Group 8-9	Age Group 10-12	Age Group 13-16
A/WM							
Pair Cancellation	.227	.409	.296	.247	.462	.391	.095
Memory for Words	.496	.329	.361	.599	.386	.544	.270
Auditory Working Memory	.574	.634	.580	.648	.647	.677	.475
Numbers Reversed	.612	.584	.534	.675	.675	.618	.522
Finger Windows	.281	.202	.328	.264	.286	.151	.324
Verbal Working Memory	.155	.092	.193	.102	.286	.050	.099
Auditory Attention	.172	.230	.190	.272	.257	.258	.098
Digit Span Backward	.065	.212	.081	.164	.079	.165	.072
Letter-Number Sequencing	.232	.098	.281	.233	.064	.093	.196
Visuospatial							
Spatial Relations	.658	.657	.635	.323	.540	.704	.622
Arrows	.231	.264	.205	.395	.262	.349	.172
Geometric Puzzles	.127	.273	.218	.152	.326	.087	.136
Picture Puzzles	.456	.339	.353	.617	.430	.469	.312
Block Design	.034	.236	.023	.326	-.067	.346	.058

Table 25, cont.

	Boys	Girls	Caucasian	Not Caucasian	Age Group 8-9	Age Group 10-12	Age Group 13-16
Auditory							
Incomplete Words	.438	.460	.299	.476	.407	.558	.535
Sound Blending	.744	.634	.658	.695	.647	.715	.727
Memory							
Story Memory	.930	.321	.640	.933	.665	.451	.480
Design Memory	.423	.451	.645	.436	.572	.699	.611
Sound Symbol	.295	.125	.191	.192	.327	.239	.100
Narrative Memory	.092	.288	.263	.049	.086	.135	.264
Memory for Names	.154	.569	.348	.061	.338	.281	.176
Executive Functioning							
Concept Formation	.781	.668	.783	.597	.710	.763	.722
Analysis/Synthesis	.660	.441	.620	.542	.512	.588	.645
Trail Making Test	.193	.266	.270	.038	.218	.294	.133
Design Fluency	.429	.559	.406	.397	.454	.517	.369
Verbal Fluency	.183	.284	.251	.217	.191	.340	.039

Table 25, cont.

	Boys	Girls	Caucasian	Not Caucasian	Age Group 8-9	Age Group 10-12	Age Group 13-16
Working Memory/Attention							
Visuospatial	.820	.796	.931	.213	.710	.643	1.202
Auditory	.739	.707	.804	.687	.669	.722	.662
Memory	.338	.469	.316	.349	.522	.226	.470
Executive Functioning	.819	.916	.866	.915	.837	.809	.871

Table 26

Model Fit Indices of Demographic Splits for the Attention/Working Memory (A/WM) Structural Regression (SR) Model

	Boys	Girls	Caucasian	Not Caucasian	Age Group 8-9	Age Group 10-12	Age Group 13-16
χ^2	919.65	956.21	763.22	456.51	873.92	487.88	785.14
df	294	294	294	294	294	294	294
Adjusted χ^2	3.13	3.25	2.60	1.55	2.97	1.66	2.67
p-value	< .001	< .001	< .001	< .001	< .001	< .001	< .001
RMSEA	.087	.086	.085	.067	.101	.085	.101
RMSEA (C.I.)	(.081; .094)	(.080; .092)	(.077; .092)	(.055; .079)	(.093; .109)	(.078; .092)	(.092; .109)
SRMR	.091	.088	.091	.098	.105	.092	.109
CFI	.682	.672	.680	.681	.581	.706	.532

Note. df = degrees of feedom; C.I. = 90% Confidence Interval.

CHAPTER V

DISCUSSION

The current study evaluated whether neurocognitive constructs including attention, processing speed (PS), and working memory (WM) act in concert to constrain or support basic cognitive processes including visuospatial, auditory, memory and executive processes in a consistent and predictable manner as suggested by Miller's (2013) Integrated School Neuropsychological (SNP)/Cattell-Horn-Carroll (CHC) model. Two theoretical models were analyzed and compared to determine the best fit with regard to the relationship between measures of attention, PS, and WM within the sample data. These models included a three-factor model and a one-factor model of attention, PS, and WM. A structural regression (SR) model was then executed in order to evaluate the impact of attention, PS, and WM upon basic cognitive processes, and to establish the validity of one facet of the Integrated SNP/CHC model.

Purpose and Goals

One goal of this study was to examine the relationship between attention, PS, and WM. Despite the presence of a significant body of research directed at the relationship between PS and WM (Fry & Hale, 2000; Kail, 2007; Nettelbeck & Burns, 2010; Willmott et al., 2009) and WM and attention (Cowan, 2010a; Oberauer & Bialkova, 2009), there is a paucity of research related to the relationship between all three of these constructs. A number of theorists engaged in research related to these neurocognitive processes have discussed the conceptual and functional intersection among attention, PS, and WM (Barrouillet et al., 2004; Barrouillet et al., 2009; Miller, 2013). The various conceptualizations and models of these three constructs can be described as similar and often encompass each other (Baddeley & Hitch, 1994; Barrouillet et al., 2009; Cowan, 2010a; Miller). In addition, the developmental trajectories and neurological substrates supporting these neurocognitive abilities largely coincide (Blumenfeld, 2011; Gilchrist et al., 2009; Goldstein et al., 2011; Kail, 2008; Stahl, 2008). Nonetheless, the specific nature of their relationship has rarely been investigated; and, when it has, the samples examined have consisted of adults or children who are neurotypical. Thus, the current study represents leading research in this area.

