AN EXAMINATION OF THREE THEORETICAL MODELS

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ABSTRACT

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The prominent focus on the study of executive functioning in the field of neuropsychology has yielded increased attention on the presentation of executive function and dysfunction in childhood (Hunter & Sparrow, 2012; McCloskey, Perkins, & Van Divner, 2009). The importance of executive skills in academic and social functioning has been demonstrated in brain and developmental research (Brock, Rimm-Kaufman, Nathanson, & Grimm, 2009; Shaul & Schwartz, 2014). Deficits in executive functioning have also been documented in many disorders found in childhood (Riccio, Sullivan, & Cohen, 2010). Researchers have created numerous theories and models to better understand executive functions. Continued disagreement exists in the field and no one theory or model has been accepted at this time; however, most researchers agree that executive functioning involves higher-order skills, which serve to monitor, control, and organize complex thoughts and behavior (Anderson, 2008). The purpose of this study was to compare three models of executive functions that represented common themes in the literature: a single-factor model, a model based upon the Integrated School Neuropsychology (SNP)/Cattell-Horn-Carroll (CHC) model, and a six-factor model proposed by the researcher.

Participants in the this study were drawn from an archival data set of neuropsychological case studies previously obtained through the KIDS, Inc. School Neuropsychology Post-Graduate Certification Program. Structural equation modeling (SEM) using confirmatory factor analysis (CFA) was the statistical technique utilized to examine the three theoretical models. The factors were comprised of subtest scores from the four neuropsychological assessment batteries of the Woodcock-Johnson Tests of Cognitive Abilities, Third Edition Normative Update (WJ III COG NU), A Developmental Neuropsychological Assessment, Second Edition (NEPSY-II), the Test of Everyday Attention for Children (TEA-Ch), and the Delis-Kaplan Executive Function System (D-KEFS). Findings indicated that none of the original models tested successfully represented the construct of executive functioning as measured with a clinical sample of children. Theoretically sound modifications were then conducted to improve the models as measured by fit indices and standardized coefficients. The six-factor model proposed by the researcher demonstrated best fit of the three models after model modifications; however, a high degree of multicollinearity between factors continued to be observed for the both the Integrated SNP/CHC and six-factor model proposed by the researcher. The construct of cognitive flexibility was especially problematic for these models. Findings suggest that an even higher degree of overlap between executive skills may exist for children with disabilities compared to their typically developing peers. Future research is warranted to better understand how theoretical models of executive functioning present in children at different developmental periods or within similar disabilities.

Additional constructs, such as theory of mind, as well as alternative theories of executive functioning should be tested to explore whether another model may better represent the construct of executive functioning in a clinical population of children. This study provides additional insight into how executive functions present in children with disabilities, and contributes to a better understanding of how to appropriately provide assessment and intervention services for this population.

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CHAPTER I

INTRODUCTION

Executive functioning is a thriving area of study in the field of neuropsychology that is continuing to receive increased attention in both clinical research and applied practice (Hunter & Sparrow, 2012; McCloskey et al., 2009; Packwood, Hodgetts, & Tremblay, 2011). At the same time, there is vast disagreement as to what actually constitutes executive functions. There is no current consensus on how to define the construct or which abilities should or should not be included in the definition (Packwood et al., 2011). Researchers have proposed numerous models and theories without any one theory receiving complete acceptance in the field (Hunter & Sparrow, 2012). This disagreement is confounded by difficulties measuring executive functions in isolation, the use of inconsistent research methods and assessments, and a lack of empirical studies considering developmental trends in childhood. Despite these limitations, most theorists agree that the term executive function represents higher-order processes that serve to control and coordinate complex cognition and behavior (Anderson, 2008; Hale & Fiorello, 2004; Hunter & Sparrow, 2012). Executive functions are important for success in both childhood and adulthood, and are highly predictive of academic, social, and behavioral functioning (Brock et al., 2009; Shaul & Schwartz, 2014).

Executive dysfunction, or significant deficits in higher-order abilities, has been documented in a wide range of clinical disorders found in childhood (Anderson, 2008;

Hunter & Sparrow, 2012). The popularity of assessments for executive functioning demands increased research on the presentation of executive dysfunction specifically in clinical samples of children. Thus, continued research on the factor structure of executive functioning using a child clinical sample will help clinicians obtain a better understanding of how executive deficits present with this population. This research will also assist practitioners with appropriate and meaningful assessment and intervention.

Brief Literature Review

History

Although there has been a significant increase in research on executive functioning in recent years, historical descriptions of higher-order functions can be found in antiquity (Mashour, Walker, & Martuza, 2005; Pennington, 2009). Clinical advances in the neurosciences propelled the understanding of brain-based relationships during the 18th and 19th centuries, with the field of clinical neuropsychology officially established during this period of time (Benton & Sivan, 2007; Jurado & Rosselli, 2007; Pennington, 2009). More recent medical advancement has produced increased knowledge of the importance of the frontal lobes for complex cognition through the study of patients with brain lesions and resections. These individuals often displayed difficulties with inhibition, personality changes, poor decision-making, and attention/memory deficits (Mashour et al., 2005). At the same time, advanced neuroimaging techniques have contributed to increased knowledge about how executive functions are processed in the brain (Hunter & Sparrow, 2012). Present-day conceptualizations of executive functions contend that these skills are the result of the recruitment of a wide range of neural networks and brain regions as opposed to a one-to-one correspondence between brain structure and deficit.

Neuropsychological assessment practices have continued to be refined over the last 200 years due to improved psychometric techniques (Flanagan & Harrison, 2012). Further, advanced research techniques in the field of psychology have contributed to specific batteries for identification of brain dysfunction (Miller, 2013). Current neuropsychological assessment involves consideration of developmental trends (Hunter & Sparrow, 2012) and relationships between various cognitive strengths and weaknesses (Miller, 2013). Individual tasks commonly used to measure executive skills include the Wisconsin Card Sorting Task (WCST; Heaton, Chelune, Talley, Kay, & Curtiss, 1993) and the Stroop Color and Word Test (i.e., Stroop test; Golden & Freshwater, 2002), as well as numerous types of tower tasks, trail making tests (TMTs), go/no-go tasks, and clock drawings (Davis, 2011). Formal assessment batteries have also been used to measure aspects of executive function in children and adolescents, such as the D-KEFS (Delis, Kaplan, & Kramer, 2001), NEPSY-II (Korkman, Kirk, & Kemp, 2007), and the TEA-Ch (Manly, Robertson, Anderson, & Nimmo-Smith, 1999). Most of these individual tasks and assessment batteries were initially developed for use with adults and were extended downward to include younger ages (Miller, 2013).

Prominent Theories

As previously mentioned, numerous models and theories exist to define and explain executive function and dysfunction in both adult and child populations. Models are typically divided into unitary and multidimensional models of executive function

(Flanagan & Harrison, 2012). Unitary theorists place all higher-order abilities under one overall construct or executive control center. Many of the theorists supporting unitary models were early pioneers in the field; their theories have since been updated to include multiple factors (Anderson, 2008). Even so, unitary theories of executive function are still commonly referenced in the literature today. Current proponents of the unitary model contend that executive function is similar to or even the same as the overall intelligence quotient (IQ; Davis, 2011; Jurado & Rosselli, 2007). Other theorists assert that executive functions are better represented by the constructs of working memory or fluid reasoning. Many of these researchers view the different aspects of executive function as highly intercorrelated, and therefore contend that it is not possible to identify distinct subfactors (Flanagan & Harrison, 2012). Empirical research also suggests that executive functions in early childhood may factor together to form one collapsed construct (Hughes, Ensor, Wilson, & Graham, 2010).

In contrast, multidimensional models of executive function propose that separate factors work together to produce higher-order functions (Banich, 2009; Blair & Ursache, 2011). Support for these models includes brain-imaging data that connects behavioral deficits to specific neural circuits (Flanagan & Harrison, 2012; Jurado & Rosselli, 2007). The majority of factor analytic studies have documented at least a two-factor structure in executive functioning (Anderson, 2008). Widely cited proponents of multidimensional models include Lezak's (1995) conceptualization of executive function, Anderson's (2002) executive control system, and McCloskey and colleagues (2009) holarchical model. Other theorists divide executive skills into hot functions, which are emotional/behavioral in nature, and cold functions, which represent cognitive skills (Zelazo & Carlson, 2012). Some of the most popular multidimensional models include elements of working memory, such as Baddeley and Hitch's (2000) model of working memory and Barkley's (1997) model of self-regulation. Other executive function models, such as the Supervisory Attentional System (SAS), commonly conceptualize executive function as executive attention (Norman & Shallice, 1986). All of these theories will be discussed further in Chapter 2.

Neuroanatomy and Neurochemistry

The frontal cortex has long been the focus of executive function and dysfunction in neuroanatomical and neurobiological research (Jurado & Rosselli, 2007). The three specific areas of the frontal cortex related to executive functions are the dorsolateral prefrontal cortex (dlPFC), the orbitofrontal cortex (OFC) or ventral medial prefrontal cortex (vmPFC), and the anterior cingulate cortex (ACC). Both an increased number of white matter tracks (Woodward, Clark, Pritchard, Anderson, & Inder, 2011) and decreased gray matter volume (Ghassabian et al., 2013) have been associated with improved executive function performance in children. While frontal regions are important components, the neuroscience literature indicates that executive skills require recruitment of multiple integrated brain regions and systems for successful completion of higher-order tasks (Blair & Ursache, 2011). Specifically, the following five brain networks have been implicated in executive functions: the motor circuit, oculomotor circuit, dlPFC circuit, OFC circuit, and ACC circuit (Blumenfeld, 2010; Hale & Fiorello, 2004). These circuits project sensory and perceptual information to frontal regions, which then provide feedback to lower brain areas forming a continuous loop. The dlPFC network is of particular importance for attention, set shifting, planning, and task initiation. A neuroanatomical theory for how these circuits work is the default mode network (DMN; Raichle et al., 2001). The DMN is activated during resting and habituated activities, while the central executive network (CEN) is engaged when tasks are novel and complex.

Research on brain chemistry in children is significantly lacking and most studies have utilized animal models or adult samples (Hunter & Sparrow, 2012). In general, neurotransmitters implicated in executive functioning include dopamine and norepinephrine, and to a lesser degree serotonin and acetylcholine (Logue & Gould, 2013). Animal studies suggest that atypical levels of neurotransmitters and associated enzymes impact performance on executive tasks, with type of effect (i.e., positive or negative) dependent on the specific chemical. While current research highlights important brain regions and chemicals necessary for executive functions, there is still much that is unknown (Flanagan & Harrison, 2012). Brain functioning is highly complex and a combination of networks and chemical reactions are likely involved.

Development

Increased attention to the importance of development in relation to executive functions has highlighted the inadequacy of adult models and the crucial need to consider developmental trends when measuring executive deficits in children (Hunter & Sparrow, 2012). In contrast to the paradigm that executive functions are only observed in adolescence and beyond, recent research supports the notion that many skills are developing as early as the preschool period (Miller, Giesbrecht, Müller, McInerney, & Kerns, 2012). Research suggests specific sensitive periods of growth in executive functions during birth to age 2, 7 to 9, and 16 to 19 years compared to other times in childhood (Banich, 2009). The development during the preschool period and adolescent years are often targeted as crucial periods due to the heightened amount of plasticity and environmental demands that occur during these ages (Zelazo & Carlson, 2012). A detailed outline of the development of specific executive functions can be found in Chapter 2.

Genetic and Environmental Influences

Appropriate development of executive functions is associated with both genetic (Leve et al., 2013) and environmental factors (Dawson & Guare, 2010); however, most studies point to the high heritability of executive skills with specific findings ranging from 40 to 80% (Leve et al., 2013). Both twin studies and examination of single nucleotide polymorphisms (SNPs) have implicated certain genetic patterns related to executive functions or dysfunction (Friedman et al., 2008; Logue & Gould, 2013). Polymorphisms in catechol-O-methlytransferase (COMT), Reelin, and dopamine receptor genes have been connected to performance differences on executive tasks (Baune et al., 2010; Logue & Gould, 2013; Rueda, Rothbart, McCandliss, Saccomanno, & Posner 2005).

In contrast, other research highlights the importance of a wide variety of environmental factors for development of executive functions. Drug use (Riccio et al., 2010), maternal depression (Hughes, Roman, Hart, & Ensor, 2012), and exposure to environmental toxins (Dawson & Guare, 2010) during pregnancy all affect development of executive skills. As children develop, the structure of the school and home environments (e.g., caregiving styles, nurturance, attachment, sleep) likely influence development of these executive functions (Bernier, Carlson, Deschênes, & Matte-Gagné, 2012; Hunter & Sparrow, 2012; Jurado & Rosselli, 2007). Numerous studies have also associated decreased socioeconomic status (SES) and poverty with executive dysfunction in childhood (Evans, Schamberg, & McEwen, 2009; Rhoades, Greenberg, Lanza, & Blair, 2011).

Prevalence in Clinical Populations

Executive dysfunction is a commonly cited occurrence in many clinical disorders diagnosed in childhood (Hosenbocus & Chahal, 2012) and children with executive dysfunction are likely to have academic problems in school (Brock et al., 2009). Some clinicians argue that executive dysfunction should qualify as its own disorder based upon the number of children with executive deficits that do not fit other diagnostic criteria (Hosenbocus & Chahal, 2012). The most frequently researched disorder in relation to executive dysfunction is attention-deficit/hyperactivity disorder (ADHD; McCloskey et al., 2009; Willcutt, Doyle, Nigg, Faraone, & Pennington, 2005). Other disorders with executive deficits include intellectual disability (ID), autism spectrum disorder (ASD), learning disabilities (LD), mood disorders, acquired brain injuries, and fetal alcohol syndrome (FAS; Banich, 2009; Hunter & Sparrow, 2012; Riccio et al., 2010).

In order to identify executive deficits in these clinical populations, a number of formal assessments have been created (Banich, 2009). Many of these measures are downward extensions of adult tests that do not consider developmental trends (Miller, 2013). It is also difficult to determine precisely what is being measured during an executive task because such tasks require basic cognitive skills (e.g., motor performance) as well as higher-order functions for successful completion (Jurado & Rosselli, 2007). The most common forms of assessment for executive functions include computerized continuous performance tasks (CPTs), behavior rating scales, and standardized neuropsychological assessments (Davis, 2011). Behavior rating scales have been adopted to provide an assessment of how a child is functioning outside of the testing environment, but are limited by the subjectivity of the rater. CPTs are used as a direct measure of attention by requiring a child listen and respond to a string of auditory or visual cues for a set duration of time. While CPTs are often used in neuropsychological assessments, their validity and reliability have been questioned. This research study only utilized data from neuropsychological batteries. Many neuropsychological assessments exist to measure different facets of executive functions, including cognitive/intelligence, memory, attention, and specific executive function tests. Of particular importance for this research study are the WJ III COG NU (McGrew, Schrank, & Woodcock, 2007), NEPSY-II (Korkman et al., 2007), TEA-Ch (Manly et al., 1999), and the D-KEFS (Delis et al., 2001).

Purpose, Rationale, and Significance of Study

As noted in the literature review, there is continued disagreement in the field regarding what constitutes executive function, particularly regarding child and adolescent populations (Hunter & Sparrow, 2012; Packwood et al., 2011). Scholars are only beginning to understand the complex neuroanatomical, neurochemical, and developmental components related to executive function and dysfunction. Empirical research using child-clinical populations is also severely lacking. The existing literature has utilized inconsistent methods and theoretical models, which in turn makes comparisons between findings difficult (Jurado & Rosselli, 2007). Even as disagreement continues, there is heightened interest in incorporating assessment of executive functions into clinical practice. Based on this pattern, there is a dire need to better understand how executive function and dysfunction present in children with clinical disorders so that appropriate assessment practices and interventions can take place. The purpose of the this study was to examine the factor structure of executive functioning using models that represented differing theoretical perspectives in the current literature.

This study utilized three different models of executive function based on popular theories in the field today. The first model was a single-factor model that represented the unitary perspective. This model collapsed all of the subtests into one latent variable. The single-factor model was also chosen for comparison based upon its simplicity.

The second model was the Integrated SNP/CHC model (Miller, 2013). This model incorporates aspects of the CHC theory of intelligence, factor analytic research, and theoretical perspectives in clinical neuropsychology. As a hierarchical organization system, the Integrated SNP/CHC model divides neuropsychological domains into basic sensorimotor processes, facilitators/inhibitors, basic cognitive processes, and acquired knowledge. These domains are further divided into second- and third-order classifications based upon subtypes. Cognitive facilitators/inhibitors in Miller’s (2013) model are attention, working memory, and processing speed. All three of these facilitators/inhibitors function to support and integrate higher-order processes and help to produce acquired knowledge. Attention is further divided in Miller's model into selective/focused attention, sustained attention, and attentional capacity. The executive function domain is considered a basic cognitive process and includes the subtypes of cognitive flexibility or set shifting; concept formation; problem solving, planning and reasoning; and response inhibition. The three domains represented by the Integrated SNP/CHC model for the study were attention, working memory, and executive functions. The Integrated SNP/CHC model was chosen because it was developed using a child-clinical population (Miller, 2013). This model also uniquely conceptualizes attention and working memory as supporting executive functions without including them in the executive domain.

The third model that was measured in the research study was a six-factor model proposed by the researcher. The goal of this model was to represent the overall body of neuropsychological research on the topic, and not one specific theory. The six-factor model was loosely based on Anderson's (2008) general assessment of the major components of executive function found in neuropsychological literature as well as Miyake and Friedman's (2012) work using SEM. Anderson's (2008) components were the domain names in the model and included "anticipation and deployment of attention, impulse control and self-regulation, initiation of activity, working memory, mental flexibility and utilization of feedback, planning ability and organization, and selection of efficient problem-solving strategies" (2008, p.4).

Miyake and Friedman (2012) have suggested a three-factor model of executive function comprised of working memory/updating, inhibition, and set shifting. Numerous additional studies have attempted to confirm these three factors with a typically developing sample of young and school-aged children (Röthlisberger, Neuenschwander, Cimeli, & Roberts, 2013; van der Ven, Kroesbergen, Boom, & Leseman, 2013; Wu et al., 2011). Miyake and Friedman's (2012) three factors of working memory/updating, inhibition (i.e., self-regulation and impulse control), and set shifting (i.e., mental flexibility and use of feedback) were represented in the six-factor model. Three additional factors titled deployment of attention; initiation, planning, and organization; and problem solving were also included to extend the work of Miyake and Friedman. The function of this expansion was to determine if additional variables more comprehensively represent the factor structure of executive function in a clinical sample of children. The inclusion of Miyake and Friedman's work was important due to the minimal amount of empirical research with a child-clinical population coupled with its frequent use in psychological literature. Overall, the six-factor model was created because many prominent theories of executive functions are not easily testable due to their complex theoretical nature or because they oversimplify the construct. The model was also chosen for analysis based on its inclusion of attention and working memory as separate factors under the overall latent variable of executive function, which allowed for comparison between the six-factor model and Miller's (2013) Integrated SNP/CHC model.