Another goal of this study was to investigate the collective impact of attention, PS, and WM upon basic cognitive processes including visuospatial, auditory, memory, and executive processes. Each of these neurocognitive constructs have been conceptualized as supporting higher-order cognitive processes, such as problem-solving and decision-making (i.e., executive functioning), or general intelligence (DeLuca, 2008; Fry & Hale, 2000; O'Brien & Tulsky, 2008; Salthouse, 1996). The recognition of the relative importance of these constructs for higher-order cognitive functioning, activities of daily living, and academic success is underscored even in early conceptualizations of attention, PS, and WM (Conklin et al., 2008; Salthouse). Despite this recognition, investigation of the joint impact of attention, PS, and WM upon basic cognitive processes is limited. While a number of studies have examined the influence of PS and WM upon general intelligence (Fry & Hale, 1996, 2000; Kail, 2007; Nettelbeck & Burns, 2010), the potential simultaneous impact of attention has not been considered. Therefore, the current study represents premier research investigating the collective impact of attention, PS, and WM upon several cognitive processes associated with intelligence.

The Integrated SNP/CHC model is a comprehensive model of pediatric neuropsychological assessment (Miller, 2013). This model suggests that attention, PS, and WM can be considered cognitive facilitators/inhibitors given they are hypothesized to communally support or constrain basic cognitive processes. These processes are hypothesized within the model to include visuospatial, auditory, memory, and executive processes. Thus, the novel hypotheses associated with the Integrated SNP/CHC model have served as the impetus for the current study. In this way, an additional goal of this study was to validate aspects of the Integrated SNP/CHC model. The specialty area of school neuropsychology represents a growing field wherein the model of assessment utilized by a large number of clinicians is likely to be the Integrated SNP/CHC model; thus, validation of this model is paramount. In general, this will facilitate responsible and ethical use of the model among clinicians when assessing, diagnosing, and intervening with the pediatric population. Validation of aspects of the Integrated SNP/CHC model in the current study represents original research associated with this model.

Summary of Results

Preliminary Analyses

The preliminary analyses were conducted to gain a comprehensive understanding of the data and to determine which demographic factors needed to be accounted for in the primary analyses. These analyses indicated that slightly more than half of the sample was composed of girls. Although not statistically significant, this was unexpected given clinical disorders typically manifest more often in school-age boys in comparison to girls (Gerhson, 2002). While the ethnicities of much of the sample were unknown, a large number of those with known ethnicities identified as Caucasian. This made sense given that those who identify as Caucasian represent the largest ethnic group in the United States (retrieved from www.census.gov). Similarly, a large number of participants were not given definitive clinical diagnoses; however, of those who were given a clinical diagnosis, numerous individuals were diagnosed with a learning disability (LD). This was also expected given that a diagnosis with a specific LD represents the most common disability among children seeking educational services (Flanagan & Alfonso, 2011).

Multivariate analyses focused upon demographic variables indicated a relationship between clinical diagnosis and age such that younger children (i.e., those between the ages of 8 and 9) were more likely to be diagnosed with LDs or an autism spectrum disorder (ASD). In addition, children in the middle of the age range (i.e., 10- to 12-year-olds) were more likely to be diagnosed with speech/language disorders and ASDs, while older children (i.e., those between the ages of 13 and 16) were more likely to be diagnosed with neurological impairments/general medical conditions and emotional disturbances (ED). This relationship between age and diagnosis may be related to the tendency for symptomatology to become more distinct as children age (Brassard & Boehm, 2007; Lidz, 2003). It may be likely that older children previously diagnosed with ASDs received more accurate diagnoses of ED as their symptoms became clearer over time. The tendency for older children to be more frequently diagnosed with neurological impairment made sense given that children within this age range are more likely to experience traumatic brain injuries than are younger children (Anderson & Yeates, 2010). With regard to LD diagnoses, it may be that successful academic interventions precluded the need for diagnosis following the age of 9.

Analyses of the sample's collective performance across measures utilized in the current study revealed that most participants performed within the average range on subtests associated with intellectual measures including the *Wechsler Intelligence Scale for Children, Fourth Edition* (WISC-IV; Wechsler, 2003) and the *Woodcock-Johnson Tests of Cognitive Abilities, Third Edition Normative Update* (WJ-III Cog; McGrew et al., 2007). This was also true for the *Woodcock-Johnson Tests of Achievement, Third Edition Normative Update* (WJ-III Ach; Mather et al., 2001), the sole achievement measure utilized in the study. The sample performed within the average range on subtests associated with neuropsychological measures used in the study including the *Delis-Kaplan Executive Function System* (D-KEFS; Delis et al., 2001) and the *Wide Range Assessment of Memory and Learning, Second Edition* (WRAML2; Sheslow & Adams, 2003). Although this was true for the majority of subtests associated with the *NEPSY: A Developmental Neuropsychological Assessment, Second Edition* (NEPSY-II; Korkman et al., 2007), the average score on the Geometric Puzzles subtest was outside the average range. This suggested that children with clinical diagnoses struggled with this subtest significantly more than those without clinical diagnoses.

Bivariate correlational analyses demonstrated that intercorrelations among subtests making up the WISC-IV, WJ-III Cog, and WJ-III Ach each reached statistical significance. This is consistent with previous research regarding subtest correlations conducted on each of these measures (Mather et al., 2001; McGrew et al., 2007; Wechsler, 2003). Intercorrelations among subtests associated with the D-KEFS were all significant as well. This is inconsistent with previous research conducted with this measure in that these subtests typically do not correlate highly (Delis et al., 2001); however, it is likely that correlations were improved given that only three subtests from the D-KEFS were retained and utilized in the primary analyses.

The majority of subtests selected for use from the WRAML2 were significantly correlated with the exception of the Sound-Symbol and Number/Letter subtests. Although this is largely consistent with previous studies examining intercorrelations within this measure (Shelslow & Adams, 2003), the nonsignificant, negative correlation between these subtests may be related to the restricted age-range associated with the Sound-Symbol subtest. Subtests associated with the NEPSY-II were characterized by a number of nonsignificant correlations; however, this is consistent with previous research associated with this measure (Korkman et al., 2007). Interestingly, a number of subtests theorized to tap memory were not correlated; however, these subtests tended to be either visual or verbal in nature. This may suggest that children with clinical diagnoses exhibit discrepant performance on visual versus verbal tasks of memory.

Correlations between overall measures were also examined as a method of evaluating the data. With regard to the WISC-IV, the highest percentage of correlations ($\alpha = .01$) between measures was accounted for by the NEPSY-II. The NEPSY-II Picture Puzzles and Phonological Processing subtests were correlated ($\alpha = .01$ and $.05$) with the majority of WISC-IV subtests utilized in the current study. Subtests from the D-KEFS including Trail Making Test and Verbal Fluency were also correlated with a number of the WISC-IV subtests. These substantial correlations across subtests may be reflective of the tendency for subtests associated with the NEPSY-II and D-KEFS to tap into a number of cognitive processes. The subtests making up the WJ-III Cog demonstrated the lowest percentage of correlation with subtests from the WISC-IV. Regarding the WJ-III Cog, the greatest percentage of correlations ($\alpha = .01$) between measures was accounted for by the D-KEFS. The Design Fluency subtest was correlated ($\alpha = .01$ and $.05$) with every subtest from the WJ-III Cog included in the current study. A number of subtests from the NEPSY-II were correlated with a number of the WJ-III Cog subtests as well. This again likely reflects the relative task complexity of the subtests included on the D-KEFS and NEPSY-II. The WJ-III Ach exhibited the greatest percentage of correlations ($\alpha = .01$) with the NEPSY-II; and, the lowest percentage of correlations with the WISC-IV.

With respect to the D-KEFS, the highest percentage of correlations ($\alpha = .01$) between measures was accounted for by the WJ-III Cog. However, a number of subtests from the NEPSY-II including Geometric Puzzles and Phonological Processing were correlated ($\alpha = .01$ and $.05$) with the majority of D-KEFS subtests. The Sound-Symbol subtest from the WRAML2 was also correlated with the majority of D-KEFS subtests. The subtests making up the WRAML2 exhibited the lowest percentage of correlations with the D-KEFS. Although the NEPSY-II was relatively equally correlated with several measures, the highest percentage of correlations ($\alpha = .01$) was accounted for by the WJ-III Cog. Of note, Picture Puzzles and Phonological Processing tended to correlate ($\alpha = .01$ and $.05$) with a number of other subtests across measures; in addition, Geometric Puzzles correlated with a number of D-KEFS subtests. This may indicate that these subtests in particular, and the NEPSY-II in general, are cognitively complex. The NEPSY-II was least correlated with the WRAML2. In contrast, the WRAML2 exhibited the greatest percentage of correlations ($\alpha = .01$) with the NEPSY-II when compared to other measures. The WRAML2 demonstrated the lowest percentage of correlations with the D-KEFS although the Sound-Symbol subtest correlated ($\alpha = .01$ and .05) with a number of D-KEFS subtests. This may indicate that the Sound-Symbol subtest is relatively cognitively complex; however, it is important to note that this subtest demonstrated poor test-retest reliability among neurotypical children (Sheslow & Adams, 2003).

Correlational data were also utilized to examine the relationship between subtest performance and demographic variables. This data revealed that numerous subtests from the WISC-IV, WJ-III Cog, and WJ-III Ach were correlated to a highly significant degree ($\alpha = .01$) with demographic variables including gender, ethnicity, and age. In addition, the majority of these subtests (i.e., 83%) exhibited some degree of correlation ($\alpha = .01$ and .05) with the three aforementioned demographic variables. This indicated that a child's performance on subtests exhibiting these correlations could be more related to demographic variables than actual cognitive functioning among children with clinical diagnoses. These results were expected given that previous studies involving these measures also found significant correlations with demographic data (Avirett, 2011). This underscored the importance of executing separate modeling procedures based upon gender, ethnicity, and age. It is interesting to note that the Analysis/Synthesis and

Auditory Working Memory subtests from the WJ-III Cog were correlated (α = .01 and .05) with all three demographic variables of interest.

A large number of subtests associated with neuropsychological measures within the study including the D-KEFS, NEPSY-II, and WRAML2 were also highly correlated (α = .01) with the demographic variables. The majority of these subtests (i.e., 76%) exhibited some degree of correlation (α = .01 and .05) with gender, ethnicity, and age. This again indicated that performance on these measures may be related to a child's gender, ethnicity, or age rather than his or her cognitive abilities, and emphasized the need to conduct separate modeling procedures based upon demographic variables. Again, this finding was expected given previous studies involving these neuropsychological measures have demonstrated the apparent influence of demographic variables upon performance among clinical groups (Avirett, 2011; Fournier, Canas, Sevadjian, Miller, & Maricle, 2012; Sevadjian, Canas, Fournier, Miller, & Maricle, 2011). Of note, the Geometric Puzzles subtest from the NEPSY-II was correlated (α = .01 and .05) with each of the three demographic variables investigated.

A number of multivariate analyses were conducted across measures included in the study. These analyses assisted in determining whether clinical diagnoses impacted performance; however, only subtests associated with the WJ-III Cog, D-KEFS, and WRAML2 exhibited significant findings. While clinical diagnosis did not appear to impact performance on the D-KEFS, it was found that children with ASDs were more likely to perform poorly on subtests making up the WJ-III Cog including Pair Cancellation, Visual Matching, and Incomplete Words. This suggested that a child's performance on these specific subtests was more related to the presence of an ASD rather than the underlying skill the subtest purports to assess. It was also found that children with speech/language disabilities were more likely to perform poorly on specific subtests associated with the WRAML2 including Sound-Symbol and Symbolic Working Memory. This indicated that poor performance on these subtests was more related to speech/language deficits rather than deficits associated with verbal learning or WM. Despite these findings, it was decided to avoid conducting separate modeling procedures upon various diagnostic groups since this would produce an inadequate sample size among these groups.