Research Question and Hypotheses

The aforementioned research procedures and statistical techniques were used to answer the following research question:

Which theory best describes the factor structure of executive functioning using a mixed-clinical sample of children?

a. A one-factor model?

b. A model based upon the Integrated SNP/CHC model?

c. A six-factor model proposed by the researcher?

The researcher predicted three separate hypotheses for the proposed study findings. It was expected that the single-factor model would not represent the best model fit for the mixed-clinical sample. This expectation was based off of recent research indicating that a multiple factor structure is present in school-aged children (Xu et al., 2013; Zelazo & Müller, 2010). The second hypothesis was that the Integrated SNP/CHC model would be the model of executive function that best fit the sample data. This hypothesis was supported by previous factor analytic research illustrating the facilitative nature of working memory and attention for executive functions (Miller, 2013). The final hypothesis was that the six-factor model would fit the data, but not as well as the Integrated SNP/CHC model. This model may not be as representative of the sample data due to its self-created nature and lack of factor analytic research using a mixed-clinical sample of children. Overall, a better understanding of the factor structure of executive functioning should provide additional insight into the presentation of executive dysfunction in children with disabilities and assist practitioners in determining appropriate assessment and intervention procedures.

CHAPTER II

REVIEW OF THE LITERATURE

This chapter provides an overview of the current research that is relevant to this study. A brief history of executive functioning and prominent theories is reviewed. Available research relating to the neuroanatomy, neurochemistry, genetics, and the development of executive skills, as well as the importance of executive functions for success, is also discussed. This chapter concludes with pertinent research on the various clinical disorders with associated executive deficits, relevant neuropsychological assessment batteries, and the rationale for the proposed study.

Overview of Executive Functioning

Executive functioning has become an increasingly popular area of focus in the field of neuropsychology (McCloskey et al., 2009). Research on the role of executive functions in assessment and its presentation in clinical disorders has received heightened attention in recent years. Numerous, sometimes divergent, theories exist to describe, define, and classify executive functions (Packwood et al., 2011). There is presently no consensus in the field of neuropsychology regarding the exact nature or definition of executive functioning; however, most researchers agree that it is an overarching system that functions to regulate complex cognition and behavior (Anderson, 2008; Hale & Fiorello, 2004; Hunter & Sparrow, 2012). Executive dysfunction is considered the breakdown of these cognitive and behavioral abilities, resulting in difficulty with appropriate functioning in a wide range of everyday life events (Anderson, 2008).

History of Executive Functioning

Viewing the brain as a source of pathology and dysfunction extends back to antiquity when trephining, the process of drilling a hole into the skull, was a common practice to alleviate a wide variety of psychiatric symptoms (Mashour et al., 2005). Historical writings also contain descriptions of what is presently considered executive function, such as the mention of self-control in the Hebrew Bible. Although early philosophers once believed the heart was the organ responsible for thought, the brain became associated with higher-order thinking and cognition by the 17th century (Pennington, 2009). The philosophy of this period was that the brain was a unitary organ representing mental thought.

1700-1800s

In the late 18th and early 19th century, researchers began to examine different brain functions instead of seeing it as a unitary organ of the mind (Benton & Sivan, 2007). Franz Joseph Gall (1835) theorized that the brain was made up of separate organs, with each representing a different ability. Other researchers, such as Paul Broca (2011) and Carl Wernicke (1881), began to identify specific functions of brain regions. For example, Broca used patients with brain damage to localize language in the left hemisphere, thus establishing the notion of hemispheric dominance (Benton & Sivan, 2007).

Although earlier accounts exist, clinical neuropsychology is thought to have its official start in the 19th century (Mashour et al., 2005). Specific lesion studies during this time period led scientists to ascribe any number of higher-order functions to the frontal lobes (Hunter & Sparrow, 2012). When individual functions were documented, it was generally to illustrate a one-on-one relationship between damage to a region and a disability (Pennington, 2009). Describing one of the most infamous cases in the history of psychology, Harlow (1848) wrote an account about Phineas Gage who experienced frontal lobe damage when a rod went through his vmPFC. Gage displayed significant signs of personality change, behavioral impulsivity, and difficulty with motivation and initiation, which helped researchers to better understand the importance of the frontal lobes for behavior, cognitive control, and personality (Mashour et al., 2005).

As with other fields of psychology, clinical neuropsychology owes much to the early pioneers in intelligence testing, including those studying the philosophy of the mind, as well as prominent figures conducting experimental research on sensation and perception (Benjamin, 2009). The 19th century also witnessed an increased interest in mental tests, which set out to systematically measure components of thinking and intelligence (Guthrie, 2004). Alfred Binet, with the assistance of Theodore Simon (Binet, Simon, & Town, 1912), is credited with creating the first intelligence test to indicate which children had the cognitive ability to be educated (Flanagan & Harrison, 2012). Lewis Terman (1922) added to the testing procedure by developing a formula that would produce the IQ using several abilities. Concurrent with IQ testing, the first neuropsychological assessment procedures in the United States simply assessed for overall brain dysfunction (Miller, 2013). Early clinicians frequently used one measure to determine if an individual was functioning normally.

1900-Present Day

In the early 20th century, physicians experimented with frontal lobe ablation to alleviate symptomatology of tumors, lesions, and psychiatric illness (Mashour et al., 2005). World War II produced a high number of soldiers with head trauma or psychiatric illness who were frequently placed in mental institutions. In an attempt to cure psychiatric illness, medical professionals during this period advocated for frontal lobotomies that severed white matter tracks in the prefrontal cortex (PFC) in order to disrupt neural circuitry. The clinical efficacy of this procedure was never proven, and common side effects included flat affect, dementia, poor attention, disinhibition, and sometimes death. Although the frontal lobotomy often had dire side effects for the patient, it also shed light on the importance of these brain regions for specific functions. The majority of early medical research in the 20th century focused on brain damage to the frontal cortex without consideration of the involvement of other brain regions (Mashour et al., 2005).

As the 20th century continued, neuropsychological assessment procedures also expanded to include multiple types of data to measure brain dysfunction (Miller, 2013). Psychological tests to assess individuals with brain damage from World War II were developed during the 1940s to 1970s. For example, in 1947 Ward Halstead worked with individuals who had acquired damage to the frontal lobe. In conjunction with Ralph Reitan, he produced a neuropsychological test intended to discriminate between different types of brain dysfunction (Reitan & Wolfson, 1993). The result was the Halstead-Reitan Neuropsychological Test Battery, which is still used with adults today.

A. R. Luria’s (1973) work is undoubtedly foundational to the present day understanding of executive function and dysfunction (Jurado & Rosselli, 2007). Luria described what he called the *frontal lobe syndrome* based off of a lifetime of qualitative research in the Soviet Union on adults with brain damage. Using patterns of performance errors, Luria identified the frontal lobes as the main tool for recruiting, engaging, and organizing higher-order functions, such as problem solving and regulation of other functions; however, Luria did not actually title these skills as executive functions (Hunter & Sparrow, 2012). Lurian theory divided cognitive functions into systems, with higher-order functions requiring the use of numerous basic brain systems. He argued that damage to the basic functions is detrimental for more complex processes. Anne-Lise Christenson transformed Luria’s materials into a standardized version, which was later updated for use in the United States by Charles Golden (Golden & Freshwater, 2001). Thus, the Luria-Nebraska Neuropsychological Battery was produced in 1978 and revised in 1986. While this battery is no longer representative of the United States population, it has been foundational in the development of other assessment batteries, such as the Kaufman Assessment Battery for Children, Second Edition (KABC-2; Kaufman & Kaufman, 2004a), the NEPSY-II (Korkman et al., 2007), and the Differential Ability Scales, Second Edition (DAS-2; Elliott, 2007).

Another important movement in the early development of neuropsychological assessments is the Boston Process Approach (Miller, 2013). Edith Kaplan (1988) and associated clinicians used a standardized battery to research the processes adults recruit to produce answers to complex questions. This approach focuses on qualitative behaviors over quantitative test answers and sets out to more fully understand how a person thinks. Many of these types of observations have been incorporated into more recent assessments, such as the NEPSY-II (Miller, 2013).

In conjunction with the development of neuropsychological assessment batteries, several independent tests produced in the mid to late 20th century have been foundational to the field of clinical neuropsychology, including the WCST (Heaton et al., 1993) and the Stroop Color and Word Test (Golden & Freshwater, 2002), as well as various tower tasks, TMTs, go/no-go tasks, and clock drawings (Davis, 2011). A review of these tasks is warranted as they are frequently used in empirical research due to their historical lineage and ability to be administered individually without a full assessment battery.

The Wisconsin Card Sorting Task (WCST). One of the most widely used tasks for measuring executive function is the WCST (Davis, 2011; Heaton et al., 1993). The WCST was first produced in 1948 by Esta Berg and has traditionally been used to measure dysfunction in individuals with brain damage. Examinees being administered the WCST are shown a set of 64 cards one at a time that vary based on color, number, and shape (Heaton et al., 1993). They are asked to sort the cards by indicating what is similar about them. This task requires an examinee to incorporate examiner feedback to learn the rules for appropriate sorting, which change frequently. It is often referred to as the *gold standard* of executive functioning tasks and is still used today. The WCST is primarily a measure of set shifting as participants have to shift between different task rules depending on the feedback; however, it also involves abstract thinking, problem solving, inhibition, sustained attention, and working memory (Berman et al., 1995; Davis, 2011). Individuals with brain damage and healthy children under age 4 typically struggle to switch to the new rule and are more likely to perseverate by staying on the old sorting rule (Banich, 2009). The WCST now exists in multiple versions that are not necessary equivalent, including a computerized version (Davis, 2011).

The Stroop Interference Test. Another traditional neuropsychological task that has maintained its popularity for measuring executive dysfunction is the Stroop Interference Test (Davis, 2011; Golden & Freshwater, 2002). J. Ridley Stroop first created it in 1935 to examine selective attention and cognitive flexibility (Davis, 2011). It has been updated and is now administered as the Stroop Color and Word Test (Golden & Freshwater, 2002). On the interference portion of this task, individuals are shown a list of color words (e.g., yellow, red) that are printed in colors different than the word itself. Children and adults are required to inhibit and override the dominant response of reading the word to instead say the color in which the word is printed. The need to utilize different executive skills for this task is deduced from the fact that participants take longer when trying to inhibit than when they are allowed to read the word in a control trial (Banich, 2009). Similar to other tasks, multiple versions of the Stroop test exist that differ slightly in their format. This task has also been adapted for inclusion in assessment batteries, such as the D-KEFS (Delis et al., 2001).

Tower tests. The Tower test exists in several versions, including the Tower of Hanoi, Tower of London, and the newest version of Tower on the D-KEFS (Banich, 2009; Davis, 2011; Delis et al., 2001). It was also included in the executive functioning domain on the NEPSY, but was removed when the measure was updated to the NEPSY-II (Korkman et al., 2007). On the original Tower of Hanoi test created in the 1970s, an individual is shown a picture of the end goal. He or she must position a set of disks in the fewest number of moves to obtain the end goal location; however, the participant must also follow specific rules (i.e., larger disk not on smaller one) about how pieces can be moved and plan out a series of steps to efficiently move the disks. A similar version, the Tower of London was created to simplify the Tower of Hanoi and uses balls on three pegs (Davis, 2011). The Tower tests were designed to assess an individual's reasoning skills through problem solving, cognitive flexibility, and learning. All of the Tower tasks also require motivation, planning, goal setting and completion, working memory, and inhibition. They currently exist in computerized versions in addition to the traditional versions.

Trail making tests (TMT). The TMTs are primarily a measure of visual-motor executive functioning (Davis, 2011; Dawson & Guare, 2010). On a TMT, a child is required to switch between two different types of stimuli in order, such as numbers and letters, by drawing lines from one stimuli to the next. The TMT part B, was established by Reitan and Wolfson (1993) and has since been adapted for use on the D-KEFS (Delis et al., 2001) as well as the Comprehensive Trail-Making Test (CTMT) by Cecil R. Reynolds (2002). The switching component of these TMTs requires several cognitive skills. Individuals must utilize visual perception, attention, fine and gross motor skills, and set shifting to switch between numbers and letters while inhibiting incorrect stimuli that may be on the page nearby.

Go/no-go tasks. A go/no-go task teaches an individual to identify a target each time it is presented (Davis, 2011); however, in additional trials, the target stimulus is switched and the participant has to inhibit the first target and switch to the second task. There is a wide range of go/no-go tasks used in both applied psychology and in research studies. Luria (1973) created one of the commonly used tests as a screening tool. On this task, an individual has to follow a series of taps depending on what the examiner taps. Go/no-go tasks are thought to measure inhibition, set shifting, and sustained attention (Davis, 2011).

Clocks. The clock drawing tests have been used for many years as a way to measure brain damage in adult populations (Davis, 2011). Clocks tasks have been incorporated into various adult batteries, and one can now be found on the NEPSY-II (Korkman et al., 2007). Clock drawings require an individual to copy several types of clocks, with different patterns of performance indicating deficits (Davis, 2011). There is current debate over whether clock drawing is primarily a measure of executive dysfunction or sensorimotor and visual-spatial deficits.

Tests for children. All of these aforementioned approaches and individual tests were created using adult brain pathology and function (Miller, 2013). Additional batteries, particularly with downward extension of questions were created for children in the late 20th century. The first battery specifically for younger individuals was the Halstead-Reitan Test Battery for Older Children, which was created in the 1970s for children ages 9 to 14 (Reitan & Davison, 1974). Another version, the Reitan-Indiana Neuropsychological Test Battery was published for younger children ages 5 to 8. Similarly, the Luria-Nebraska Neuropsychological Battery: Children's Revision (Golden, 1987) was produced as a way to assess neuropsychological functioning in children ages 8 to 12. All of these instruments have outdated normative data, poor clinical discrimination between diagnoses, and do not incorporate current understanding of developmental patterns in childhood. They have been improved greatly through the use of newer assessment procedures (Miller, 2013) that will be described later in this chapter.

Modern clinical advances. Advances in cognitive neuroscience in the 1980s impacted how both researchers and practitioners viewed neuropsychological functions (Pennington, 2009). At the same time, improvements in neuroimaging highlighted brain-behavior relationships in a more advanced way. While much of this work focused on language and hemispheric specialization, a better understanding of the PFC was established during this time. Of particular importance was the discovery of synaptogenesis and plasticity (Pennington, 2009).

As child neuropsychologists began to better understand brain development and function through modern clinical research and brain scans, the use of adult tests for children was seriously questioned (Miller, 2013). Early studies on executive function treated the construct as a unitary factor with the assumption that everyone agreed upon its definition (Hunter & Sparrow, 2012). Instead of using tests to identify functional and structural damage, psychologists in the 21st century began looking at a child's overall cognitive profile. By incorporating continued advancement in neuroscience and child development, psychologists are now able to use psychometrically validated batteries developed specifically to comprehensively identify strengths and weaknesses in children with a purpose of understanding how these abilities influence function in everyday settings (Miller, 2013).

Prominent Theories of Executive Function

There is great variation in how executive skills are theoretically conceptualized, as well as significant disagreement regarding what skills should be included in models of executive function (Hale & Fiorello, 2004). The difficulty formulating a strong, testable, and concise theory to successfully represent this construct is demonstrated by a recent meta-analysis indicating that over 98 tasks have been used to represent executive functions (Packwood et al., 2011). Additionally, more than 68 different terms exist in the literature to define variables or components of executive skills. Of these, the most frequently used terms are: planning, inhibition (i.e., interference, response control, mental control), temporal coding/working memory, selective attention, shifting attention, attentional control/set shifting, attentional set formation, response modulation, generation and suppression, executive motor skills, self-monitoring, verbal formation, and concentration (Packwood et al., 2011). These terms will be described in more detail as they relate to the following theories and proposed models.

The wide disagreement on what constitutes executive functions is also the result of several difficulties in researching the construct. First, executive functions are complex skills that are impure by nature (Hunter & Sparrow, 2012). Recruitment for a higher-order task always involves basic skills, making it impossible to completely parse an executive function from other lower-level abilities, such as perception or motor functioning. This confluence of skills results in task impurity on neuropsychological assessment batteries where scores set to represent a complex skill also incorporate basic abilities. Secondly, there is no agreement in the field on how executive functions should be measured in research studies. This inconsistency makes comparison of research results and reproduction of findings challenging. The use of different measures explains why support for theoretical models varies depending on the specific study. As previously noted, another problem with defining and assessing executive functioning in children and adolescents is that most of the early theory and research was conducted using an adult population (Hunter & Sparrow, 2012). Assumptions about how adults experience executive dysfunction were simply passed down to childhood; newer research indicates that executive functions are dependent on development and show significant variability in children compared to adult functioning (Davis, 2011).

Present theories have been built off of neurological, neurochemical, theoretical, and empirical research studies (Hunter & Sparrow, 2012). All theories generally share two common components: They involve cognitive processes that guide other processes or behaviors, and they are in some way related to the frontal lobes of the brain (McCloskey et al., 2009). Theories describing the nature and function of executive skills also typically fall into two categories of either a unitary construct or a multidimensional model (Flanagan & Harrison, 2012).

Unitary Theories

Continued disagreement abounds on whether executive function is a unitary construct (Gioia, Isquith, & Guy, 2001). Most of the first models used to conceptualize executive functions were unitary (Anderson, 2008). Early attempts by Baddeley (1986) and Norman and Shallice (1986) tended to focus more on a singular, overarching *conductor* guiding all other functions; however, they have both updated their theories to incorporate multiple functions, which will be described further in the next section. Other researchers who support the notion that executive functions are unitary believe that it is one overarching cognitive construct that is similar to IQ (Davis, 2011; Jurado & Rosselli, 2007). These models typically focus on fluid intelligence, working memory, or reasoning and problem solving (Banich, 2009). Unitary theories also continue to exist because of the difficulty distinguishing the various aspects of executive function from each other due to high intercorrelations between different subtypes (Flanagan & Harrison, 2012).

There is some empirical support for a unitary construct using factor analysis, particularly with young children under age 6. In preschool children, Wiebe, Espy, and Charak (2008) documented a unitary model of executive functioning consisting of tasks measuring working memory and inhibition. Hughes and colleagues (2010) also conducted a factor analysis noting that tasks measuring inhibition, working memory, and planning all collapsed together into a unitary factor of executive function for children ages 4 to 6.

Multidimensional Theories

Although some researchers contend that executive function is one overarching construct, the majority of the field acknowledges that the concept is most appropriately broken down into separate and distinguishable factors and is multidimensional (Banich, 2009; Blair & Ursache, 2011). Support for separate executive constructs is the result of several trends in the literature. First, patients with executive dysfunction generally have impairments of different regions, and do not simply have comprehensive executive dysfunction (Anderson, 2008). There is also significant variability when executive functions come online in childhood and adolescence. Lastly, neuropsychological assessments of executive skills are only moderately correlated. Studies using SEM have noted varying factor structures depending on the sample characteristics and measures used (Anderson, 2008).