Primary Analyses

The primary analyses were conducted in order to explicitly address the two research questions posed in this study. These inquiries related to examination of the relationship between attention, PS, and WM; and, examination of the impact of these three constructs upon basic cognitive processes. These questions were tested using confirmatory factor analysis (CFA) and SR modeling.

Initial question. One primary goal of this study was to examine the relationship between attention, PS, and WM. Two theoretical models of possible relationships between these three constructs were developed. One model, the one-factor model, was consistent with the Integrated SNP/CHC model (Miller, 2013) and represented the idea that these three constructs functioned together to operate upon basic cognitive processes thereby creating one factor. The other model, the three-factor model, represented the null model or the idea that there was no discernible, meaningful relationship among these three constructs. The utility of these two models was analyzed separately and compared through use of CFA. Goodness-of-fit statistics and local parameters were examined to determine which model offered the best description of the relationship between attention, PS, and WM within the context of the clinical sample.

One-Factor Model. Examination of global and local indicators of fit associated with the one-factor model indicated that this model was a poor fit to the observed data. Numerous modifications, including the removal of half of the initial subtests associated with the model, were required in order to reach minimal statistical guidelines with regard to global fit. In addition, a number of atheoretical correlations between the measurement errors associated with various subtests were suggested via modification indices.

All subtests from the WISC-IV were retained in this model; however, a nonsensical, negative correlation between Letter-Number Sequencing and Pair Cancellation from the WJ-III Cog was required. While the NEPSY-II Auditory Attention subtest was retained, an odd correlation with Pair Cancellation was required. These atheoretical correlations could be viewed as indications of general problems with the fit of the model. The majority of subtests from the WJ-III Cog could not be retained in the model while no subtests from the WRAML2 were viable for retention. These results suggested that the one-factor model could not adequately explain the relationship between attention, PS, and WM given the observed data.

Three-Factor Model. Goodness-of-fit indices associated with the three-factor model indicated a minimally adequate fit across indices of absolute and parsimonious fit; however, this model was inadequate with regard to comparative fit. This suggested that the three-factor model did not differ substantially from a model wherein the variables exhibit no relationship to their respective factors. Local fit was also minimally adequate with slightly more than half of the variables exhibiting salient loadings upon their respective factors.

While the attention factor remained as originally structured, two subtests hypothesized to measure PS were excluded from the model. Thus, the remaining subtests associated with the PS factor essentially represented the Processing Speed Index (PSI) from the WISC-IV (Wechsler, 2003). A correlation was required between two of these subtests which seemed acceptable given they both exist within the PSI; however, this correlation was curious given the similarity across all three subtests making up the PS factor. The WM factor was largely similar to original hypotheses although one subtest was removed. A correlation was required between the Digit Span Backward and Letter-Number Sequencing subtests which seemed appropriate given these subtests both make up the Working Memory Index (WMI) on the WISC-IV (Wechsler). However, the negative correlation between the Letter-Number Sequencing subtest and the Numbers Reversed subtest from the WJ-III Cog seemed largely atheoretical. In general, these findings indicated that the three-factor model provided a better description of the relationship between attention, PS, and WM in comparison to the one-factor model; however, the relationship was not explained well.

Two-Factor Model. Given the limited fit associated with the three-factor model, global and local fit statistics related to a number of two-factor models were examined. The two-factor model demonstrating the best global fit combined the attention and WM factors while the PS factor remained separate. This model exhibited slightly better absolute and parsimonious fit than the three-factor model; however, adequate fit was not achieved with regard to comparative fit. As with the three-factor model, this again indicated that the two-factor model did not differ significantly from the null. The local fit associated with the two-factor model was minimally adequate with about half of the indicators exhibiting salient loadings onto their respective factors.

Essentially, all indicators of the original attention and WM factors were retained with the exception of one for each. The correlation between Digit Span Backward and Letter-Number Sequencing remained; however, the atheoretical correlation between Numbers Reversed and Letter-Number Sequencing found in the three-factor model was not required. This could be viewed as a general indication of the better fit of the two-factor model to the data. The PS factor again was consistent with the PSI from the WISC-IV (Wechsler, 2003). Overall, these findings suggested that the two-factor model explained the relationship between attention, PS, and WM better than the one-factor model; but, was similar to the three-factor model in its ability to describe that relationship in the context of the data.

Summary. In general, the three- and two-factor models are quite comparable with regard to global and local fit. The relatively better fit of the two-factor model is not altogether surprising given observations by a number of researchers that attention and WM appear to hinge upon each other (Cowan, 2010a; Oberauer & Bialkova, 2009). Specifically, focused attention is viewed as necessary for determining what information is held in mind. The influence of attention upon WM may account for why one factor involving these constructs resulted in the slightly better global fit of the model. These findings contrast with studies demonstrating a relationship between PS and WM (Baddeley & Hitch, 1994; Fry & Hale, 2000; Kail, 2007; Nettelbeck & Burns, 2010), or a relationship between all three of these constructs (Barrouillet et al., 2004; Barrouillet et al., 2009).

The structure of the one-factor model can be viewed as most consistent with the hypotheses associated with the Integrated SNP/CHC model given attention, PS, and WM are examined as one construct (Miller, 2013). The results suggested that the relationship between attention, PS, and WM was not well-explained by either the three-factor or two-factor models; however, the one-factor model exhibited the poorest fit. It is important to note that the observed relationship between attention, PS, and WM in the current study may have been an artifact of the subtests selected for use in the CFA. Because the three-factor and two-factor models exhibited minimally adequate global fit across a number of indices, they were both utilized in the SR modeling procedure.

Subsequent question. Another goal of this study was to examine the joint impact of attention, PS, and WM upon basic cognitive processes. As described in the Integrated SNP/CHC model (Miller, 2013), these processes include visuospatial, auditory, memory, and executive processes. Factors reflective of these constructs were created through use of CFA; and, the ability of the two- and three-factor models to predict performance across measures associated with these factors was evaluated through use of SR modeling. Again, global and local fit statistics were used to determine whether the Integrated

SNP/CHC model adequately explained the impact of attention, PS, and WM upon basic cognitive processes.

Due to the gender, ethnicity, and age confounds identified in the preliminary multivariate analyses, the final SR model was analyzed and compared using seven subsamples. These included boys, girls, children who were Caucasian, children who were not Caucasian, and children between the ages of 8 and 9, 10 and 12, and 13 to 16. Traditionally, path coefficients of .71 and greater are considered “excellent,” while those between .63 and .70 are considered “very good” (Comrey & Lee, 1992; Tabachnick & Fidell, 2001). Those between .55 and .62 are considered “good,” whereas those between .45 and .54 are considered “fair.” Coefficients ranging from .32 to .44 are considered “poor” and those less than .31 are referred to as “uninterpretable.”

In establishing the cognitive processes factors associated with the measurement models for the SR models it was found that all of these factors were characterized by poor convergent validity. In other words, the factors were not cohesive in nature; however, the visuospatial and executive processes factors were characterized by salient loadings across indicators. In contrast, the auditory and memory processes factors exhibited poor loadings across indicators. Ultimately, the visuospatial processes factor was consistent with its original conceptualization when used in the SR models; however, the Sound Awareness subtest from the WJ-III Ach and Phonological Processing subtest from the NEPSY-II were not retained in the auditory processes factor. The NEPSY-II Memory for Designs subtest was not retained within the memory processes factor, while the Color-Word Interference subtest from the D-KEFS and the Inhibition and Response

Set subtests from the NEPSY-II were removed from the executive processes factor. In addition, a correlation between the Concept Formation and Analysis/Synthesis subtests of the WJ-III Cog was required within the executive processes factor; however, this seemed acceptable given both of these subtests exist on the Executive Processes Cluster of the WJ-III Cog (McGrew et al., 2007).

Three-Factor SR Model. The three-factor model was initially utilized in the SR model in order to determine the impact of attention, PS, and WM upon basic cognitive processes. With regard to global fit, the three-factor SR model exhibited good absolute fit and minimally adequate parsimonious fit; however, comparative fit was inadequate. This suggested that the model did not differ significantly from the null. With regard to local fit, two of the three factors were characterized by multicollinearity. This indicates a high degree of overlap between factors such that they do not appear to be separate constructs.

The multicollinear relationship between the memory processes and WM factors is not surprising given WM has been conceptualized as a facet of memory (Baron, 2004); and, tasks believed to tap these constructs that were utilized in the study may poorly discriminate between the two. The multicollinearity existing between the WM and executive processes factors may be related to the inclusion of a number of D-KEFS subtests within the executive processes factor. Preliminary correlational data found a number of D-KEFS subtests to be significantly correlated with a number of subtests making up the WISC-IV and WJ-III Cog; and, subtests from these measures predominantly made up the WM factor. However, WM appeared to highly predict visuospatial and auditory processes. This made sense given the tasks associated with these two factors rely heavily upon one's ability to hold information in mind and then manipulate that information in some way.

The attention factor was problematic given half of the path coefficients were uninterpretable. The attention factor appeared to have no impact upon the auditory processes factor and only a minimal impact upon the visuospatial processes factor. This was inconsistent with theory given attention has been viewed as necessary for outside stimuli to be acknowledged and operated upon (Baron, 2004; Miller 2007, 2013; Mirsky et al., 1991). The other half of the path coefficients were characterized by multicollinearity and an unexpected negative correlation. The negative, multicollinear relationship between the attention and memory processes factors seemed largely nonsensical and may have been a statistical artifact of a poor model; however, it is notable that the WJ-III Cog Memory for Words subtest may have a significant degree of overlap with the subtests making up the memory processes factor. The strong, negative correlation between the attention and executive processes factors seemed generally atheoretical given these two constructs are viewed as having a positive (as opposed to negative) relationship (Barkley, 2012; McCloskey & Perkins, 2012).

All path coefficients associated with the PS factor were either poor or uninterpretable. The PS factor was most predictive of the memory processes factor; however, the path coefficient was still poor. This suggested that the PS factor had little or no impact upon basic cognitive processes. As with the two-factor CFA model, this seemed inconsistent with previous research and theory given PS has been found to be supportive of higher-order cognitive processes (Fry & Hale, 1996, 2000; Kail, 2007;

Nettelbeck & Burns, 2010; Salthouse, 1996). Overall, both global and local fit of the three-factor SR model were inadequate with more than half of the path coefficients in the model being characterized by multicollinearity or as poor/uninterpretable. These findings suggested that the three-factor SR model was not able to adequately explain the impact of attention, PS, and WM upon basic cognitive processes.