Baddeley and Hitch's model of working memory. The first official mention of executive functions as they are known today came from Baddeley and Hitch's (2000) conceptual model and their central executive (Hunter & Sparrow, 2012). This model of working memory is an updated version of short-term memory from the information processing approach. The original model was comprised of the phonological loop, visuospatial sketchpad, and central executive. The visuospatial sketchpad recruits visual information from long-term memory and holds new visual stimuli while it is being used. Similarly, the phonological loop pulls information stored in language areas of the brain while repeating it to stay in awareness. These two components of working memory are considered *slave systems* as they are lower in order and do not synthesize information.

Instead, the central executive is the attentional function that coordinates information. It works to focus attention on important information, inhibit distractor stimuli, switch tasks based on task demands, organize resources, and retrieve required components from long-term memory. The newly added episodic buffer is an attempt by Baddeley and Hitch to provide a synthesizing function and a place for information to be temporarily stored during use for working memory tasks.

Baddeley and Hitch (2000) consider the model to be representative of functional brain networks, such as the dlPFC. This model is strongly supported in the literature, but does not completely cover all components of executive functioning and is sometimes used to oversimplify neural networks (Hunter & Sparrow, 2012). Based off of Baddeley and Hitch's research, there is a general consensus that working memory is highly implicated in higher-order processing (Blair & Ursache, 2011). Many theorists often combine working memory into the overarching umbrella term of executive function; however the degree to which working memory belongs under the heading of executive functions continues to be debated (Dehn, 2008).

Lezak's conceptualization of executive function. A major contributor to the way executive functions are understood is Murial Lezak (1995). Lezak (1995) was one of the first theorists to describe components of executive functions (Hunter & Sparrow, 2012). She primarily divided executive functions into volition, planning, purposive action, and effective performance. Volition is described as the awareness and choice to initiate an action or behavior. It includes an individual's focus or purpose to complete a behavior or goal in the future. To have volition, a child must be aware there is a need, be able to identify his or her goals, and have appropriate motivation to start the task. Planning includes the specific steps that need to be outlined before the task can be effectively begun or completed. A child needs planning to appropriately break down the task into achievable steps, to understand what may get in the way of success, and to predict what events may occur in the future. Specific skills required in planning include working memory, inhibition, and sustained attention (Anderson, 2008).

Another component of Lezak's (1995) model is called purposive action. After a task is planned, a child needs to be able to actually start the task and ensure that the steps are completed until the goal is achieved. Included in this step is the ability to adjust or stop the plan if needed. Executive skills recruited during this step include cognitive flexibility and inhibition. Finally, the last component is effective performance, which is a form of evaluation. Individuals must be able to identify errors through monitoring and then adjust for the mistakes.

Each of these domains regulates specific actions that can be observed, although multiple domains are often affected during executive dysfunction. In contrast to other theories, Lezak's (1995) model serves as an applied framework for assessment and practice (Anderson, 2008). Some important elements, such as working memory, are not formally included. Furthermore, Lezak does not elaborate on how complex executive functions (e.g., impulse control) are specifically involved in her framework. Instead, this description serves as a general guide and is not well accepted as an empirically testable model of executive functions (Anderson, 2008).

Supervisory attentional system (SAS). The SAS is a popular model of executive functioning first introduced by Norman and Shallice in 1986. Its original conceptualization focused heavily on the role of attention as an overall regulator for behavior. The amount of attention required is dependent on the type of task, specifically whether it is automatic or requires deliberate and controlled actions. Automatic responses occur without much attention and include behaviors that are routine or well learned. In contrast, higher amounts of attention are required for complex decision-making, inhibition, or unique situations that are not regular occurrences (Norman & Shallice, 1986).

Another important component of the SAS model is contention scheduling, which occurs during automatic responses. Norman and Shallice (1986) describe *schemata* as specific programs that are used for completion of common tasks. On a regular basis, different schemata are competing or need to be activated simultaneously. The SAS model states that contention scheduling takes into account which schema best fits the necessary action of the task. The individual will use this one schema until the task is no longer necessary, it is turned off, or another schema is activated. Importantly, more complex tasks may not have previously established schemas, which is when the SAS is engaged (Norman & Shallice, 1986).

The SAS model has been updated by Shallice and Burgess (1996). They argue that an overall *supervisory system* manages a wide variety of lower systems. Shallice and Burgess also produced a three-step process comprised of different stages to explain how novel situations are handled. Stage 1 is when the individual recruits a temporary schema to plan out the problem, generate possible ways to tackle the problem, and define goals necessary for completion. At stage 2, the individual tries out the schema, with particular recruitment of working memory. Finally, in stage 3, the individual performs progress monitoring to see if the schema worked or needs to be adjusted in some way. Overall, the SAS model has empirical support from neural network research, but is not easily applied in practice and may oversimplify brain functioning (Anderson, 2008; Hunter & Sparrow, 2012).

Barkley's model of self-regulation. Another major contributor to the field is Barkley (1997) and his model of behavioral self-regulation. Barkley's work focuses more on the behavioral components of executive function as an overarching construct. His model was highly influenced by other prominent theorists who incorporated elements of language, such as internalized speech, as part of executive functions (Hunter & Sparrow, 2012). Important to Barkley's model is an overarching factor of behavioral inhibition, which includes inhibition of the dominant or previously conditioned behavior, breaking the habituated response, and the ability to prohibit things that may interfere during this time. These three components of behavioral inhibition allow for enough time so that the executive processes can respond appropriately. Barkley argues that behavioral inhibition should be considered hierarchically above other components of executive function and self-regulation.

Barkley's (1997) system of self-regulation is made up of four domains of executive functioning, which he titles working memory, self-regulation of affect/motivation/arousal, internalization of speech (i.e., verbal working memory), and reconstitution. All four of these domains control motor output. First, working memory includes the ability to maintain the current task demands as well as those from previous situations so that goals can be planned and kept. An individual also has to hold the current plan in memory during analysis, planning, and completion of the task. The self-regulation domain involves emotion, which is either recruited (e.g., for motivation) or inhibited depending on the task needs. Internalization of speech is considered self-directed speech that helps an individual process, examine, question, and produce plans. It is seen as a way to support an individual during problem solving or times when self-control is necessary, and is sometimes conceptualized as verbal working memory. Finally, reconstitution is the analysis of a problem to divide it into specific components. Reconstitution also involves the ability to use synthesis, which helps to adapt the problem, if required (Barkley, 1997).

Barkley (1997) conceptualizes executive functions through his developmental model that primarily focuses on behavioral inhibition, which he believes is the main deficit in children diagnosed with ADHD. Secondary deficits stem from difficulties inhibiting, which include poor nonverbal working memory, verbal working memory, reconstitution, and internalization of speech. While Barkley's model is helpful for understanding self-regulation, particularly for children with ADHD, it is still unclear how the hierarchy is applied in assessment and neural models, specifically for support of behavioral inhibition being placed as an overarching construct over other executive skills (Anderson, 2008).

Anderson's executive control system. Anderson's (2002; 2008) executive control framework utilizes both factor analysis and research on the developmental nature of neuropsychological functions as its foundation. It is made up of the four domains of attentional control, cognitive flexibility, goal setting, and information processing. While they are separate, Anderson (2008) sees each of the four domains as representing an overarching executive control network. Additionally, the domains function in a bidirectional relationship with the different components continually influencing one another; however, the degree to which they are recruited is dependent on the specific task. They are all reliant on incoming information from a wide range of brain regions.

Attentional control is a domain that functions to focus attention and sustain it long enough for the task to be completed (Anderson, 2002; 2008). Other components of this domain include the ability to use self-regulation to determine if the individual is on target for achieving the goal as well as self-monitoring to ensure steps are completed correctly, to note errors, and to correct them so they do not interfere with goal completion. The ability to inhibit competing stimuli or processes to avoid errors or mistakes is also an important aspect of self-control. Similarly, the domain of cognitive flexibility includes working memory capacity as well as set shifting. It also incorporates cognitive skills needed to divide attention, adjust for errors, and change plans when necessary.

Another domain in Anderson's (2002; 2008) model is goal setting, which requires individuals to set goals, plan out specific steps to achieve the goal, and then initiate activity to complete the goal. Children must also be able to organize pertinent information relevant to the goal and think critically about potential solutions. Strong goal setting abilities demonstrate strategic planning and clear organization. The last domain in Anderson's framework is information processing, which includes skills related to processing speed, fluency, and the ability to quickly and efficiently complete tasks. While it is considered an important factor in this model, the information-processing domain helps to improve other executive skills when required by the task (Anderson, 2000; 2008).

Hot and cool executive functioning. Another broad theory for conceptualizing executive functions involves dividing them into hot and cool functions (Zelazo & Carlson, 2012). This division was first posed by Abelson in 1963. Abelson categorized hot cognition as behaviors related to affect and emotion, and cold cognition as intellectual problem solving or rational thought. His theory was expanded by Mischel, Shoda, and Rodriguez (1989) who focused it more specifically on delayed gratification. Cool executive functioning skills are those traditionally measured by neuropsychological batteries, such as cognitive inhibition and sorting. In contrast, hot executive functions are those that are required to appropriately function during highly emotional situations. Hot executive skills are associated with motivation, reward, and self-regulation of behavior. The two systems are thought to be influenced by an individual's level of stress as well as developmental factors (Hunter & Sparrow, 2012). Although increased research has focused on hot executive functions, the remainder of this literature review will describe research as it relates to cognitive executive functions because it is a primary focus of the proposed study.

McCloskey and colleagues' model. McCloskey et al. (2009) take a middle ground position by conceptualizing executive functions as *co-conductors* that work together in concert to produce higher-order cognition and behavior. Their comprehensive model aims to represent and appreciate the vast complexity of interrelationships that are required to produce executive functions. McCloskey and colleagues consider their model to be developmental and describe it as *holarchical*. This term was chosen by McCloskey and colleagues to represent the interconnectedness of executive functions because all components of the model serve as both a part and whole of the system. They also note that the model is not unidirectional, and children move back and forth between tiers as they progress through development. Executive functions are stratified in tiers ranging from self-activation, self-regulation, self-control (i.e., self-realization and self-determination), self-generation, and trans-self integration. The lower levels represent more basic functions, such as attending or storing information, while the higher levels involve broader goals and identity (i.e., cosmic consciousness).

The main focus of psychologists is the self-regulation tier, which guides behavior on a daily basis (McCloskey et al., 2009). McCloskey and colleagues (2009) have divided self-regulation into four domains: emotion, perception, action, and cognition. These domains work together with each other as well as with a variety of sensory information to produce 23 specific self-regulation behaviors, which also interact with each other. The result is a complex web that represents the neural networks in the brain. Executive functions can also impact a child in several arenas, such as the intrapersonal (e.g., self, feelings, perceptions), interpersonal (e.g., relationships), environmental (e.g., physical environment, surroundings), and symbol system arenas (e.g., culture, logic, language). They believe that some networks and skills are more developed than others. Thus, variability occurs between individual skills, with certain networks functioning at higher levels than others and different arenas impacted depending on the child (McCloskey et al., 2009).

The Cattell-Horn-Carroll (CHC) model. The CHC model of intelligence has been one of the most influential in the field of cognitive psychology (Flanagan & Harrison, 2012). It is a hierarchical model that combines two prominent theories of intelligence: the Gf-Gc model and Carroll's (1997) three-stratum theory of intelligence. Gf-Gc theory was pioneered by Raymond Cattell in 1941 (Cattell, Feingold, & Sarason) and conceptualizes intelligence as two different facets with Gf representing fluid reasoning and Gc crystalized knowledge. Cattell saw crystalized knowledge as semantic or factual information that is gathered from experience and stored. It is also highly dependent on culture. In contrast, Gf or fluid reasoning involves higher-order problem solving that is recruited when crystalized knowledge is not adequate. Cattell viewed Gf as the more valuable aspect of intelligence. John Horn then supported this theory with his work (Horn & Cattell, 1966), and specifically documented that the two facets of intelligence also develop at different rates (Flanagan & Harrison, 2012).

The other major influence in the development of what is now CHC theory was John Carroll (1997; Flanagan & Harrison, 2012). Carroll (1997) theorized that intelligence exists in stratums that are hierarchically divided into broad and narrow factors. He organized these factors into an overall intelligence (i.e., Stratum I), eight broad factors (i.e., Stratum II), and up to 69 narrow abilities (i.e., Stratum III). Carroll's model of intelligence was supported through numerous and extensive data sets using factor analysis. The two separate models Gf-Gc and Carroll's three-stratum theory were combined to create an integrated second stratum of the following broad cognitive factors: acculturation-knowledge (Gc), fluid reasoning (Gf), short-term memory (Gsm), long-term storage and retrieval (Glr), processing speed (Gs), visual processing (Gv), auditory processing (Ga), and quantitative knowledge (Gq; Flanagan & Harrison, 2012).

Present-day CHC theorists see these facets of intelligence as separate, but highly correlated to represent a broad overall IQ (Flanagan & Harrison, 2012). CHC theory was first applied to formal assessments through the publication of the Woodcock-Johnson Psychoeducational Battery-Revised (WJ-R; McGrew, Werder, & Woodcock, 1991). It is now incorporated into numerous cognitive tests, including the WJ III COG NU, the Woodcock Johnson Tests of Achievement, Third Edition Normative Update (WJ III ACH NU; McGrew et al., 2007) the Kaufman Test of Educational Achievement, Second Edition (KTEA-2; Kaufman & Kaufman, 2004b), the KABC-2 (Kaufman & Kaufman, 2004a), and the Stanford-Binet Intelligence Scale, Fifth Edition (SB-5; Roid, 2003). Continued debate on CHC theory also highlights divergent opinions about whether intelligence can be accurately represented by an overall factor, or whether it is more important to look at the individual narrow abilities as a pattern of cognitive strengths and weaknesses (Flanagan & Harrison, 2012).

Additional research on CHC theory has linked it to neuropsychology in different ways (Flanagan & Harrison, 2012). More research is needed in this area, particularly with children who have suffered brain injuries and may perform differently than the typically developing population. Specifically, McGrew (2009) has attempted to theoretically merge the two types of testing using a 16-domain CHC model titled the Multidimensional Cognitive Abilities framework.

The two broad domains of intelligence that relate most strongly to this research study are Gf and Gsm. Gf includes components of attention that are focused on a task to solve problems that are considered unfamiliar (Flanagan & Harrison, 2012). Consistent with the executive functioning literature, tasks are thought to tap into Gf when previous knowledge or strategies are not effective. This domain is generally thought to represent the specific skills of deductive or sequential reasoning, induction, and quantitative reasoning. Similarly, Gsm includes the narrow ability of working memory, which requires selective attention and inhibition to manipulate information in some way before producing it back in a transformed state. While there is some suggestion of overlap, the general consensus in cognitive research is that Gf and Gsm are separate domains (Flanagan & Harrison, 2012).

The Integrated SNP/CHC model. Miller (2013) has created an integrated school neuropsychology conceptual model that incorporates elements of CHC theory as well as current empirical research on the factor structure of neuropsychological constructs. The most recent version, the Integrated SNP/CHC model also includes prominent research from clinical neuropsychology, such as the Lurian (1973) model of brain functioning, cross-battery assessment procedures, and clinical approaches to neuropsychology (e.g., Baddeley and Hitch's (2000) working memory model). The Integrated SNP/CHC model functions as an overarching structure to organize neuropsychological assessment information for comprehensive evaluation of a wide variety of neurodevelopmental disorders. Further, it aids practitioners in connecting assessment results to appropriate interventions. This model is comprehensive and incorporates data from cognitive, achievement, neuropsychological, and social-emotional tests. It also utilizes the process approach and data obtained from behavioral rating scales. Most of the commonly used neuropsychological tests and subtests created for children have been categorized in the Integrated SNP/CHC model based on factor analysis of similar correlating groups. When this data was unavailable, tests were classified based upon the test author's definition of what the task measures (Miller, 2013).

The theoretical organization of the Integrated SNP/CHC model is arranged hierarchically, with a significant focus on the specific type of deficit an individual may have (Miller, 2013). First-order domains, such as memory and attention, are classified by type. The four types of domains in the Integrated SNP/CHC model are basic sensorimotor functions, facilitators/inhibitors, basic cognitive processes, and acquired knowledge. Basic cognitive processes include the domains of language, learning and memory, executive functions, and auditory processing. In his updated model, Miller (2013) has identified three cognitive facilitators: attention, working memory, and processing speed, that mediate and support the integration of sensorimotor information for higher-order functioning. All of these functions produce acquired knowledge and skills, such as academic ability. Cognitive domains can be further broken down into second- (e.g., subtypes of gross and fine motor skills) and third-order classifications (e.g., visual, auditory). The Integrated SNP/CHC model will be described at the end of this chapter as it relates specifically to this study.

The three-factor model using structural equation modeling (SEM). One of the more recent approaches for conceptualizing models of executive functioning is the use of SEM. A consistent model in the literature is the three-factor model by Miyake and Friedman (2012), which divides executive functions into three core components of attentional set-shifting, working memory (i.e., updating), and inhibition. Each of these constructs has been shown through factor analysis to be separate variables that also load together on one larger factor considered executive functioning. Set shifting is considered the ability to switch between different task demands or rules depending on the stimuli provided. Working memory requires an individual hold and manipulate information pertinent to the task in mental awareness long enough to complete the activity. Inhibition is the ability to suppress a dominant response for a less common or conditioned response. The three primary cognitive skills are thought to produce secondary behaviors of organization, planning, and self-monitoring (Friedman et al., 2006; Miyake & Friedman, 2012).

Clinical support for the three-factor model was first established with an adult sample (Miyake & Friedman, 2012; Miyake, Friedman, Emerson, Witzki, & Howerter, 2000). It has been reproduced in adults using a wide variety of measures (Friedman et al., 2006); however, evidence for this model with younger children and adolescents is varied (Xu et al., 2013). Some research indicates that younger children may have a collapsed single factor of inhibition and working memory (Wiebe et al., 2008). van der Ven et al.

(2013) also examined the factor structure of executive functioning with a sample of school-age children longitudinally over 18 months. They intentionally chose tests of inhibition, working memory, and shifting that involved verbal and visual stimuli and were popular tests, such as the Stroop test, card sorting, and digit span tasks. van der Ven and colleagues (2013) noted that once speed was accounted for, the factor structure that best fit typically developing school-age children was a two-factor model of updating/working memory and then a collapsed factor combining inhibition and set shifting. They renamed the second factor as conflict resolution instead of inhibition/shifting because the two skills work simultaneously together. The three-factor model is also explained in more detail at the end of this chapter, as it was included in this study.

Neuroanatomy

Research on the neuroanatomical structures and circuits implicated in executive functions is compiled from brain scans of both healthy individuals as well as those with diagnosed clinical disorders (Davis, 2011). Additional studies using participants with neurological damage shed light on the importance of integration and cooperation between brain systems regulating executive functions (Blair & Ursache, 2011). Researchers now understand that a one-to-one correspondence between brain structure and behavior is not fully representative of human cognition (Logue & Gould, 2013). Ethical guidelines limit the amount of experimental manipulation that is possible with human participants. Thus, much of the current literature on executive functioning in humans is inferred from animal research (Chudasama, 2011). Although there is an abundance of research hypothesizing brain regions and networks implicated in executive functions, there is still a large amount that is unknown (Flanagan & Harrison, 2012).

The importance of the frontal lobes in executive skills has been consistently documented through neuroimaging studies (Jurado & Rosselli, 2007). This brain region comprises one-third of the cortex, and is also known for being the most complicated area to study based on its diverse networks and functions (Blumenfeld, 2010). For instance, individuals may have frontal lobe damage and perform appropriately on standardized tests, while still struggling to function in real-world situations. Scientists divide the frontal lobes into the lateral, medial, and orbitofrontal surfaces. The lateral frontal cortex includes several smaller components, such as the primary motor cortex, the primary somatosensory cortex, as well as association areas, such as Broca's area (Blumenfeld, 2010).

At the most anterior point of the frontal lobes is the PFC (Blumenfeld, 2010). The PFC can be further split into the dlPFC, the OFC or vmPFC, and the ACC. These three areas are the primary regions researched for executive functions (Flanagan & Harrison, 2012). While the PFC is undoubtedly involved in executive tasks, recruitment from additional brain regions is thought to occur during executive tasks (Anderson, 2008). Other brain regions that mediate executive functioning include the parietal lobes, temporal lobes, brain stem, occipital lobes, limbic system, and subcortex, with different regions recruited depending on the task. Damage to any of these systems may impact executive functioning as communication systems in the brain are disrupted (Hale &

Fiorello, 2004). Therefore, executive functions and frontal lobe functions are not synonymous (Anderson, 2008).

Structural Differences

Several recent studies on structural differences related to performance on executive tasks have been documented in healthy children. Using a sample of preschool-aged children, abnormalities in the white matter tracks of the frontal lobe were connected with executive dysfunction as measured on psychological tests (Woodward et al., 2011). Another longitudinal study indicated that a shorter corpus callosum at 7 weeks of age for healthy infants was correlated with poorer performance on executive tasks at 4 years of age, specifically regarding inhibition and emotional control (Ghassabian et al., 2013). The researchers postulated that a shorter corpus callosum might be indicative of decreased overall brain white matter.

Additional studies have documented executive dysfunction in healthy participants related to executive functions during everyday events (EFEEs; Takeuchi et al., 2013). EFEEs are typically measured out of the laboratory and are engaged when an individual needs to problem solve outside his or her routine. In a non-clinical sample of adults, Takeuchi and colleagues (2013) found correlations between regional brain volume and self-reported scores on a survey of executive function. Results indicated that individuals with higher executive function also had lower regional gray matter volume and increased regional white matter volume in the OFC. The decreased gray matter volume may be associated with cortical thinning due to effective synaptic pruning. Children with higher ratings of executive functions also had more regional white matter volume in the right hippocampus, superior temporal gyrus, middle temporal sulcus, and right parahippocampal gyrus.

Hemispheric differences. Specific hemispheric and regional differences related to executive functioning have been observed, particularly for the frontal lobe (McCloskey et al., 2009). There is evidence that the left hemisphere of the frontal lobe is recruited more often for processing positive information and events, while the right is more likely to be activated during the processing of negative emotional stimuli. Moreover, anterior frontal lobe regions tend to be recruited for monitoring thoughts and posterior regions process cognition related to perception and action. Finally, the upper portion of the frontal lobes generally controls the relationship between perception and thinking while the lower portion is activated for things that are emotionally salient (McCloskey et al., 2009).

Additional research identifies hemispheric differences in processing information as well (Hale & Fiorello, 2004). One theory states that task requirements are related to hemisphere activation. The right hemisphere is now thought to be involved in multimodal representations and the left hemisphere is hypothesized to be more able to handle automatic tasks with an individual focus. The task difficulty level may be the deciding factor in whether the brain engages the right hemisphere for complex tasks.

The Prefrontal Cortex (PFC)

The PFC is still the main focus of neurological research on executive functioning (Blair & Ursache, 2011). Neuroanatomical differences for clinical groups and during specific tasks highlight the importance of this region for higher-order cognition. For example, brain injury in the PFC has been associated with significant difficulty completing the steps necessary to attain goals (Blumenfeld, 2010). Other research indicates that adults with lesions in the frontal regions of the brain are less able to switch between sets of information and display decreased levels of self-control (Goldberg, 2001). The importance of the PFC for executive functions has also been documented in young children. At an early age, infants display heighted blood flow in the PFC when participating in a complex searching task (Baird et al., 2002). Brain scans of the PFC in young children and adolescents support the notion that executive functions are developmental (Blair & Ursache, 2011). These scans indicate that the PFC does not mature at the same rate as the remaining brain cortex.

Neural Networks

Instead of seeing brain structures as important for executive functioning, many researchers now argue for a network view (Hale & Fiorello, 2004; Logue & Gould, 2013; Miller, 2013). There are five major networks that have been implicated in some form of higher-order thinking: the motor circuit, oculomotor circuit, dlPFC circuit, OFC circuit, and ACC circuit (Blumenfeld, 2010). All five circuits form feedback loops that excite neurons in the striatum, the globus pallidus, substrantia nigra, and thalamus until they connect back in the originating PFC region (Blumenfeld, 2010; Hale & Fiorello, 2004). At a more basic level, damage to the motor or oculomotor circuits affect executive skills by breaking the feedback obtained from these regions so that input is not received to guide appropriate attention or motor functioning.

The dorsolateral prefrontal cortex (dlPFC) network. The dlPFC is the most well researched neural circuit and is the most traditionally established circuit implicated in executive function or dysfunction (Hale & Fiorello, 2004). It is also frequently conceptualized as the control system of the brain (Miller, 2013). The dlPFC has been connected to regulation of attention, cognitive flexibility, initiation, monitoring, and planning. In animal studies, rhesus monkeys with damage to the dlPFC are less effective in their planning strategies (Chudasama, 2011). Thus, planning tasks are thought to recruit the dlPFC in conjunction with the hippocampus and cerebellum. Hemispheric differences may exist with this network as the right dlPFC appears to be more engaged during monitoring tasks and the left dlPFC is implicated in processing verbal stimuli for executive tasks (Jurado & Rosselli, 2007).

The orbital-frontal cortex (OFC) network. The OFC, which is often considered synonymous with the vmPFC, is another important neural circuit for executive functions. In general, when the OFC is damaged, individuals have significant impairment in inhibiting responses (Logue & Gould, 2013). Furthermore, lesions in the OFC of rats increased their perseverative responses when performing search tasks (Chudasama, 2011). Damage to the rodent vmPFC has also been associated with working memory deficits. Rats with vmPFC lesions could not hold and alternate between their previous food patterns and were unable to complete foraging tasks, such as the radial arm maze. Damage to the vmPFC in adults has been associated with poor decision-making, behavioral impulsivity, and an inability to adjust behavior in risk-taking tasks (Chudasama, 2011). It also creates a heighted number of perseverative responses on set shifting tasks, such as the WCST. Overall, the OFC circuit is primarily thought to regulate emotions and behavioral impulsivity (Hale & Fiorello, 2004). There is also some evidence that damage to this circuit is connected to attention difficulties as well as poor set-shifting (Logue & Gould, 2013).

The anterior cingulate cortex (ACC) network. The ACC circuit is an important network for working memory, attention, and task motivation (Hale & Fiorello, 2004). Neuroimaging research regarding executive skills also implicates the inferior frontal gyrus and ACC as necessary structures for monitoring, decision-making, and cognitive control (Menon & Uddin, 2010). The ACC circuit also connects to the limbic system in combination with limbic structures, including the amygdala and medial OFC (Blumenfeld, 2010). When adults have damage to the ACC circuit, they are less likely to follow directions without external motivation. Divided attention generally involves the ACC as well as the dlPFC (Chudasama, 2011).

The basal ganglia thalamocortical loop. Another important neural circuit for executive functions is the basal ganglia thalamocortical loop, which is thought to regulate executive attention and working memory (Brocki, Fan, & Fossella, 2008). This feedback loop also has a high concentration of the neurotransmitters dopamine and noradrenaline. In particular, dopaminergic input is thought to regulate several components of the loop as evidenced by the impact of dopamine agonists and antagonists on neuropsychological tasks, such as the go/no-go task. The basal ganglia thalamocortical loop involves the structures of the frontal cortex, such as the dlPFC and ACC; striatum; thalamus; basal ganglia; and the visual, motor, and auditory association areas. Additional support for this loop in attention and executive functions stems from neuroanatomical differences between typically developing children and children with ADHD, who have decreased cortical volume in the structures involved in the loop (Qiu et al., 2011; Rapoport et al., 2001).

***Combinations of networks*.** For many higher-order tasks, recruitment of multiple neural networks is required (Hale & Fiorello, 2004). For example, neuroimaging studies on children completing set-shifting tasks indicates that this one activity recruits the rostrodorsal PFC, left parietal lobe, OFC, dlPFC, ACC, and left inferior frontal gyrus (McCloskey et al., 2009). Similarly, tasks of concept generation likely recruit the left inferior frontal gyrus, bilateral frontal cortex, superior parietal lobes, dlPFC, and ACC. Researchers believe that sustained attention is thought to recruit the DLPFC, OFC, thalamus, and ACC.

Functional magnetic resonance imaging (fMRI) scans have also indicated combinations of networks involved in working memory tasks. Individuals using working memory to manipulate pieces of information while holding multiple task rules show activation in the right inferior PFC (Jurado & Rosselli, 2007). If this data needs to be updated or if the activity involves time, the superior frontal cortex is also activated. Other research suggests that the brain areas needed for working memory tasks include the dlPFC, anterior cingulate gyrus, left frontal cortex, anterior insula, frontal gyrus, cerebellum, and hippocampus (McCloskey et al., 2009).

Default Mode Network (DMN). Another way to conceptualize brain functioning related to executive functions is through Miller and Cohen's (2001) integrative theory of the DMN. Evidence for this theory comes from brain scans showing decreased activity in specific brain regions during challenging executive tests (Raichle et al., 2001). Areas of decreased activation during executive tasks have been collectively labeled the DMN. Brain regions implicated in the DMN are the vmPFC, medial temporal lobes, angular gyrus, and posterior cingulate cortex (PCC). These regions are primarily activated during resting states. In contrast, the CEN recruits the dlPFC and the posterior parietal cortex (PPC). The DMN and CEN are activated at opposing times. In order to participate in goal-directed or higher-order functions, the DMN must be shut down so that other brain regions can be engaged (Greicius, Krasnow, Reiss, & Menon, 2003). Specifically, the PCC and portions of the vmPFC are thought to be regions that must be suppressed for accurate higher-order cognition. The CEN is typically engaged during tasks measuring working memory and problem solving or decision-making (Menon & Uddin, 2010). Individuals with ADHD may have difficulty shutting down the DMN during executive tasks (Whitfield-Gabrieli & Ford, 2012).

Neuroanatomy and Clinical Disorders

A significant body of research has examined how neuroanatomical differences in children with ADHD may explain executive dysfunction in the brain (Brocki et al., 2008). Researchers theorize that atypical levels of the catecholamine neurotransmitters impact the frontal and subcortical circuits, specifically affecting performance of the PFC, basal ganglia, and cerebellum (Flanagan & Harrison, 2012). Children with ADHD have shown differential development of white matter tracks in this network (Brocki et al., 2008). They also commonly display decreased regional volume for gray and white matter in frontal brain areas. Frontal gray matter volume has been negatively correlated with attention. Moreover, frontal regions are commonly atypical in individuals with obsessive-compulsive disorder (OCD), anxiety, and depression.

Research using both human and animal participants implicates the PFC in various attentional processes in addition to traditional executive functions (Chudasama, 2011). Attention is often divided into three networks of orienting, alerting, and executive control (Brocki et al., 2008). The orienting network is thought to be primarily associated with the parietal and superior temporal lobes, which serve to focus attention toward a specific cue that has been detected. For instance, individuals with damage to the parietal lobe struggle to orient to new cues. The alerting network is comprised of the frontal, parietal, and thalamic regions that assist an individual in becoming aware of and maintaining focus on highly salient perceptual stimuli. This system has been connected to changes in norepinephrine in these brain regions. Finally, the executive control component of the neural model of attention is thought to activate numerous brain feedback loops that support working memory, inhibition, and set shifting, such as the basal ganglia thalamocortical loop described above (Brocki et al., 2008).

Neurochemistry

In children and adolescents neurochemical changes in the brain do not follow a simple path (Hunter & Sparrow, 2012). They are also not easily distinguishable from other changes and cannot be as clearly demarcated as in research with adult participants. Much of the research on brain chemistry related to executive function and dysfunction also involves the PFC; however, the development of the whole brain is important for understanding executive functions and damage or dysfunction to any part of it can have detrimental effects on higher-order cognition (Hunter & Sparrow, 2012). The PFC contains a high number of pyramidal cells, which are extremely sensitive to neurochemical changes (Hosenbocus & Chahal, 2012). An over or under stimulated environment will impact neurotransmitters as the brain will either release too much or not enough in the PFC. In particular, dopamine regulation is critical for a child's interpretation of reward, emotional regulation, and motivation. The medial PFC and OFC are the most commonly researched portions of the PFC and are highly dependent upon input from neurotransmitters, particularly dopamine, serotonin, norepinephrine, and acetylcholine (Logue & Gould, 2013).

Dopamine. One of the most widely studied neurotransmitter systems is the dopamine system (Logue & Gould, 2013). The two brain regions highly involved in executive functions, the medial PFC and OFC, have a large number of dopamine receptor sites including D1, D2, D3, and D4 receptors; dopamine functions in these regions are correlated with specific executive skills. In general, decreased amounts of dopamine in the medial PFC have been associated with impaired set shifting and attention, with the contrast being true for high amounts of dopamine. Other research highlights COMT as an important enzyme for dopamine depletion. When COMT was inhibited, higher amounts of dopamine in the medial PFC were connected with better performance on set shifting and attention tasks in humans. Dopamine does not appear to be an important neurotransmitter in the OFC for attention or set-shifting (Logue & Gould, 2013).

Rodent studies on attention using the 5-choice task highlight the importance of dopamine in attentional abilities as well as other executive functions (Chudasama, 2011). Dopamine D1 agonists decrease medial PFC function in rodents, while antagonists boost the attentional performance of rodents with previously established deficits. This pattern has alluded to the relationship between attentional resources and the baseline level of dopamine in the PFC for children. Finally, working memory is also implicated in dopaminergic pathways between the frontal cortex and basal ganglia (Banich, 2009). Neural connections that branch into the frontal cortex help to determine if data needs to be held in working memory or if it can be discarded for new information.

Norepinephrine. Another important neurotransmitter in executive functions is norepinephrine (Logue & Gould, 2013). The effect of norepinephrine on executive functions is more general than dopamine as norepinephrine equally impacts the medial PFC and OFC. Numerous receptors, such as α1, α2, and β-receptors, are all located on presynaptic noradrenergic axons, while α2 also exist on the postsynaptic neurons. Animal studies indicate that the α1 receptors are primarily active during stressful times. Norepinephrine transmission levels are thought to be involved in multiple executive functions including set shifting, attention, and cognitive flexibility. Attention and set shifting are inefficient for individuals with decreased levels of norepinephrine in the medial PFC. In animal studies, lesions in this region are associated with the same deficits in attention and set shifting. These deficits were improved by giving rodents atomoxetine, which stops the selective norepinephrine reuptake inhibitor from taking in norepinephrine and results in an excess of this neurotransmitter. Moreover, heightened amounts of norepinephrine in the OFC have been connected to heightened performance on response inhibition and reversal learning tasks (Logue & Gould, 2013).

Executive dysfunction in children with ADHD also involves the catecholamine system, predominantly the neurotransmitters norepinephrine and dopamine (Hosenbocus & Chahal, 2012). Differences in both dopamine and norepinephrine neurotransmission have been documented in individuals with ADHD, which are thought to impede regulation of the frontal-cortical circuit (Flanagan & Harrison, 2012). In animal studies, research with synthetically altered brain chemistry highlights the effect of catecholamine neurotransmission on working memory abilities (Chudasama, 2011). The ability to complete complex working memory tasks in both rats and primates depends on a very specific range of dopaminergic activity, with too many or too few dopamine D1 agonists or antagonists impacting performance. Differences also exist between delayed searching and self-ordered working memory tests (Chudasama, 2011). Alterations in dopamine in rodents affected the delayed task but not the self-ordered task. Heightened amounts of the neurotransmitter norepinephrine improved working memory performance, particularly when rodents are under high levels of stress.

Serotonin. Another important neurotransmitter for executive functions is serotonin (Logue & Gould, 2013). Three of the subtypes of serotonin are found in frontal brain regions: 5-HT1, 5-HT2, and 5-HT3. Serotonin levels in the OFC are connected with levels of inhibition and visual reversal learning, with high levels of serotonin connected with improved inhibition. Adults with depleted serotonin also scored lower on a go/no-go task. These findings are not associated with the medial PFC, where serotonin does not regulate attention or set shifting (Logue & Gould, 2013). Serotonin depletion in primates has also been connected to perseverative responding (Chudasama, 2011). These deficits have not been well established in human research.

The cholinergic system. The final system involved in executive functions in the medial PFC and OFC is the cholinergic system as each of these brain regions provide information to and receive input from the basal forebrain (Logue & Gould, 2013). The cholinergic system primarily utilizes the neurotransmitter acetylcholine. It is divided into muscarinic and nicotinic receptor types. The muscarinic receptors are thought to be involved in cognitive flexibility. More research has been conducted on the nicotinic receptors, which excite neurons by modulating neurotransmitter levels presynaptically. The cholinergic system is hypothesized to moderate the neurotransmitters that are necessary for executive functions in the PFC. These chemicals impact attention, set shifting, and response inhibition, particularly through nicotine. The cholinergic system works through complex chemical reactions that vary depending on the type of neurotransmitter. For instance, animal studies injecting nicotine have produced increased dopamine in the PFC. Increased nicotine is hypothesized to impact the amount of neuronal firing, which may increase dopamine in synapses of brain regions implicated in executive functions. Much less information is known about how the cholinergic system affects norepinephrine and it is not thought to affect or modulate serotonin activity (Logue & Gould, 2013).

Development of Executive Functions

Developmental Trends

The historical model of executive functions not developing until early adulthood, while still held by some, is no longer the dominant theory in the field (Hunter & Sparrow, 2012). The overall consensus in the neuropsychological literature suggests that executive functions develop over time, with more complex abilities coming online during adolescence and beyond. Three periods of particular importance are birth to age 2, 7 to 9 years, and 16 to 19 years (Banich, 2009). Other researchers argue that the pattern of development indicates that higher-order functions begin to peak between ages 11 and 17 and form a linear pattern up until age 22 (Taylor, Barker, Heavey, & McHale, 2012).