Attention/Working Memory Model. A SR model utilizing the two-factor model was next conducted and examined. Given that all path coefficients associated with the PS factor within this model were uninterpretable, the factor was removed and the SR model was examined without it. Given only the attention and WM factors remained, this model was referred to as the attention/WM (A/WM) model. The meager path coefficients associated with the PS factor within the A/WM model is consistent with findings related to the three-factor SR model. Again, these findings were inconsistent with previous research that suggests higher-order cognitive functioning relies upon PS (Fry & Hale, 1996, 2000; Kail, 2007; Nettelbeck & Burns, 2010; Salthouse, 1996; Willmott et al., 2009). In addition, these findings can be viewed as standing in contrast to various theories of WM that suggest PS supports this neurocognitive ability (Baddeley & Hitch, 1994; Fry & Hale, 1996, 2000). One may expect that WM and PS would form a factor if PS is truly supportive of WM. However, as with the two-factor CFA model, these findings are consistent with theories of WM that suggest attention is paramount (Cowan, 2010a; Oberauer & Bialkova, 2009).

Goodness-of-fit indices for the A/WM model indicated absolute fit that was slightly better than that of the three-factor SR model; however, parsimonious fit was minimally adequate and equivalent to that of the three-factor SR model. As with the three-factor SR model, the A/WM model exhibited inadequate comparative fit. Again, this model failed to differ significantly from the null in its ability to predict performance on measures of cognitive processes. In contrast to the three-factor SR model, local fit of the A/WM model was good. The path coefficients related to visuospatial, auditory, and executive processes could all be described as excellent. This suggested that performance on tasks tapping A/WM adequately predicted a child's performance on subtests associated with basic cognitive processes. The path coefficient associated with the memory processes factor could be characterized as poor suggesting that performance on subtests of A/WM were not predictive of performance on subtests of memory processes. This is curious given that a degree of overlap between measures of WM and memory might be expected. In addition, directing attention at incoming information may be viewed as necessary in order for that information to be encoded and later recalled.

Given this model exhibited the best global and local fit, the utility of the A/WM model was evaluated among the aforementioned subsamples (i.e., boys, girls, children who were Caucasian, children who were not Caucasian, and children between the ages of 8 and 9, 10 and 12, and 13 to16). In general, none of these subsamples demonstrated fit across global indices that was better than that of the A/WM model when used with the entire sample. In addition, there were concerns with local fit across each of the subsamples. Given that global and local fit statistics were largely consistent across subsamples and did not approximate that of the A/WM model when used with the overall sample, the full sample group was considered to be the most interpretable. Not only were the fit statistics more appropriate for the overall sample, but also the statistical power associated with the larger sample size would be higher.

Summary. In general, the global fit of the three-factor SR model and the A/WM model are comparable. Both models exhibit adequate absolute fit, but cannot be considered highly parsimonious models. In addition, both fail to differ significantly from the null. However, the A/WM model exhibited much better local fit in that the majority of path coefficients associated with the model are excellent, and there are no concerns regarding multicollinearity. The structure of the three-factor SR model can be viewed as most consistent with the hypotheses associated with the Integrated SNP/CHC model given that the impact of attention, PS, and WM upon basic cognitive processes is examined (Miller, 2013). The current findings suggested that the impact of attention, PS, and WM upon cognitive processes was best explained by the A/WM model in the context of the clinical sample; however, it is important to keep in mind the similar global fits of both models.

Implications for the Fields of Pediatric and School Neuropsychology

Given the functional overlap between the specialty fields of pediatric neuropsychology and school neuropsychology, the findings of the current study have implications that cut across both areas of practice. With regard to the field of pediatric neuropsychology, the observed relationship between attention and WM seems of particular import. Traditional conceptualizations of pediatric neuropsychological functioning dictate that attention and WM are separate constructs (Baron, 2004; Koziol & Budding, 2011). Most typically, WM is considered to exist within the broader domain of memory while attention exists within its own comprehensive purview. Despite research demonstrating the conceptual and functional similarities between these constructs (Cowan, 2010a; Oberauer & Bialkova, 2009), attention and WM are typically assessed and discussed separately within pediatric neuropsychological evaluations. Often, deficits associated with one are related to the other through use of a clinician's judgment, but rarely are these constructs conceptualized via assessment as two sides of the same coin. However, the current findings would suggest that attention and WM may be best conceptualized together.

In addition, the typical pediatric neuropsychological evaluation does not commonly tie attention and WM functioning specifically to auditory, visuospatial, and executive functioning in a predictive manner. These processes are viewed as largely separate cognitive entities (Baron, 2004; Koziol & Budding, 2011). However, the findings of the current study would suggest that attention and WM could adequately predict functioning across tasks tapping these processes. Thus, it may be prudent for clinicians practicing neuropsychology who work with the pediatric population to thoroughly assess these processes in the face of deficits in attention and WM particularly among those with clinical diagnoses.

Taken together, the current findings have general implications for traditional conceptualizations of pediatric neuropsychological functioning. This becomes important in that the conceptual framework upon which a clinician relies influences that clinician's view of the patient. The clinician's method of assessment is bound by the conceptual framework to which he or she ascribes. Furthermore, the results of that assessment drive both diagnosis and intervention. In this way, the use of a conceptual framework for pediatric neuropsychological assessment that is well-aligned with actual pediatric neuropsychological functioning is of principal significance.

The Integrated SNP/CHC model is unique in that this conceptual framework of pediatric neuropsychological assessment explicitly conceptualizes attention and WM as related cognitive constructs (Miller, 2013). In this regard, the findings of the current study were supportive of the structure of the Integrated SNP/CHC model. However, this model suggests that PS is related to attention and WM as well. Specifically, these three constructs are hypothesized to represent cognitive facilitators/inhibitors. In addition, the Integrated SNP/CHC model suggests that these three constructs collectively influence basic cognitive processes including visuospatial, auditory, memory, and executive processes. Given that the Integrated SNP/CHC model is commonly utilized within the field of school neuropsychology, these results have implications for this specialty area.

The current findings suggest that attention and WM appear to represent a cohesive cognitive construct separate and distinct from that of PS. This is inconsistent with the hypotheses associated with the Integrated SNP/CHC model (Miller, 2013). It is important for clinicians practicing school neuropsychology to recognize the overlap in tasks tapping attention and WM; however, they should be aware that this overlap is minimal or nonexistent for subtests assessing PS. Given the aforementioned relationship between conceptual framework, assessment, diagnosis, and intervention, this seems most important when devising interventions that assist with management of deficits related to these three processes. Specifically, the relationship between attention and WM suggests that intervening upon attention may impact WM. Based upon conceptualizations of these two constructs (Baron, 2004; Goldstein et al., 2011; Mirsky et al., 1991), it is unlikely that intervening upon WM will impact attention. Given that PS does not appear to share a discernible, meaningful relationship with attention and WM, it is important for clinicians to intervene upon this process separately. Based upon the current findings, it cannot be expected that interventions directed at attention or WM will improve PS.

The results of the current study also suggest that attention, PS, and WM did not collectively impact basic cognitive processes. Although these findings are inconsistent with the structure of the Integrated SNP/CHC model (Miller, 2013), it is important to note that attention and WM appeared to impact performance on some basic cognitive processes outlined in the model. Specifically, performance on tasks of attention and WM appeared to predict or impact performance on tasks of visuospatial, auditory, and executive processes. As with the field of pediatric neuropsychology, these findings underscore the importance of exhaustively assessing across these processes when deficits in attention and WM arise. However, clinicians operating under the Integrated SNP/CHC model should be aware that deficits in attention and WM may not predict deficits related to memory processes. In addition, deficits in PS do not appear to be related to deficits across any cognitive processes specified in the Integrated SNP/CHC model. The converse of this also warrants mention in that normative strengths with regard to attention and WM may not indicate normative strengths with regard to memory processes. In addition, normatively strong PS may not impact basic cognitive processes such that performance is outside the normative range. Overall, however, it is important to note that each of the aforementioned implications is inextricably tied to the assumptions and limitations associated with the current study.

Assumptions and Limitations

A number of assumptions were required in order to begin to analyze the results of the current study. It was first assumed that all subtests utilized were administered and scored in a valid, standardized fashion. This assumption seemed reasonable given that the student-clinicians administering these subtests received specific training and supervision in both administration and scoring. In addition, general consistency in administration and scoring procedures across student-clinicians was expected given these individuals received training through one credentialing body. Another assumption relates to clinical diagnoses assigned to participants. It was assumed that all diagnoses given to participants were accurate and based upon established, research-based diagnostic criteria. This assumption seemed practical given that the student-clinicians responsible for assigning diagnoses received supervision from professional, licensed clinicians; however, the use of clinical judgment plays a significant role in discerning a patient's ultimate diagnosis. These assumptions have implications for the general validity of the current study (Cohen & Swerdlik, 2005; Gravetter & Forzano, 2009). Thus, it is possible that the results of the current study are impacted by these assumptions.

The limitations associated with the current study also have implications for the general validity of the results (Cohen & Swerdlik, 2005; Gravetter & Forzano, 2009). Internal validity refers to the ability of a study to produce one, clear explanation for the results of that study. The internal validity of the current study may be limited given the indicators or subtests included in the study were selected in an effort to limit the complexity of the Integrated SNP/CHC model (Miller, 2013).

The selection of subtests was based upon the nature of the data set, reliability and validity of the individual subtests, and the aspect of the construct the subtests purportedly measure. Within the Integrated SNP/CHC model, a number of subtests can be utilized across domains (Miller, 2013); however, each subtest must be used as an indicator for only one factor within modeling procedures. In addition, a number of subtests lacked an adequate sample size within the data set in order to be included in the current study. In this way, a number of subtests were removed from various factors. Subtests associated with PS were significantly reduced; and, those selected were considered more traditional measures of PS (D. Miller, personal communication, July 16, 2012). This is also true for the executive processes domain wherein subtests that were retained can be considered traditional measures of executive functioning. Subtest selection within the memory processes domain was limited to measures of immediate verbal and visual memory and associative memory (Miller).

Clearly, the subtests selected for use in the current study to represent cognitive facilitators/inhibitors and basic cognitive processes do not provide a comprehensive representation of the Integrated SNP/CHC model (Miller, 2013). In this way, the results of the current study may be more related to the nature of and relationship between the specific subtests selected for use. It is possible that had different subtests associated with the Integrated SNP/CHC model been selected for use that a cognitive facilitators/inhibitors factor may have emerged; in addition, this factor may have been highly predictive of basic cognitive processes. However, the inverse of this is also true; thus, the A/WM model may not have emerged when other subtests were investigated. This limitation seems to have clear implications for the PS factor in the two-factor model and the A/WM model in the current study and previous studies supporting the influence of PS upon higher-order cognitive processes (Fry & Hale, 2000; Kail, 2007; Nettelbeck & Burns, 2010).

The general nature of SEM procedures can also be considered a limitation to the internal validity of the current study (Fabrigar & Wegener, 2009; Kline, 2005). Procedures such as CFA and SR modeling allow for the comparison and evaluation of various models specified a priori in association with research and theory with a specific set of data. Although a number of models can be compared and/or evaluated in an effort to describe a construct or support a theory, the presence of alternative models is essentially unlimited. Despite the relative utility of the A/WM model, there may be several other models not investigated in the context of the observed data that explain this data equally well or better. In this way, the results of the current study are somewhat limited given only a finite number of models can feasibly be investigated; nonetheless, local and global aspects of fit were examined which does much in the way of providing information regarding the utility of the model. Overall, given the complexity of the Integrated SNP/CHC model coupled with the nature of SEM procedures, the results of the current study cannot be viewed as definitive.