Development of executive functions may follow physical growth spurts, and is likely connected to similar neural growth in the prefrontal regions (Jurado & Rosselli, 2007). Brain plasticity is one factor hypothesized to explain developmental patterns in executive skills (Zelazo & Carlson, 2012). During sensitive periods when the brain is more plastic or malleable (e.g., preschool and adolescence), children are especially vulnerable to environmental experiences that may boost or deplete their executive functions, such as the introduction of a stimulating classroom environment in preschool. The development of physical abilities also influences executive functions. For instance, preschool children are not capable of performing specific motor tasks of inhibition, even though they are able to verbally explain the correct responses (Banich, 2009). Another important period for neural development is adolescence when young adults have the highest volume of gray matter in the PFC and experience numerous environmental changes (Zelazo & Carlson, 2012).

While certain trends exist in the literature, it is important to note that significant variability exists for both the timeline and rate of development for typically developing children (McCloskey et al., 2009). Hunter and Sparrow (2012) caution neuropsychologists to resist the desire to oversimplify executive function development and to avoid extending research with adult samples down to children. The overall pattern of development lasts for much longer than once thought, and spans from infancy into adulthood. Another way of conceptualizing this trend is to see children as having different executive resources that are available to them for specific age-related expectations (Hunter & Sparrow, 2012).

Infancy and preschool years. One of the more prominent executive skills developing in early infancy is attention (Hunter & Sparrow, 2012). Young children must learn to orient themselves to the world by learning what information is salient and how to use attention to elicit needs. They also experience greater behavioral control, self-regulation, and sustained attention. In late infancy and the toddler years, children further explore their world and obtain a heightened awareness of the effect of their actions and behavior (Hunter & Sparrow, 2012). They also explore different strategies to get their needs met. Basic cognitive flexibility by trying out actions or choices is established at this age, as well as emerging problem solving skills, self-monitoring, and working memory.

Early experiences transform these skills and allow children and adolescents to refine and practice them over time (Hunter & Sparrow, 2012). During this period, attention and memory are highly connected and are thought to serve as a base for later executive functions. Early experiences also create schemas or representations that will be later used for more complex cognitions. Moreover, infants display a strong interest in situations that are novel. As situations become more familiar and younger children interact with their environment, the child becomes more aware that he or she can influence the environment as well. This process sets the stage for early goal setting and problem solving (Hunter & Sparrow, 2012).

Research charting the developmental trajectory of executive functions highlights the preschool years as a crucial time for changes in brain functioning (Miller, Giesbrecht, et al., 2012). Many researchers argue that it is the most rapid period of executive skill development (Garon, Bryson, & Smith, 2008). In general, theorists agree that several executive skills are apparent by age 3 (Hunter & Sparrow, 2012). Around age 5, exposure to environmental situations conducive to learning and skill development contribute to synaptic pruning, which also heightens brain efficiency by reducing neural connections that are unnecessary (Dawson & Guare, 2010). Most research using preschool children confirms between one and four different facets of executive function in this population (Miller, Giesbrecht, et al., 2012).

The preschool period is increasingly seen as a time when working memory and inhibition begin to develop (Garon et al., 2008). A factor analysis of executive functions in preschool indicated that a two-factor structure comprised of working memory and inhibition best matched sample data of typically developing preschool children (Miller, Giesbrecht, et al., 2012). In a longitudinal study comparing prekindergarten, kindergarten, and school-aged children, executive functions improved in the areas of working memory, inhibition, and set shifting, with particular growth present between preschool and kindergarten (Röthlisberger et al., 2013). Growth curves for preschool children ages 3 to 5 suggest that performance increases between ages 3 and 4, but less variation is observed between ages 4 to 5 (Willoughby, Wirth, & Blair, 2012). Executive deficits in inhibition have also been documented (Garon et al., 2008). For example, young children who struggle with inhibitory functions tend to also perform poorly on a preschool version of the WCST.

Another commonly researched executive skill, set shifting, is thought to initially develop between the ages of 3 and 5; however, when task demands increase in complexity, younger children make higher numbers of errors than older children (Jurado & Rosselli, 2007). Children also vary by age on how many rules they are able to hold in their mind while completing a set-shifting activity. At younger ages, preschoolers can only hold one set and struggle with complicated rules. When they are older, children can handle a more complex set of rules and then can switch between them without making a high number of perseverative errors (Jurado & Rosselli, 2007).

Middle childhood. As a child progresses into middle childhood, additional executive functions are built upon existing structures and skills first established in infancy and preschool (Hunter & Sparrow, 2012). Neurological processes such as synaptic growth and pruning along with heightened myelination also contribute to more efficient executive systems as children age. Other regions, such as the hippocampus, aid the process as memory storage is expanded and attentional capacities for sustained attention increase (Hunter & Sparrow, 2012). All of these skills continue to be refined for some years.

Specific traits have been documented as beginning at different times during middle childhood. One of the earliest traits, executive attention, is generally established by age 7 (Brocki et al., 2008). Cognitive flexibility is thought to come online during the middle childhood years along with planning, metacognition, and some basic decision-making (Hunter & Sparrow, 2012). As young as age 3, children are able to explain their plans verbally in a simplistic manner and by age 7 they are generally capable of using problem solving to plan out a complex strategy (Jurado & Rosselli, 2007). Planning is now thought to come online during ages 5 to 8, when the largest growth of this skill is achieved. Even so, it is not generally considered fully developed until age 12 because younger children continue to make a higher number of errors on planning tasks (Jurado & Rosselli, 2007). Additionally, research places inhibition as an established skill by ages 10 to 12. Finally, working memory skills are thought to continue to mature during middle childhood, although they are not completely developed until early adulthood (Brocki et al., 2008).

Factor analytic research using school-aged children highlights that two or three factors of executive functions are typically found in this population (Zelazo & Müller, 2010). For instance, updating/working memory and set shifting were the best fit for children ages 9 to 12 after researchers accounted for additional non-executive factors, such as age, gender, and general cognitive ability (van der Sluis, de Jong, & van der Leij, 2007). When the age range is expanded from 7 to 14, the best model fit was a three-factor model of updating/working memory, set shifting, and inhibition (Wu et al., 2011). In order to parse out the impact of development on the factor structure of executive function, Xu and colleagues (2013) compared three different age groups on the same measures of executive function. A CFA supported previous research that a single-factor model was the best fit for the two groups of younger children (i.e., 7 to 9, and 10 to 12 years), but the structure expanded to include three factors for the oldest ages of 10 to 15 years (Xu et al., 2013). Importantly, all of these studies were completed using typically developing children.

During middle childhood executive dysfunction begins to become more apparent based upon the additional task demands in school and social environments (Hunter & Sparrow, 2012). The rate of development of executive skills is also associated with a child's emotional and academic functioning (Blair & Razza, 2007; Carlson, Mandell, & Williams, 2004). Early school experiences lay the foundation for self-control, behavioral motivation, and social learning, all of which are paramount for continuing to develop and refine executive functions. Additional academic and social demands in middle childhood increase the need for higher-order cognition and self-regulation (Hunter & Sparrow, 2012). Children in later elementary grades depend on increased working memory, organization, and inhibition skills to learn more complex information and practice problem solving. Students at this age are also expected to pay attention for longer periods of time in the classroom. Children with executive functioning deficits tend to struggle with perspective taking, problem solving, and inattention at school (Hunter & Sparrow, 2012).

Adolescence. Adolescence is another major developmental period resulting in alterations of executive functions due to important brain reorganization (Hunter & Sparrow, 2012). A significant growth of neurons in the gray matter, particularly in the frontal region of the brain, begins during ages 11 and 12 (Dawson & Guare, 2010). These neurons are cut down as a period of increased synaptic pruning occurs in adolescence. Brain development during this time is also characterized by changes in hormonal levels and chemical alterations. Based on these changes, adolescents typically display higher amounts of white matter and lower grey matter volume in brain scans (Brocki et al., 2008). Thus, adolescence is a significant opportunity to develop executive functions that will be used for the remainder of a child's life.

The period of adolescence is a time when individuals build and refine executive functions (Hunter & Sparrow, 2012). The aforementioned neurological changes are associated with a strengthening in working memory, attention, problem solving, and heightened speed of processing. Furthermore, this time is crucial for development of metacognition, which is a person's ability to think critically about how they think and how to appropriately make choices; however, adolescents also display decreased activation of brain regions thought to control inhibition, set shifting, and perspective taking (Barker, Andrade, Morton, Romanowski, & Bowles, 2010). Neurologic changes combined with increased social and emotional demands frequently lead to heightened vulnerability in adolescence. Individuals at this age tend to participate in increased levels of risk-taking behaviors. Young adults who display executive dysfunction during this developmental phase may be difficult to identify based on the heightened hormone levels and risky behavior that are common during adolescence (Barker et al., 2010).

Early and late adulthood. Trends in the developmental literature support the notion that age differences exist in adulthood regarding recruitment and efficiency of executive functions (Bouazzaoui et al., 2014). During early adulthood the brain continues to mature through additional structural enhancement and increased myelination of the PFC. Executive functions, such as working memory, cognitive set shifting, and problem solving are at their highest levels in early adulthood (Hunter & Sparrow, 2012). The disparity between those with strong executive skills and those with executive dysfunction is most apparent during young adulthood, particularly for those attending college.

Other differences exist between younger and older individuals. Adults at older ages are more intentional in performing executive tasks compared to younger adults who complete them with less effort (Hunter & Sparrow, 2012). Furthermore, older adults have shown an age related decline in various memory tasks, including working memory. Recent research indicates that older adults rely on working memory skills to complete tasks of executive functioning at a higher rate than young adults (Bouazzaoui et al., 2014). Executive functions have been consistently documented as one of the cognitive skills most impacted by aging, particularly for those with diseases, such as Alzheimer's disease (Banich, 2009). Some researchers have postulated that executive functions, primarily working memory and inhibition, are responsible for the overall cognitive decline that occurs during aging (Blair & Ursache, 2011). This theory is in contrast to research suggesting that decreased processing speed is a more influential component of cognitive decline.

Genetics

Current research overwhelmingly supports a strong genetic component for developing executive function or dysfunction. The level of heredity ranges from 40 to 80% depending on the specific study (Leve et al., 2013). One study observed that the executive functions of inhibiting, updating, and shifting when collapsed into one factor were 99% heritable in their sample with zero variability accounted for by environmental factors (Friedman et al., 2008). These functions were also represented by three individual factors with different genetic influences predicting them separately. The high heritability of executive functions has been confirmed using the WCST (Godinez, Friedman, Rhee, Miyake, & Hewitt, 2012). All types of errors were at least moderately heritable with almost no support for shared environmental variance. The vast majority of research on the genetic underpinnings of executive functions has involved twin studies or research on SNPs of specific genes (Friedman et al., 2008; Logue & Gould, 2013). Candidate gene studies have suggested that genetic polymorphisms in COMT and dopamine receptor genes impact executive functions, specifically in the PFC (Logue & Gould, 2013).

Catechol-O-methlytransferase (COMT). COMT is an enzyme that helps to regulate amounts of dopamine in the synapse by breaking down dopamine (Logue & Gould, 2013). Different alleles are connected with varying amounts of COMT: the Val allele is associated with increased COMT enzymes and lower dopamine levels, while the Met allele is connected with decreased levels of degradation and increased amounts of dopamine. Differential patterns of performance have been noted with individuals carrying the Met/Met type having better sustained attention and cognitive flexibility than the Val/Val type, which is thought to be connected to high levels of dopamine in the PFC (Logue & Gould, 2013). Gender effects were also documented in relation to COMT. Boys with at least one Met allele displayed increased performance on working memory tasks than those with the Val/Val allele. This pattern was not observed in girls.

Reelin gene. One of the most studied genes in animal and human studies is the Reelin gene (Baune et al., 2010). Various disruptions to this gene have been associated with increased vulnerability for common disorders, such as schizophrenia, depression, and ASD. In general, Reelin is a protein involved in neural migration and development. It is implicated in higher-order processes because of the high vulnerability of the medial PFC to alterations in Reelin. Specifically, two specific SNPs in the Reelin gene have been associated with heightened perseverative errors on a task measuring cognitive set shifting. Similarly, one SNP is connected with haplotypes for increased executive functions, thus supporting the theory that polymorphisms of the Reelin gene may be associated with increased or decreased vulnerability for executive dysfunction (Baune et al., 2010).

D4 dopamine receptor (DRD4). Polymorphisms of the D4 dopamine receptor (DRD4) have shown differential performance depending on genotype (Logue & Gould, 2013). In particular, having the 7-repeat variant is connected with decreased dopamine sensitivity and heightened cognitive flexibility. This is consistent with neurologic findings demonstrating that the D4 dopamine receptor site is actually an antagonist to dopamine production. Other caudate gene studies have focused on the role of dopamine associated with executive skills and diagnosis of ADHD in children (Shaw et al., 2007). The 7-repeat allele of the DRD4 gene located on chromosome 11 has been connected to thinning of the cortex. These brain regions are thought to be associated with attention. Importantly, cortical thinning was most apparent during early childhood years, but improved somewhat during adolescence.

DAT1. Rueda and colleagues (2005) have documented that executive attention network shows differential performance based upon specific genetic patterns. They found that children with a long allele of the DAT1 gene for dopamine demonstrated significantly fewer problems with resolving conflict during executive training compared to those with one long and one short allele. Attention training improved performance for children with two long alleles and activation in the ACC was decreased after training, implying more efficient processing (Rueda et al., 2005).

Twin studies. One limitation to genetic studies is that they frequently involve twin pairs and have not parsed out how environmental factors influence children being raised with their biological parents (Leve et al., 2013). Even more lacking is research with children ages birth through 2. To counter these limitations, Leve and colleagues (2013) conducted a study using a full adoption design. This type of research design allows for comparisons of twin children in adoptive homes. Information is gathered from the adoptive parents, adoptive child, and biological parents. This study calls into question the influence of prenatal risk, as they found that the association between risk and executive dysfunction was removed once genetic factors were included. Specifically, a connection between the biological mother's verbal IQ and effortful attention were documented. No associations were found for the young children's delay of gratification, suggesting a stronger genetic link to cognitive executive functions versus emotional control (Leve et al., 2013).

Temperament

Several components of executive function have been connected to temperament characteristics in young children (Hunter & Sparrow, 2012). Researchers have examined how specific temperament and traits are associated with cognitive abilities, such as attention and executive skills. These traits influence how a child interacts with his or her environment, which is thought to alter development of some executive skills. For instance, children in preschool who display high amounts of anxiety and shyness are less likely to engage in play with others. This pattern influences behavioral regulation and social interactions.

Other research has indicated that personality characteristics may be associated with differential performance on executive tasks (Murdock, Oddi, & Bridgett, 2013). Using the Big 5 personality traits, Murdock and colleagues (2013) compared personality with performance on inhibition, updating, and shifting tasks. They noted that each of the three executive skills were predictive of certain personality traits. For instance, updating or working memory was connected to neuroticism, while working memory and flexibility predicted openness. Those with high levels of openness may also display more flexibility in life. Similarly, Burton and colleagues (2010) found that differential performance on a CPT was related to specific personality traits. Better vigilance was connected with increased neuroticism, and decreased extraversion and agreeableness. Lower ratings of conscientiousness were also linked to increased levels of risk taking on the CPT. While most personality findings are with adults, some research with children has explored temperament and personality at younger ages (Stifter, Cipriano, Conway, & Kelleher, 2009). For instance, based on ratings of approach or inhibition in a strange situation simulation, children rated at age 2 as inhibited and with low cognitive executive functions also demonstrated high emotionality.

Environmental Differences

Evidence for environmental influence on executive function skills begins with characteristics of mothers (Hughes et al., 2012). Maternal depression during pregnancy is predictive of executive function deficits in children at 6 years of age. Specifically, levels of depression in biological mothers have been connected to a child's ability to inhibit responses and decreased levels of working memory. Strength of depressive symptoms also influences a child, with more mild depressive symptoms corresponding with less severe deficits on tasks (Hughes et al., 2012).

Teratogens and environmental toxins. Numerous environmental toxins during pregnancy have been associated with executive deficits in children (Riccio et al., 2010). Moreover, use of recreational substances such as alcohol disrupts brain circuitry and chemistry. Children with fetal alcohol exposure are more likely to have microcephaly (i.e., small head), decreased volume in the frontal lobe, loss of both gray and white matter volume in the cortex, and cerebellar abnormalities. Mothers who use illicit drugs, including cocaine, amphetamine, and marijuana, are also more likely to have children who display similar neurologic dysfunction. High amounts of alcohol use have been associated with problems with attention and emotional regulation, while illicit drugs impact a child's attention, impulsivity, reasoning skills, and working memory (Riccio et al., 2010). Some variation is observed depending on type of drug and period of use during the pregnancy; a full review of these effects is beyond the scope of this chapter.

Children who are exposed to environmental toxins show differences in brain development compared to healthy controls (Dawson & Guare, 2010). For example, research on lead, manganese, and mercury exposure at early ages indicates that these children are more likely to demonstrate executive dysfunction (Riccio et al., 2010). Pesticides are thought to increase amounts of acetylcholine in the brain, which heightens activation of the cholinergic system. This chemical imbalance has been connected to attention problems, difficulty with inhibition, and further developmental issues in children.

Low birth weight. In early development, research suggests that executive function differences related to low birth weight and preterm delivery exist. These children demonstrate poorer performance on tasks measuring working memory, set shifting, and inhibition (Ritter, Nelle, Perrig, Steinlin, & Everts, 2013). Children born with low birth weight also appear to struggle with verbal working memory tasks, organization, attention, planning, and reasoning (Riccio et al., 2010). Parents may experience heightened stress as they navigate difficulties related to low birth weight in their children, which then creates a cyclical problem for healthy development. Different perspectives can be found in the literature on whether children born preterm or with low birth weight are able to make up the deficit in cognitive functions as they age, or if these deficits remain throughout the life span (Ritter et al., 2013). A prospective study supported the hypothesis that children born preterm or with very low birth weight demonstrated a delay in executive functions, which eventually evened out as they aged; however, this sample included children from affluent families with no additional neurodevelopmental impairments. There is also some support that certain environmental influences and cognitive interventions are able to reduce the delay in executive skills demonstrated at a very young age (Ritter et al., 2013).

Caregiving and parenting styles. Maternal and paternal caregiving and nurturance are also frequently researched as environmental influences on the production of functional executive skills. Parenting styles highly correlated with attention and executive function include responsive, nurturing, and attentive (Bernier et al., 2012; Blair et al., 2011). Higher scores on typical parenting measures were associated with increased levels of executive function as measured on traditional neuropsychological tests of inhibition, set shifting, and working memory, at both 36 and 60 months of age (Blair, Raver, & Berry, 2014). Preliminary research suggests that adults who are not parents may also be able to influence a child's executive functioning abilities through school and community interventions (Raver et al., 2011).

Another common environmental factor that appears to affect executive function is parent education levels (Jurado & Rosselli, 2007). Specifically, parents with more than 5 years of post-high school education tended to have children with higher levels of executive functioning scores than those without the additional training (Ardila, Rosselli, Matute, & Guajardo, 2005). The effect of parenting on executive skills is also likely connected to increased amounts of language exposure; research indicates that households with more language and communication support higher-order functions (Hunter & Sparrow, 2012). Additionally, language is associated with internalized speech, and can help develop additional skills in working memory, behavioral inhibition, and problem solving. Developmental research highlights important actions that parents model for children to assist in developing executive functions. For example, parents have the opportunity to display how to respond in appropriate ways to problems and to model useful decision-making strategies (Hunter & Sparrow, 2012).