Another limitation relates to the use of imputed data (Schlomer et al., 2010). Given that a number of scores associated with subtests of interest were not available, multiple imputation (MI) was utilized. Thus, a number of scores in the current study reflect statistically-likely scores rather than actual scores. It is therefore possible that the results of the current study may have been different had actual scores been utilized exclusively. This represents a potential threat to the external validity of the current study which has implications for the overall generalizability of the study (Cohen & Swerdlik, 2005; Gravetter & Forzano, 2009). However, the use of MI maintained the sample size and statistical power of the current study which likely improved external validity (Schlomer et al., 2010). In a related vein, the large sample size associated with the current study may have impacted the validity of global fit statistics; however, this impact was minimized by calculating and interpreting a number of indices of goodness of fit (Comrey & Lee, 1996).

The nature of the sample used in the current study can also be viewed as a limitation to external validity (Cohen & Swerdlik, 2005; Gravetter & Forzano, 2009). Because the sample was made up of children with clinical diagnoses, it is possible that the results of the current study would be drastically different when examining a population of children without clinical diagnoses. This becomes particularly salient given that preliminary multivariate analyses indicated that performance across a number of measures utilized in the current study may be more related to a child's diagnosis than actual cognitive ability. Thus, it is important to exercise caution before applying the results of the current study to non-clinical pediatric populations. However, it is important to reiterate that the sample was characterized by demographic and geographic diversity which may have positively impacted generalizability.

Statistical conclusion validity may also be limited in the current study. This refers to the ability of a study to reach the correct conclusions regarding the variables of interest within the study (Gravetter & Forzano, 2009). This type of validity is predominantly impacted by statistical power (Aberson, 2010). Thus, studies characterized by low statistical power are often lacking in statistical conclusion validity. Statistical power refers to the ability of a study to detect a relationship between the variables of interest when that relationship actually exists. This ability is highly influenced by sample size. Despite the large sample size associated with the current study, low statistical power is still a concern.

Within the realm of SEM, it has been recommended that between 10 and 50 participants per parameter estimate be utilized in order to achieve adequate power (Kline, 2005; Weston & Gore, 2006); however, there has been no consensus reached with regard to sample size when conducting SEM procedures. Other authors have suggested a minimum sample size of 200 although this recommendation varies with the complexity of the model of interest. Given the models associated with this study are characterized by a high degree of complexity with regard to the number of factors and indicators, it is possible that low power impacted the results of this study. However, the sample size associated with the current study was greater than 500 and numerous fit indices that function independently of sample size were reported and interpreted.

A final limitation of the current study relates to investigation of a theory that has not been previously researched in the literature. Given that the Integrated SNP/CHC model is presently void of research, the results of the current study are not comparable to prior research and literature directed at this model. Therefore, the general validity of the current findings remain unclear.

Recommendations for Future Research

The current study represents premier research directed at investigation of the relationship between attention, PS, and WM; and, the collective impact of these neurocognitive constructs upon basic cognitive processes. Consequently, this study provides a useful contribution to the fields of pediatric and school neuropsychology. Given that this study examined a novel model of pediatric neuropsychological functioning, replication is essential to establish both the results of the current study and the utility of the Integrated SNP/CHC model. In replicating the current study, it may be helpful to utilize different or additional subtests when creating factors in order to better approximate the true spirit of the Integrated SNP/CHC model. Replication of the current study may also focus upon the production of more cohesive attention, PS, and memory factors. In other words, it may be helpful to focus upon only one aspect of attention (i.e., sustained attention), PS (i.e., performance fluency), or memory (i.e., verbal memory) given the multifaceted nature of these constructs. It also may be helpful to simply replicate the current study with a sample of children who do not have clinical diagnoses.

A study utilizing exploratory factor analytic techniques directed at subtests associated with attention, PS, and WM as delineated by the Integrated SNP/CHC model may be beneficial. This type of study would aide in the understanding of the natural structure of subtests associated with these three neurocognitive processes. It may also benefit the fields of pediatric and school neuropsychology to conduct additional predictive research directed at the relationship between attention, PS, and WM. This type of research can do much in the way of determining whether WM is more supported by attention or PS which has been debated in the literature (Cowan, 2010a; Fry & Hale, 2000; Kail, 2007; Nettelbeck & Burns, 2010; Oberauer & Bialkova, 2009). In addition, these analyses can clarify the general relationship between the three which would assist in supporting or refuting various hypotheses regarding their relationship (Barrouillet et al., 2004; Barrouillet et al., 2009; Miller, 2013).

Summary

In conclusion, the goals of the current study were to examine the relationship between attention, PS, and WM; and, examine the collective impact of these three neurocognitive constructs upon basic cognitive processes including visuospatial, auditory, memory, and executive processes. Essentially, this served to validate aspects of the Integrated SNP/CHC model; however, the relationship between and impact of attention, PS, and WM has been consistently debated in the literature (Cowan, 2010a; Baddeley & Hitch, 1994; Barrouillet et al., 2004; Barrouillet et al., 2009; Fry & Hale, 2000; Kail, 2007; Miller, 2013; Nettelbeck & Burns, 2010; Oberauer & Bialkova, 2009). The findings of the current study suggested that there was no meaningful relationship between attention, PS, and WM within the context of the clinical sample and subtests utilized. However, there did appear to be a meaningful relationship between tasks of attention and WM. These tasks were also found to be predictive of a number of basic cognitive processes including visuospatial, auditory, and executive processes. Thus, the facets of the Integrated SNP/CHC model that were investigated were not altogether supported or refuted. Given the complex nature of the Integrated SNP/CHC model and the nature of SEM procedures, more research is necessary to substantiate these findings and further validate the Integrated SNP/CHC model.

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