Attachment. A major environmental factor related to development of executive skills is attachment (Hunter & Sparrow, 2012). Infants and young children who feel more securely attached are more comfortable exploring their environment and are better able to practice attention, memory, and problem solving skills by interacting with the world in an exploratory manner. These children also obtain a more expansive set of knowledge that can be used to create additional meaning. These interactions are thought to support brain connectivity through increased myelination and coordination between brain circuits. In contrast, infants with poor attachment, particularly insecure-resistant attachment, demonstrate increased cortisol levels when faced with the strange situation procedure (SSP; Luijk et al., 2010). Specific genetic variants are more vulnerable when combined with environmental influences in the SSP as young children with more T-alleles of the genotypes of the FKBP5 SNP have heightened reactivity. This pattern makes it more difficult to shut off the negative feedback loop during stressful activity, which often reduces homeostasis (Luijk et al., 2010).

Poverty and socioeconomic status (SES). Another commonly studied predictor of executive dysfunction is SES and poverty (Rhoades et al., 2011). Research supports the notion that poverty is a significant, if not the most important, environmental predictor of executive dysfunction. For instance, children at older ages and of more affluence have demonstrated higher performance on both alerting and set shifting and inhibition (Mezzacappa, 2004). Typically developing children who grow up in low SES (a combined indicator of household income and parent education) homes also have more cognitive deficits in working memory and cognitive control (Farah et al., 2006). Cognitive control is associated with the ACC and was measured using tasks requiring monitoring for conflict and switching attention.

Functional MRI studies with children from low SES backgrounds suggest that different neural systems are affected, such as those associated with working memory and executive functions (Raizada & Kishiyama, 2010). Researchers have hypothesized that these deficits may be related to increased activation of the hypothalamic-pituitary-adrenal (HPA) axis, which is connected to heightened cortisol. Increases in cortisol have been associated with toxic effects on the dlPFC and medial PFC circuits. Blair and colleagues (2011) noted that children who grew up in low SES households had higher amounts of salivary cortisol and heightened ratings of negative parenting compared to control children not living in poverty. Children from low SES backgrounds also had decreased performance on executive measures at several points over time (i.e., working memory, inhibition, set shifting), which was mediated by positive parenting. This pattern was more severe for children from African American families, who had higher levels of cortisol and significantly lower ratings of executive functions (Blair et al., 2011).

Additional factors connected to poverty and healthy development include household chaos level and parent self-regulation (Deater-Deckard, Chen, Wang, & Bell, 2012). These aspects of development are important because they contribute to predictability and structure. Living in chaos has been associated with decreased social, emotional, and cognitive functioning (Wachs & Evans, 2009). More specifically, an interaction between SES and household chaos was predictive of lower levels of maternal executive function, a pattern that is hypothesized to impact childhood levels of executive function or dysfunction as well.

Sleep. Another environmental difference thought to impact executive skills is amount of sleep (Dawson & Guare, 2010). Children who are considered sleep deprived are thought to display deficits in initiation, sustained attention, planning, and completing steps to achieve goals. Sleep deprivation and disruption have been associated with a number of neurocognitive and neurologic detriments, such as decreased cell proliferation and neurogenesis, particularly in the hippocampus (Meerlo, Mistlberger, Jacobs, Heller, & McGinty, 2008). This pattern may be explained by decreased amounts of brain-derived neurotropic factor (BDNF) or insulin-like growth factor (INGF) recorded in rats with sleep disruption. Atypical functioning of the hippocampus in adults has been documented and is used as a hypothesis for memory problems in sleep deprived individuals (Meerlo et al., 2008). Sleep deprivation also increases allostatic load, which then decreases cognitive functioning (McEwen, 2006). A meta-analysis of adult sleep studies indicated that sleep deprivation even in short increments has a significant impact on most cognitive domains, including complex attention and working memory (Lim & Dinges, 2010). Vigilance and sustained attention had the largest effect sizes, while reasoning was not impacted.

Epigenetics. Research on epigenetics also highlights a continual interaction between environmental influences and genetic expression at the deoxyribonucleic acid (DNA) level (Champagne, 2010). Early adversity is a primary research area that illustrates the epigenetic relationship of a gene-environment interaction. Environmental experiences through processes such as methylation or acetylation of the DNA histone tail alter genetic expression for an individual. DNA is typically densely packed around proteins, or histones, to form the chromatin of a cell. The histone tail branches out of the core and wraps around the DNA. When these structures are tightly packed, the gene is usually inactive or turned off; however, an addition or removal of a protein can alter the structure of the cell through the processes of acetylation, methylation, or phosphorylation. For instance, in methylation a methyl group is added onto cytosine at the fifth carbon, which typically silences the targeted gene (Champagne, 2010). The result is a different structure and expression of the gene without its basic components changing (Mann & Haghighi, 2010). These changes have been documented in offspring without the environmental exposure experienced. Early adversity, such as child abuse, has been associated with increased methylation of specific genes, such as the glucocorticoid receptor (GR) gene involved in regulation of the HPA axis.

Maternal stress has been connected to heightened reactivity of the HPA axis in children, which is genetically passed down through offspring (Champagne, 2010). Maternal separation in rodent models highlights that a lack of caregiving is associated with offspring with heightened HPA-axis responses, decreased GRs in the hippocampus, and lower levels of BDNF. In contrast, rodents that have been exposed to nurturing environments displayed heightened amounts of dendritic branching, neurogenesis or cell production, a more responsive HPA axis, and improved cognition (Champagne, 2010).

Other gene-environment interactions have been connected specifically to cognitive and executive functions (Wersching et al., 2011). The SNP of the KIBRA gene has been associated with decreased flexibility in thinking and episodic memory. Adults have also shown poorer performance on the WCST when they carry the T-allele of the KIBRA gene. In elderly individuals a combination of the specific lifestyle factor of arterial hypertension showed an interaction between T-allele individuals on the KIBRA gene and executive dysfunction, but they did not find any effect of the T-allele without hypertension. This interaction was moderated by gender; females had the effect instead of males. Similarly, lower pulse pressure in adults with the IDE G allele was associated with improved cognitive and executive performance in comparison to a group with the AA allele (McFall et al., 2014).

Another gene-environment interaction has been documented with the dopamine receptor genes of DRD4 and D2 dopamine receptor (DRD2) genotypes involved in frontalsubcortical circuits (Ariza et al., 2012). Individuals with the A1 allele of the DRD2 polymorphism demonstrated significantly poorer performance on executive tasks, such as working memory, set shifting, and cognitive flexibility; however, an interaction effect existed documenting that obese adults with the A1 allele were at increased vulnerability for executive dysfunction compared to those without the allele. The same interaction was observed for the 7R allele of the DRD4 polymorphism with obese carriers performing more poorly (Ariza et al., 2012). Although research on these epigenetic mechanisms typically involves adult or animal samples, they infer that increased stress combined with genetic vulnerabilities likely have a unique impact on a child's higher-order cognition. Further research is warranted to better understand what environmental components may impact executive functioning for specific genetic predispositions (Wersching et al., 2011).

Stress. Stress is a factor that is frequently associated with both childhood poverty and decreased cognitive functions. Research on the influence of stress on executive functions indicates that the HPA axis plays a significant role in modulating environmental stress (Blumenfeld, 2010). While high levels of cortisol may be detrimental over longer periods of time, brief bursts of cortisol related to mild stress may be connected with improved executive functions in a preschool setting (Blair, Granger, & Razza, 2005). In small amounts, heightened activation of the HPA axis helps an individual recruit necessary systems and provides increased awareness and monitoring. At appropriate levels, a negative feedback loop is then able to downregulate the system back to baseline levels.

Chronic stress has also been associated with cell death in the hippocampus and prefrontal cortex, which is thought to negatively impact selective attention, memory, and executive functions (McEwen, 2006). High levels of stress have been connected to decreased dendritic branches in the medial PFC and increased branching in the amygdala and OFC, which enhances emotional responses. Functional MRI scans have documented decreased volume in the PFC is associated with heightened stress and neurologic changes. Childhood poverty has also been connected to decreased working memory performance in adulthood, with increased levels of childhood poverty associated with more severe deficits (Evans et al., 2009). Children living in low SES display heightened activation of the HPA axis, and higher levels of HPA activity have been connected with longer time spent in poverty (Evans & Kim, 2007). These children also show reduced electroencephalography (EEG) activity in prefrontal regions concurrent with significantly poorer performance on digit span and verbal fluency (Kishiyama, Boyce, Jimenez, Perry, & Knight, 2008).

In one study, Gathmann and colleagues (2014) increased an individual's level of stress, as measured through cortisol levels. The researchers noted that when individuals were required to recruit executive skills in decision making while concurrently using their working memory capacity, they also had increased activation of the anterior PFC. Importantly, when cortisol levels were highest, those individuals displayed decreased amounts of activation in this brain region. These findings lend support to the notion that the anterior PFC is engaged during serial processing and is potentially influenced by increased cognitive load (Gathmann et al., 2014).

Gender and Ethnic Differences

Overall, findings in the literature regarding gender differences on tasks of executive functioning are limited and inconclusive. While evidence is still scarce, there is some preliminary support for girls having stronger executive skills than boys (Else-Quest, Hyde, Goldsmith, & Van Hulle, 2006). Of the research on gender differences, most of the samples involve children with ADHD (Seidman et al., 2005). Seidman and colleagues (2005) supported the notion that children with ADHD perform more poorly on traditional executive function tasks, such as the WCST and Stroop test, but did not find notable gender differences. There was no interaction effect for gender on any of their 17 neuropsychological scores with the exception of Rey-Osterrieth Complex Figure Test (ROCFT; Osterrieth, 1944; Rey, 1941), where boys with ADHD performed significantly lower than normal controls. The ROCFT requires that individuals initiate, plan, and then complete the steps to create complex figure drawings (Seidman et al., 2005). For adults on a CPT, gender effects were noted with females responding more carefully and more slowly than males (Burton et al., 2010). Additional research on age and gender effects on the Behavior Rating Inventory of Executive Functions (BRIEF; Gioia, Isquith, Retzlaff, & Epsy, 2002) indicates that problems are rated more severely in younger children and boys consistently receive higher ratings of executive dysfunction (Langberg, Dvorsky, & Evans, 2013).

In adults, ethnic differences on neuropsychological measures have also yielded inconsistent findings. Proctor and Zhang (2008) compared behavioral rating scores on the Behavioral Assessment of Dysecutive Syndrome (BADS; Wilson, Alderman, Burgess, Emslie, & Evans, 1996) and WCST scores for healthy participants identifying as African American, European American, and Latino/a American. The researchers did not find differential performance between ethnicities or any gender effects on the WCST. Proctor and Zhang did indicate that one subtest had significant performance differences for ethnicity on the BADS, with European Americans scoring higher than the other ethnic groups, a finding the researchers attributed to cultural bias on the BADS. In children with ADHD ages 3 to 6, no gender differences were noted on tasks of inhibition, working memory, or set shifting (Martel, 2013); however, significant ethnic differences were found with African American children receiving higher behavioral ratings concurrent with decreased set shifting scores. These differences were accounted for by family income, which was highly predictive of decreased executive functions.

An important weakness of pediatric neuropsychological assessments is the lack of research on ethnic and cultural differences compared to the amount conducted with adult and elderly populations (Byrd, Arentoft, Scheiner, Westerveld, & Baron, 2008). In adult samples, significant differences for ethnic groups exist on most neuropsychological domains, which is evident for healthy samples and those with neurological damage. A meta-analysis of neuropsychological research for cultural considerations and assessment with children found a dearth of research outside of intelligence tests. The few research studies that cover culture and ethnic differences in childhood appear to focus on younger children ages 3 to 7 and on those that are considered healthy and without dysfunction. This body of research concentrates predominantly on children identifying as African American, Hispanic, or Caucasian, with little to no research on Asian or Native American populations (Byrd et al., 2008). Overall, research on ethnic differences has demonstrated inconsistent results, which may be explained by moderating variables such as SES, cultural bias in testing materials, methodological differences, or developmental differences based on age. Additional research on neuropsychological measures with children from diverse backgrounds is warranted.

Impact on Academic Success

Numerous studies have confirmed the importance of executive skills on academic achievement in the classroom. Overall, executive functions are seen as an important predictor for future success in most academic areas (Brock et al., 2009; Röthlisberger et al., 2013). They are thought to contribute to academic achievement in reading and mathematics from elementary to high school. In contrast, children with executive dysfunction may not have the skills required to perform effectively in all areas at school (McCloskey et al., 2009). These children are also more likely to experience behavioral and emotional difficulties, which may distract from time spent learning or effectiveness of teaching. The number of areas in which they have executive deficits coupled with the level of severity will likely determine how well children can reach production expectations in school. This pattern may be worse for students with executive deficits and no concurrent formal diagnosis. At earlier grades, executive dysfunction frequently impacts basic reading, writing, and mathematics abilities as well as behavioral problems. In older grades, such as middle and high school, executive deficits likely add to problems with organization, finishing or turning in work, and test taking or study habits (McCloskey et al., 2009).

In one study, school achievement in young children was predicted using a longitudinal sample of children between prekindergarten and second grade (Röthlisberger et al., 2013). Röthlisberger and colleagues (2013) found that children with higher executive function scores performed better in the academic areas of math, reading, and spelling. When IQ, SES, and vocabulary were accounted for, results still indicated that executive function made up a significant amount of the variance, particularly for math performance. Children with learning disabilities also tend to perform more poorly on assessments of executive skills (van der Ven et al., 2013). Bull, Epsy, and Wiebe (2008) documented that executive functions are predictive of math skills in elementary aged children. Similarly, Blair and Razza (2007) also suggested that executive functions are highly implicated in the development of reading skills, especially phonological awareness and letter knowledge. Executive deficits may be greatly improved by learning environments that are structured appropriately, individual interventions, and teachers with effective strategies for learning (McCloskey et al., 2009).

Additional research has examined the role of executive functions in predicting school readiness and future success in academic areas (Shaul & Schwartz, 2014). The executive functions of inhibition, working memory, and flexibility were predictive of pre-academic abilities in younger children before age 5, particularly orthographic knowledge. This pattern was documented even after accounting for other cognitive skills, such as short-term memory. The connection to written language skills may be related to the complex nature of written language, and the integration of various academic skills required. The influence of early executive skills is thought to increase as a child comes of age for school, with stronger correlations between executive functions and academic skills during this period (Shaul & Schwartz, 2014).

In addition to the academic realm, high executive functions have also been connected to a diverse number of performance indicators (Blair & Razza, 2007; Carlson et al., 2004). Most patterns are associated with increased difficulty functioning, particularly an ability to live independently, for those with more severe executive dysfunctions after brain injury (Banich, 2009). Further, executive dysfunction has been connected to lower energy, poor initiative for work completion, and deficits in social relationships (Anderson, 2008). Often, those with severe deficits in executive functions act inappropriately and have a difficult time maintaining a social support system. Executive functions are required for a number of everyday tasks, including appropriate social behavior, smart decision-making, goal planning, and adjustment to events that are unplanned (Flanagan & Harrison, 2012).

Relationship with IQ and Other Cognitive Factors

Concurrent with the disagreement over what constitutes executive function, there is also a lack of consensus regarding how executive function skills fit with other cognitive components that comprise intelligence (Davis, 2011). McCloskey and colleagues (2009) note that the relationship between IQ and executive functioning is dependent on how intelligence is conceptualized, with more broad definitions including many facets traditionally considered executive functions. Furthermore, the ability to theoretically include executive functions in a definition of intelligence is different than actually observing them during standardized testing, which typically measures executive functions as they relate to problem solving or reasoning skills. Thus, even though executive skills are undoubtedly recruited during cognitive testing, intelligence tests do not generally try to measure executive functions explicitly (McCloskey et al., 2009).

On one side, substantial evidence suggests there is a strong relationship between executive functions and factors traditionally assessed with intelligence tests (Blair & Razza, 2007). Of all the domains, working memory is thought to share the highest amount of variance with IQ (Hunter & Sparrow, 2012). Adolescents with deficits in intelligence often display deficits in working memory (Ackerman, Beier, & Boyle, 2005). Friedman and colleagues (2006) found that working memory, set shifting, and inhibition were all related to intelligence as evidenced by shared variance regardless of whether IQ was represented by an overall IQ score, Gf, or Gc; however, Gc and Gf were still separate factors from executive functions, indicating that they are comprised of other abilities not commonly represented in executive tasks (Friedman et al., 2006).

Factor analysis also provides support for a strong relationship between other cognitive abilities and executive functioning (Floyd, Bergeron, Hamilton, & Parra, 2010). Specifically, most of the subtests on the D-KEFS have been found to be highly correlated with factors on the WJ III COG NU, indicating that other cognitive abilities outside of traditional executive functions may be required for these tasks. Importantly, Floyd and colleagues (2010) found that Sorting, Twenty Questions, and Word Context on the D-KEFS loaded on Gc instead of Gf, suggesting that they depend on previous knowledge compared to novel situations. Overall, Floyd et al. state that tests of executive functions and CHC theory generally measure the same cognitive skills. They hypothesize that executive functions may actually be the overall G factor typically represented by an overall or composite IQ score.

In addition to the apparent relationship between executive functions and intelligence, there is also evidence that they are two separate factors. Comparisons on neuropsychological and cognitive tests indicate that children with frontal lobe damage display significant executive deficits while still scoring in the average range of IQ scores (Friedman et al., 2006). One explanation for differences in these scores is that children with brain damage may have impairment of Gf abilities, while information obtained before the incident (e.g., Gc) is unaffected. Success on IQ tests may rely heavily on Gc. Children with frontal lobe damage have been shown to perform poorly on Gf tasks without high Gc loading and tests of Gc are usually excluded from executive functioning batteries in clinical research (Friedman et al., 2006).

Dysfunction in Clinical Populations

Executive dysfunction is frequently cited as a major component of a wide range of mental and physical health issues (Banich, 2009; Hunter & Sparrow, 2012; Willcutt et al., 2005). Another controversy in the field regarding executive dysfunction regards its place as a separate clinical disorder (Hosenbocus & Chahal, 2012). Patterns of executive dysfunction have been documented in several Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition (DSM-5; American Psychiatric Association, 2013) diagnoses, such as ADHD, ASD, TBI, and several mood disorders; however, more and more children are being identified with deficits in executive skills who do not meet any of the other disorder criteria. These children are thought to have some difficulties but may not receive interventions or accommodations (Hosenbocus & Chahal, 2012). Some practitioners label children with executive dysfunction that do not meet other criteria as having dysexecutive syndrome. There are currently no specific criteria for this diagnosis and having this disorder may confuse diagnosis because most other disorders have associated deficits in executive skills (McCloskey et al., 2009). As it is important to better understand how executive deficits manifest themselves in clinical disorders, this study used a mixed-clinical group as its sample.

Attention-Deficit/Hyperactivity Disorder (ADHD)

One of the most common disorders associated with executive dysfunction is ADHD (Dawson & Guare, 2010; McCloskey et al., 2009). Even though not specifically included in the diagnostic criteria of the DSM-5, executive dysfunction is frequently cited as a characteristic of children with ADHD (Hosenbocus & Chahal, 2012). Measures of neuropsychological constructs such as attention, memory, and executive functioning suggest that corresponding deficits are common in children with ADHD (Arán-Filippeti & Krumm, 2013; Willcutt et al., 2005). Specifically, children with ADHD exhibit impairment in inhibitory control, particularly impulsivity, executive attention or vigilance, hypermotoric behavior, decreased fluid reasoning, long-term memory, and working memory (Willcutt et al., 2005); however, findings for fluid reasoning and working memory are inconsistent and depend on the specific research study. Executive deficits in children with ADHD are thought to persist into adulthood (Miller, Ho, & Hinshaw, 2012).

There is preliminary support in the literature for different patterns of executive skill deficits depending on the type of ADHD diagnosis (Dawson & Guare, 2010). Some research indicates that children with ADHD combined type are more likely to have executive deficits compared to those with inattentive type (Flanagan & Harrison, 2012). For instance, parents and teachers rated children with ADHD combined type higher on the Emotional Control, Monitor, and Inhibit scales of the BRIEF. Other researchers argue that these results are inconsistently replicated and may reflect developmental differences or biases in reporting.

Neurological research using children with ADHD highlights brain differences commonly associated with executive deficits (Brocki et al., 2008). For example, children with ADHD display more diffuse activation of brain areas than their peers, with more regions being activated by executive tasks. They also exhibit different patterns of activation of frontal brain regions during neuropsychological tasks. Shaw et al. (2007) noted that children with previously diagnosed ADHD had decreased cortical thickness, particularly in the lateral PFC. They hypothesized that decreased growth in this region may explain attention, inhibition, and working memory difficulties found in children with ADHD. Additional fMRI studies have illustrated that children with ADHD exhibit decreased activity in the cerebellum, ACC, and PFC (Durston & Konrad, 2007). Behavioral disinhibition typically observed in ADHD has also been hypothesized to be a result of less connectivity between the limbic system and the OFC (Plessen et al., 2006). These patterns suggest that neural connections are less efficient and are atypically developed in children with ADHD compared to those without the disorder.

Identifying executive dysfunction in children with ADHD is complicated by its developmental nature (Brocki et al., 2008). While diagnosis is based on criteria that assume the symptoms of ADHD do not change, research in the developmental psychology field indicates that children with ADHD look different at various ages, particularly regarding executive deficits. It is important to note that even though children with ADHD frequently display executive dysfunction, common assessment measures do not always demonstrate sensitive clinical discrimination between clinical groups (Flanagan & Harrison, 2012).

Autism Spectrum Disorder (ASD)

Numerous studies have documented executive dysfunction in children with ASD. While not all individuals with ASD have deficits in this area, there is a general association between an increased number of ASD symptoms and executive dysfunction (Han et al., 2013). Children with ASD who are considered low performing also demonstrate increased problems with executive tasks (Yerys et al., 2009). The most impaired areas of executive function appear to be planning and cognitive flexibility (Jurado & Rosselli, 2007). Other research indicates that children with ASD also have specific weaknesses in metacognition, working memory, and initiation (Dawson & Guare, 2010). These executive deficits may help explain lower levels of adaptive functioning documented in this population (Gilotty, Kenworthy, Sirian, Black, & Wagner, 2002). Finally, deficits in inhibition and spatial reasoning are less likely to be documented in children with ASD (Jurado & Rosselli, 2007; Semrud-Clikeman, Fine, & Bledsoe, 2014).

The presentation of cognitive flexibility deficits in children with ASD is different than other child populations with executive dysfunction. Research using the WCST with individuals with ASD illustrates that typically developing adults and adolescents appear to benefit significantly more from positive and negative feedback during the task than individuals on the autism spectrum (Broadbent & Stokes, 2013). Interestingly, those with ASD improved in performance on a condition without negative feedback compared to one with negative feedback on incorrect sorting. No differences were present for positive feedback. This pattern supports the notion that individuals with ASD are able to set shift, but do not use feedback in the same manner as typically developing peers. Thus, social norms are likely an influencing factor in neuropsychological performance and should be considered when giving executive tasks to children and adolescents on the autism spectrum (Broadbent & Stokes, 2013).

Children with ASD and executive dysfunction often experience increased difficulty with executive tasks as they age (Kenworthy, Yerys, Anthony, & Wallace, 2008). Rosenthal and colleagues (2013) supported this notion by documenting that children with ASD displayed even greater age-related differences as measured on the BRIEF. Cognitive flexibility, shifting, working memory, initiation, and organization were considered impaired in both younger and older children; however, parents endorsed more severe concerns, particularly for Shift and the Metacognition Index, when the children were of an older age compared to the younger sample. Thus, individuals with ASD likely have deficits in executive function that become even more apparent as their typically-developing peers begin to mature in their executive skills (Rosenthal et al., 2013).

Additional differences in children with ASD have been documented using brain imaging techniques. Children with an ASD who are considered to be lower functioning have been shown to display a different pattern of neural activity compared to higher functioning children with an ASD, which was also significantly related to decreased performance on executive tasks (Han et al., 2013). Those categorized in a lower functioning group displayed increased activity in the anterior network as well as different immunologic functions. Children considered lower functioning also had heightened levels of the suppressor/cytotoxic T lymphocytes. Taken together, these results support the theory that immunological components may damage brain regions important for neuronal connectivity in children with an ASD, which could explain reports of executive dysfunction (Han et al., 2013).

Learning Disability and Nonverbal Learning Disability (NVLD)

There is some neurologic evidence that learning disabilities are connected with brain abnormalities associated with executive dysfunction (Riccio et al., 2010). For example, children with reading disabilities, such as dyslexia, have shown increased activation of prefrontal areas commonly associated with working memory. Individuals with dyslexia have also displayed decreased overall volume of the cerebral cortex compared to a control group. Similarly, children completing math problem solving show activation of the medial frontal and cingulate cortex, particularly with complex problems (Ricco et al., 2010).

The majority of the executive deficits found in children with learning disabilities have focused on the academic areas of math and reading (Ricco et al., 2010). In particular, children with math disabilities also display decreased functioning in logical reasoning, working memory, and problem solving. These children may be more susceptible to distracting information that is not relevant to the problem, suggesting inhibition difficulties, as well as difficulty with switching and selection of strategies. Executive function is also predictive of later math performance (Riccio et al., 2010). Deficits in working memory in early ages were predictive of math learning disabilities in later elementary years (Toll, van der Ven, Kroesbergen, & Van Luit, 2011). Other executive deficits have been noted for children with reading disabilities. For instance, difficulties with inhibition have been documented for children with reading disabilities on a go/no go task (De Weerdt, Desoete, & Roeyers, 2013). Specifically, children with reading disabilities made more commission errors on alphanumeric codes. Inhibition and set switching abilities are also predictive of reading ability in later elementary years (Ricco et al., 2010).

There is less research on children with NVLD and associated executive deficits (Semrud-Clikeman et al., 2014). Children with NVLD have been shown to have weaknesses in fluid reasoning, particularly for spatial tasks; however, research with children with NVLD is scarce and most practitioners infer deficits based upon the spatial weaknesses typically observed in the disorder. Semrud-Clikeman and colleagues (2014) noted that this population appears to have few problems with cognitive flexibility, but has increased difficulty with visual sequencing and reasoning, especially when the task involves planning and organization. These deficits were generally less severe than an ASD sample, but more severe than a typically developing sample.

Intellectual Disability (ID)

Many of the common genetic syndromes that occur in childhood have executive dysfunction concurrent with lower intelligence and adaptive behavior scores (Hunter & Sparrow, 2012). Children with Down syndrome have chromosomal abnormalities on chromosome 21 and typically display cognitive impairments along with various physical impairments, such as gastrointestinal problems and heart defects. Cognitive impairments can range from mild to severe, and research has shown varied levels of executive dysfunction in this population. Deficits in younger children have been observed in the areas of inhibition, sustained attention, and planning. Similarly, adolescents with Down syndrome may be more likely to have problems with working memory, set shifting, and fluid reasoning as well as attention and inhibitory control (Hunter & Sparrow, 2012). Researchers believe that brain pathology related to protracted myelination, decreased brain volume and size, and an increased third ventricle may contribute to cognitive impairments. Children with Down syndrome have also been shown to have smaller regions important for higher-order functions as compared to overall volume, such as the hippocampus and corpus callosum (Hunter & Sparrow, 2012); however, much less is known about the developmental path of executive dysfunction in individuals with ID compared to other disorders, and further research in this area using longitudinal studies is needed.

Acquired Brain Injury

Traumatic brain injury (TBI). One of the most common types of acquired brain injury in pediatric populations is TBI, where damage to the brain occurs after a specific injury or insult such as head trauma (Dawson & Guare, 2010). As evidenced by extensive literature using damage to the PFC as a base for defining executive dysfunction, current research indicates that TBIs in young children have been repeatedly connected to deficits in executive functioning. Impairment is also highly dependent on the region of the brain where the injury was sustained, as well as if it is a focal or diffuse injury, with focal damage related to more precise detriments (Flanagan & Harrison, 2012). Time of injury is pertinent to impairment; earlier damage is more severe for skills that have not been developed or mastered (Riccio et al., 2010). Damage to the brain can also occur through tearing of brain tissue, chemical changes in neurotransmitter function, cell death, or damage to the brain through swelling or infection. TBIs are the second most commonly occurring incident in early childhood, are often underreported, and have been connected to later difficulty in the cognitive areas of attention, memory, problem solving, and language (Riccio et al., 2010).

Cognitive outcomes are consistently poorer for children injured at younger ages (Riccio et al., 2010). The most frequent detriments associated with TBI are decreased attention and processing speed. However, poor performance on neuropsychological tests of executive functions has been connected to decreased levels of effortful control and social cognition in children with a severe TBI (Ganesalingam et al., 2011). Attention problems may endure for a long time after the incident (Riccio et al., 2010). TBI also frequently damages white matter tracks in the brain and children with higher levels of damage to these tracks display increased attention and executive function deficits (Flanagan & Harrison, 2012). This pattern of performance was especially true for the construct of cognitive flexibility. These findings suggest that children with TBI are more likely to struggle with social and emotional components of executive functions such as behavioral self-regulation. Performance on cognitive inhibition tasks was not predictive of difficulties with behavioral executive function, which may provide support for the notion that children with TBIs perform better in structured environments versus unstructured social settings (Ganesalingam et al., 2011).

Numerous measures, including behavioral rating scales and neuropsychological tests, have indicated a wide range of deficits in children with TBI (Dawson & Guare, 2010). For instance, ratings on the BRIEF are significantly higher on both Metacognitive and Behavioral Regulation Indices for children with severe TBI compared to healthy controls and those with mild TBI (Gioia & Isquith, 2004). A longitudinal study demonstrated that children with TBI and poorer ratings of executive functions were also those with worse outcomes in later years (Yeates et al., 2004). Thus, executive dysfunction appears to continue to impact performance for many years after the initial injury (Dawson & Guare, 2010).

Both visual and verbal tasks of working memory have also been connected with executive functions of shifting, inhibition, planning, and verbal fluency using neuropsychological measures in healthy controls (Kumar, Rao, Chandramouli, & Pillai, 2013). When the same tasks were administered to adolescents and adults with mild TBI, associations between other executive tasks and working memory decreased and fewer correlations were found. The researchers concluded that working memory is a cognitive skill highly impacted by even mild TBIs. This impairment was more impactful on verbal tasks, which is a common pattern in the literature. The researchers argued that mild TBI causes a decrease in the number of executive resources, specifically those associated with poor monitoring and inhibition, which produced the poorer working memory performance (Kumar et al., 2013).

Other acquired brain injuries. Additional types of acquired brain injuries include stroke, brain tumor, and specific genetic disorders, such as those of neural migration and blood disorders (Dawson & Guare, 2010). While deficits in these populations have been documented, the significant variability and lack of research make it difficult to formulate specific patterns. Overall, research on acquired brain disorders indicates that all brain regions, including but not limited to the PFC, are necessary for higher-order thinking and an injury to any of these regions may impact executive skills (Dawson & Guare, 2010).

Impairment of executive functions is a major symptom of stroke in adults and children (Poulin, Korner-Bitensky, & Dawson, 2013). Frontal stroke has also been connected to working memory difficulties. Children with cerebrovascular diseases, such as sickle cell disease, frequently display cognitive deficits as a result of lower levels of blood flow in the brain and show higher rates of childhood stroke (Riccio et al., 2010). Individuals with sickle cell disease have atypical red blood cells (i.e., hemoglobin), which result in increased rates of clotting and stroke based on their shape. In particular, deficits have been observed in the areas of attention, planning on a Tower test, and difficulty following rules on the Tower task. These children struggle on continuous performance and card sorting tasks compared to controls (Riccio et al., 2010).

Executive deficits have also been connected to childhood cancers. The most common type of cancer diagnosed in children is leukemia, with the second most common being brain tumors (Riccio et al., 2010). Children treated with chemotherapy and radiation often have cognitive deficits due to decreased white matter volume in the PFC or atypical myelination, with more severe effects for radiation treatments. This is thought to result in a heightened risk for executive deficits, which are increased for those with environmental vulnerability risk factors. Vaquero, Gómez, Quintero, González-Rosa, and Márquez, (2008) have confirmed that brain tumors are associated with executive functioning. For both brain tumor and leukemia, areas most affected tend to be processing speed, attention, working memory, and fluid reasoning. The region of the tumor is also highly impactful in the type of deficit observed.

Mood Disorders

Neuropsychological research on the relationship between mood disorders and executive dysfunction varies (Hosenbocus & Chahal, 2012). Research in this area is also lacking compared to other diagnoses found in childhood, such as ADHD. Studies have shown that children with depressive symptoms often struggle with behavioral regulation and self-control. Further, individuals with depressive disorders often display decreased levels of dopamine in the brain, which likely influences their ability to initiate and attend to tasks (Keilp, Gorlyn, Oquendo, Burke, & Mann, 2008). Other researchers believe suicidal ideation is an example of executive dysfunction, arguing that individuals who are suicidal are unable to think critically about their actions and struggle to generate multiple solutions to a problem (Hosenbocus & Chahal, 2012).

In contrast to depression, researchers have been unable to find a strong link between executive dysfunction and anxiety disorders using traditional neuropsychological measures (Hosenbocus & Chahal, 2012). The exception to this is with OCD. Individuals with OCD demonstrate problems with set shifting and inhibition, which may be explained by dysfunction in frontal-striatal pathways (Hunter & Sparrow, 2012). Researchers have postulated that neurological changes during anxiety negatively influence executive functions. While children are in a high state of anxiety, they are thought to experience atypical function of the limbic system, which in turn affects the connection between those regions and the frontal lobe (McCloskey et al., 2009). This neural dysfunction is exhibited through the behavioral symptoms of problems handling worries, poor concentration, and sleep difficulties. Empirical research results with children have yielded mixed findings and more research is needed in this area.

Assessment of Executive Functioning

Numerous instruments exist to measure a wide range of executive functions; however, certain limitations are present when attempting to measure a construct so diverse and multifaceted in a structured setting (Banich, 2009). Typically executive functions are seen as skills recruited during novel situations, which are specific to each individual person. The standardized nature of neuropsychological assessments often makes it easy for the examiner of the test to provide support, acting as the frontal lobes indirectly by ensuring that instructions and tasks are easily understood. Additionally, due to the many different definitions of what is considered executive functions, there is not uniformity when choosing a battery to measure executive dysfunction in children and adolescents. Similarly, issues of task impurity are often present for executive function tasks (Hunter & Sparrow, 2012). As noted in the neuroscience literature, numerous brain regions are activated during these activities, suggesting that many lower-level functions are recruited as well as a diverse and variable set of higher-order functions (Jurado & Rosselli, 2007). These issues are even more challenging when working with a child population. Children are limited by their decreased language abilities and the potential difficulty they may have with task instructions. The majority of executive tests have been adapted for use with children by being simplified. Therefore, it is not known how well these tests accurately measure the complex constructs in younger individuals.

Agreement on the structure and definition of executive functions is confounded by difficulty clearly measuring these executive abilities through neuropsychological assessments (Banich, 2009). The three common forms of measuring executive functions are behavioral rating scales, standardized neuropsychological tasks, and computerized CPTs (Davis, 2011). A meta-analysis comparing behavioral rating scales of executive function and clinical neuropsychological assessments suggested that these two types of assessment actually identify different underlying concepts and are not highly correlated (Toplak, West, & Stanovich, 2013). On one hand, clinical measures of performance provide information on what is described as the algorithmic analysis, which is an information processing framework. Performance measures provide information on the efficiency of specific cognitive skills, such as working memory, that a child will need to function in the world. In contrast, behavioral rating scales take a reflective approach that focuses more on individual goals, choices, and beliefs as they are related to the overall system's goals, choices, and beliefs. These skills are more related to applied decision making and real-life goal achievement (Toplak et al., 2013).

Behavioral Rating Scales

Typically, rating scales provide a good indication of how others perceive children to be functioning in their environment in relation to observable components of executive functions (McCloskey et al., 2009). Rating scales are limited in that they are biased by the rater and only display how the child performs narrowly in specific applied settings. Recent years have seen a significant boost in the popularity of rating scales that measure executive dysfunction in children with three new scales published in the last two years. Behavior rating scales measuring executive function include the BRIEF (Gioia et al., 2002), the Comprehensive Executive Function Inventory (CEFI; Naglieri & Goldstein, 2013), the Barkley Deficits in Executive Functioning Scale – Children and Adolescents (BDEFS-CA; Barkley, 2012), and the Delis Rating of Executive Function (D-REF; Delis, 2012). While these instruments have the advantage of measuring the effectiveness of executive skills and their function in the real world, behavioral rating scales are also limited by rater bias and their subjective nature (Toplak et al., 2013).

Continuous Performance Tasks (CPTs)

Another neuropsychological assessment for attention problems is the computerized CPT. CPTs have become increasingly popular and are commonly included in neuropsychological batteries (Davis, 2011). Children are required to attend to specific auditory or visual information and respond to target stimuli presented on a computer display. CPTs are touted as measures of attention, but are often used to provide information on inhibition based on response rates, such as numbers of commission and omission errors (Miller, Giesbrecht, et al., 2012). CPTs, such as the Conners' Kiddie Continuous Performance Test, Version 5 (K-CPT V.5; Conners, 2006), utilize child-friendly images as target stimuli. CPTs for older children include the Conners' Continuous Performance Task 3 (Conners CPT-3; Conners, 2013), the Integrated Visual and Auditory Continuous Performance Tests (IVA + Plus; Sanford, Turner, Strauss, Sherman, & Spreen, 2006), and the Test of Variables of Attention (TOVA; Greenberg, 2011). While CPTs are frequently used, their reliability and validity have been questioned by many (Davis, 2011).

Neuropsychological Measures

Additional neuropsychological batteries have been developed to provide more comprehensive assessment of executive function, including elements of working memory and attention in children and adolescents, such as the NEPSY-II (Korkman et al., 2007) and D-KEFS (Delis et al., 2001). Other comprehensive batteries exist to measure deficits in memory. Some of the more common instruments include the Children's Memory Scale (CMS; Cohen, 1997), the Wide Range Assessment of Memory and Learning, Second Edition (WRAML-2; Sheslow & Adams, 2003) and the Test of Memory and Learning, Second Edition (TOMAL-2; Reynolds & Voress, 2007). Few comprehensive measures exist for attention issues in children. One of the most popular is the TEA-Ch (Manly et al., 1999).

Delis-Kaplan Executive Function System (D-KEFS). One of the most common measures for assessing executive dysfunction in children is the D-KEFS, which incorporates the traditional tasks of the TMT, the Stroop task (Golden & Freshwater, 2002), card sorting, and the Tower test into an updated battery that includes newer tests of executive function (Delis et al., 2001). The D-KEFS is considered a comprehensive measure of the components of executive functions in children and adults. It incorporates historical research on frontal lobe dysfunction by using traditional assessments combined with self-created subtests. Additional information on the D-KEFS is provided through process scores including error rates and comparison scores. Overall, the D-KEFS consists of nine subtests that provide individual scores for each task. There is no overall composite of executive function or dysfunction. This measure was updated with a standardization sample representative of the United States census in 2000. It has moderate internal consistency, but has been assessed with some questionable reliability procedures that is discussed further in Chapter 3. Some research supports the idea that the card sorting task on the D-KEFS is more sensitive than the WCST for identifying executive dysfunction with a TBI sample (Heled, Hoofien, Margalit, Natovich, & Agranov, 2012). Not only did the D-KEFS have clinical utility to discriminate between children with TBI and typically developing peers, it was better able to identify perseverative errors and set loss. Based upon its comprehensive evaluation of executive abilities, the D-KEFS was one of the measures utilized in this study.

A Developmental Neuropsychological Assessment, Second Edition (NEPSY-II). Another common battery used to assess cognitive components of executive dysfunction is the NEPSY-II (Korkman et al., 2007). Select subtests from the NEPSY-II were incorporated into the models in this research study. The NEPSY is a comprehensive neuropsychological battery of 32 subtests designed to measure the six domains of attention and executive functions, memory and learning, language, visuospatial abilities, sensorimotor functioning, and social perception. This battery is designed specifically for children and adolescents ages 3 to 16. The NEPSY-II is an extension of the NEPS, which was first produced in Finland. The first edition of the NEPSY was published in the United States in 1998 (Korkman, Kirk, & Kemp), while the NEPSY-II was published in 2007. It is based on foundational work by A. R. Luria (1973), who conducted numerous clinical studies of patients with brain damage. The NEPSY-II incorporates Lurian theory by conceptualizing neuropsychological processes functionally. Specific brain functions are hierarchically categorized so that more complex cognitive functions build upon more basic functional abilities (Korkman et al., 2007). Assessment procedures for the NEPSY-II emphasize the importance of identifying the child's primary deficit in order to better understand how it may be affecting secondary processes. Additional information is provided though process scores that are standardized behavioral observations, which provide further data on a child's functioning.

Specific referral batteries are created as a way for practitioners to individualize assessment based upon suspected areas of disability, including attention problems, learning disabilities, behavior management, perceptual and motor delays, language disabilities, school readiness, and social/interpersonal skills (Korkman et al., 2007). Practitioners also have the option of giving a general referral battery that provides data on all of the six neuropsychological domains. Scores from the NEPSY-II are provided in standard scores, scaled scores, and percentile bands. Process scores are also available as well as scores that help the examiner compare performance on different types of skills. For example, composite scores combine multiple skills to highlight how well a child did on a task overall, while contrast scores compare one component of a task to another to see if differences exist between skills needed to complete the tasks (Korkman et al., 2007). All scores on the NEPSY-II are created to identify neuropsychological deficits, and therefore only extend downward from the average range.

The NEPSY-II was re-standardized in 2007 with a particular focus on replacing subtests with weak psychometrics, extending floors and ceilings, and updating normative data to be representative of the United States census (Korkman et al., 2007). General estimates of reliability and validity of the NEPSY-II are strong. Validity is established through content validity using empirical research on neuropsychological structures and theory, convergent validity by correlating it with other similar tests, and clinical validity by showing it is predictive of clinical disorders. Reliability correlates generally indicate that subtests on the NEPSY-II display appropriate correlations using split-half reliability, test-retest reliability, and inter-rater reliability (Korkman et al., 2007). Strengths of the NEPSY-II include its ability to provide a comprehensive battery, unique referral batteries, extensive coverage of skills and scores, use with preschoolers, and strong psychometric properties (Brooks, Sherman, & Strauss, 2010). Weaknesses include a lack of index scores, some complex administration procedures, lack of validation for the clinical utility of the referral batteries, and a lack of clinical studies outside of the purview of the NEPSY-II creators.

Test of Everyday Attention for Children (TEA-Ch). The TEA-Ch is the only stand-alone battery for measuring attention problems in children (Manly et al., 2001) and several TEA-Ch subtests were included in the models of this study. Supporters of the TEA-Ch cite its user-friendly nature, ease of administration, and focus on attention as strengths of the measure (Baron, 2001). It is designed in a so-called game-like manner that is intended for children ages 6 to 16 (Manly et al., 2001). Two versions of the assessment are included in the battery so that progress can be monitored over time. The TEA-Ch is comprised of nine subtests that are designed to measure different facets of attention, such as sustained attention, selective attention, divided attention, and attentional switching/control. The battery was developed as an extension of the original Test of Everyday Attention (TEA; Robertson, Ward, Ridgeway, & Nimmo-Smith, 1994) that was designed for an adult population. The TEA-Ch is limited by the difficulty inherent in clearly delineating types of attention as well as its recruitment of other cognitive skills, making it a challenge to purely measure attention (Baron, 2001).

Test validity appears to be supported though research on neural models of attention, consistent research utilizing the TEA, and comparisons to other cognitive measures (Manly et al., 2001). The TEA-Ch was originally standardized on a small group of 55 children from Australia; however, additional research has confirmed the factor structure and function of the TEA-Ch using children from the United States and China as well as younger individuals with various disabilities (Belloni, 2012; Chan, Wang, Ye, Leung, & Mok, 2008). Reliability was established on the TEA-Ch using test-retest reliability procedures. While most reliability coefficients were adequate, some subtests were not appropriate for test-retest procedures. On these tasks, test authors used the mean scores within the first standard deviation as reliability estimates.

Research with clinical populations using the TEA-Ch has focused primarily on ADHD for obvious reasons (Heaton et al., 2001). Using children from the United States, Heaton and colleagues (2001) found that children with ADHD consistently produce poorer scores on most of the subtests of the TEA-Ch measuring sustained attention and attentional control. No differences were found on subtests labeled as measuring divided attention or selective attention. Both groups struggled on dual task subtests, while neither performed below expected levels on focused attention. Sutcliffe, Bishop, and Houghton (2006) confirmed these findings by showing that unmedicated children with ADHD performed significantly lower on four of the TEA-Ch subtests compared to matched control groups.

Using parent reports of effortful control of children, Verstraeten, Vasey, Claes, and Bijttebier (2010) measured the relationship between effortful control and the eight subtests of the TEA-Ch with a sample of typically developing children. Their findings highlighted a ceiling effect for older children where there was a lack of impairment or variability. In younger children, increased effortful control was associated with better performance on the TEA-Ch for five of the TEA-Ch subtests (Verstraeten et al., 2010).

Intelligence Batteries

Numerous assessment batteries measure the core cognitive components of intelligence (Flanagan & Harrison, 2012). These measures are built upon various theories of intelligence, such as the Planning, Attention-Arousal, Simultaneous and Successive

(PASS) theory (Naglieri & Das, 1990) and CHC theory (Carroll, 1997; Horn & Cattell, 1966). Some of the most well known cognitive assessments for children and adolescents include the WJ III COG NU (McGrew et al., 2007), Wechsler Intelligence Scale for Children, Fourth Edition (WISC-IV; Wechlser, 2003), KABC-2 (Kaufman & Kaufman, 2004a), SB-5 (Roid, 2003) and the DAS-2 (Elliott, 2007). The Universal Nonverbal Intelligence Test (UNIT; Bracken & McCallum, 1998) and the Wechsler Nonverbal Scale of Ability (WNV; Wechsler & Naglieri, 2006) are both tests of intelligence with less language and cultural knowledge required (Flanagan & Harrison, 2012).

Woodcock Johnson Tests of Cognitive Abilities, Third Edition, Normative Update (WJ III COG NU). Of these cognitive assessment batteries, this study utilized select subtests from the WJ III COG NU to represent components of executive function found on intelligence tests (McGrew et al., 2007). The WJ III COG NU was chosen due to its strong theoretical foundation in CHC theory, sound psychometric properties, and ability to easily fit into the proposed models. Until recently the WJ III COG NU was the most updated version of this assessment and was re-normed in 2007 using the 2000 United States census. This battery of 31 tests includes a standard battery, extended battery, and diagnostic supplement. It is co-normed with the WJ III ACH NU and can be administered to individuals ages five to 95. The full cognitive battery is representative of all the broad cognitive G factors (i.e., Stratum II) and 31 narrow abilities (i.e., Stratum III) that are found in CHC theory. Only the standard battery was utilized in this study. Overall, the WJ III COG NU has strong reliability and validity as evidenced by moderate reliability coefficients through split-half reliability estimates, strong connection to theory, factor analytic studies, and experimental research using diagnostic groups as well as comparison to other measures (Flanagan & Harrison, 2012; McGrew et al., 2007).

There is not a specific domain on the WJ III COG NU that represents executive functioning. Instead, the WJ III COG NU conceptualizes executive function through the Executive Processes clinical cluster, which includes the subtests Concept Formation, Pair Cancellation, and Planning, and the Broad Attention cluster, which is comprised of Numbers Reversed, Auditory Working Memory, and Pair Cancellation. Thus, the WJ III COG NU includes a variety of working memory, attention (i.e., divided, sustained, and attentional control), fluid reasoning, and processing speed tasks as part of executive functions (Flanagan & Harrison, 2012). The Gf domain includes tests that are traditionally thought to be higher-order problem solving skills: Concept Formation (i.e., inductive reasoning) and Analysis/Synthesis (i.e., deductive reasoning). It is important to note that the research connecting the WJ III COG NU to specific components of executive functions is severely lacking (Flanagan & Harrison, 2012). Additional information on the psychometrics and test content of the WJ III COG NU, NEPSY-II, TEA-Ch, and D-KEFS are provided in Chapter 3.

Rationale and Purpose of this Study

Although there is presently a significant rise in research investigating the nature of higher-order thinking in children, there is a major lack of consensus regarding what constitutes executive functions. Further, much remains unknown about the neurologic, genetic, and epigenetic underpinnings of executive dysfunction in child-clinical populations. The inconsistent support for theoretical models is problematic given the high number of disorders with associated executive deficits and the popularity of executive function assessments in present-day neuropsychological evaluations. As mentioned previously in this chapter, empirical research on this neuropsychological construct has utilized a variety of techniques, inconsistent sample characteristics, and research or techniques originally created for an adult population. The majority of the literature available on models of executive functioning utilizes a healthy sample of children or focuses on children with ADHD. Thus, the purpose of this study was to examine the factor structure of executive functions in a clinical sample of children using three models chosen to represent divergent themes in the literature.

Models of Executive Functioning

Overall, models of executive function are typically classified as either unitary or multidimensional (Flanagan & Harrison, 2012). The majority of the models cited in the neuropsychological literature are considered multidimensional as they divide executive functions into separate but related domains that represent different facets of the construct. As previously reviewed, no one model of executive function has received complete acceptance in the field (Hunter & Sparrow, 2012; Packwood et al., 2011). Many of the current models have received inconsistent empirical support, lack research with child-clinical populations, or are not easily testable (Anderson, 2008). Thus, this research study extended previous analyses of the factor structure of executive function in order to better understand how the construct presents in children with various clinical disorders (see Avirett, 2012; Fournier, 2014; Miyake & Friedman, 2012). Three different models were used in the analysis: the single-factor model, the Integrated SNP/CHC model, and a six-factor model proposed by the researcher.

Single-factor model. The single-factor model incorporated all of the executive tasks from the aforementioned neuropsychological measures into one latent variable. This model represented the unitary perspective still held by certain researchers in the field. Support for a single-factor model can be found in early conceptualizations of executive function by Baddeley (1986) and Norman and Shallice (1986). Some researchers continue to view executive functions as a single overarching factor, such as G in intelligence theory (Davis, 2011; Jurado & Rosselli, 2007). Additional theorists also argue that executive function is represented by one single construct, such as working memory or fluid reasoning (Banich, 2009). The predominant empirical support for a single-factor model is found in factor analytic studies that document a collapsed factor of executive functions, particularly in younger children (Hughes et al., 2010; Wiebe et al., 2008). The single-factor model was also chosen for comparison based upon its simplicity.

Integrated SNP/CHC model. The Integrated SNP/CHC model was used to represent another one of the factor structures of executive functions in this research study. As noted earlier in this chapter, Miller (2013) divides cognitive functions into the overall classifications of basic sensorimotor functions, facilitators/inhibitors, basic cognitive processes, and acquired knowledge. Executive functions are considered one of the four types of basic cognitive processes in the Integrated SNP/CHC model. Miller's model does not include working memory or attention as core components of executive functions, but instead classifies them as facilitators/inhibitors. The domains of working memory and attention were included in the model because of their popularity in the executive functioning literature, to provide a unique comparison of their role in executive tasks, and as further validation of the cognitive facilitator/inhibitor framework. The three factors for the Integrated SNP/CHC model are executive functions, attention, and working memory. More detail on the individual tasks comprising the Integrated SNP/CHC model as well as a graphic representation of the proposed model is provided in Chapter 3.

Executive functions. The executive functions domain in the Integrated SNP/CHC model is conceptualized by Miller (2013) as an overall control center for other cognitive functions. It includes the four second-order classifications of cognitive flexibility/set shifting; concept formation; problem solving, planning, and reasoning; and response inhibition. This domain also incorporates data from behavioral rating scales measuring the regulation of actions and emotions, as well as qualitative data from various measures in Miller's model. Data from behavioral rating scales or qualitative measures were not included in the Integrated SNP/CHC model for this study.

The first second-order classification in Miller's (2013) model is cognitive flexibility or set shifting. It is further divided into the third-order classifications of verbal set shifting, visual set shifting, and verbal and visual set shifting. Cognitive flexibility and set shifting are measured by tests that require a child to switch between separate task demands or a set of rules. Children who have difficulty in this area often perseverate on one thing and have a hard time switching from one activity to the next.

Another subtype of executive functioning in the Integrated SNP/CHC model is concept formation (Miller, 2013). Concept formation according to Miller (2013) requires that an individual recognize and understand patterns or classifications using reasoning skills. In the Integrated SNP/CGC model it is broken down into the third-order classifications of concept recognition, which requires a child recognize and classify patterns in a set of information, and concept generation, which calls for an individual to produce different patterns or concepts from provided stimuli. Individuals who struggle with concept formation may not be able to connect newly learned skills or knowledge to their pre-existing understanding of a concept. These individuals also may struggle with problem solving or complex tasks that require them to understand patterns and similarities (Miller, 2013).

The third component of executive functioning included in Miller's (2013) executive function domain is problem solving, planning, and reasoning. While these skills are combined for one second-order classification, they separately represent different third-order classification skills of planning, sequential reasoning, inductive and deductive reasoning, and quantitative reasoning within the Integrated SNP/CHC model. Planning requires a child to think clearly before acting and have an organized strategy to complete a task. Deductive/sequential and inductive reasoning call for complex problem solving skills in order to generate a rule or identify patterns in information. Quantitative reasoning measures problem solving as it relates to mathematical and numerical calculations. This third-order classification was not included in the study because it is not represented on any of the neuropsychological measures chosen for the analysis.

Finally, the second-order classification of response inhibition is subdivided into third-order classifications of cognitive and behavioral inhibition in the Integrated SNP/CHC model (Miller, 2013). Cognitive inhibition requires a child to inhibit a dominant response based upon previously learned patterns of thinking and instead produce a novel response for the task. Errors on these tasks occur when a child forgets the requirement or fails to inhibit the dominant response. Behavioral inhibition occurs when an individual has difficulty controlling desires or behaviors, such as blurting out answers (Miller, 2013).

Attention. As noted earlier in this chapter, Miller (2013) conceptualizes attention as a cognitive facilitator that supports higher-order cognitive functions in the Integrated SNP/CHC model. Attention/concentration is considered a first-order classification in his model. It is further divided into the second-order classifications of selective/focused attention, sustained attention, and attentional capacity. All of these types of attention can also be further divided into auditory and visual capacities. In Miller's perspective, focused attention requires that an individual direct attention at the appropriate stimuli, whereas sustained attention is the continual focus on salient information for as long as it is necessary for task completion. Attentional capacity is a more complex type of attention that measures the amount of information an individual can hold or attend to at one time. This type of attention is typically measured in the Integrated SNP/CHC model with basic memory tasks. It is also broken down into the third-order classifications of memory for numbers, letters, or visual sequences; memory for words and sentences; and memory for stories (Miller, 2013).

Working memory. Similar to attention, working memory is a cognitive facilitator in Miller's (2013) model. It is both a first- and second-order classification. This construct assists higher-order cognition by holding or manipulating information in the mind for as long as it is required by a task. Deficits in working memory make it difficult for a child to complete tasks or organize thoughts and actions. Working memory in the Integrated SNP/CHC model is also further divided into the third-order verbal and visual modalities.

Six-factor model. The third model that was assessed in the research study is a six-factor model organized by the author. This model was proposed for a number of reasons. In order to be considered appropriate, a model must be based on strong theory, include all main components of the construct, consider how impairments in clinical populations relate to the model, be consistent with neurological research, and possess the ability to be assessed in the field (Anderson, 2008). Thus, a six-factor model was proposed because no one model or theory has successfully met these criteria or been fully accepted in the field. The six-factor model also included the domains of attention and working memory as separate factors under the overall latent variable of executive function, which allowed for comparison between the six-factor model and Miller's (2013) Integrated SNP/CHC model.

The proposed six-factor structure was loosely based off of Anderson's (2008) overall assessment of the main components of executive functioning that are traditionally described in the literature. Anderson breaks down executive functioning into "anticipation and deployment of attention, impulse control and self-regulation, initiation of activity, working memory, mental flexibility and utilization of feedback, planning ability and organization, and selection of efficient problem-solving strategies" (2008, p.4). These components served as the descriptive titles of the six factors for this model.

A second guideline for the six-factor model was findings from Miyake and Friedman's (2012) SEM research. As noted earlier in this chapter, Miyake and Friedman have conducted numerous factor analytic studies that consistently show three separate but related factors of executive function as inhibition, updating/working memory, and set shifting. These findings are based off of research using typically developing college students and children. Miyake and Friedman's three-factor structure is a commonly cited paradigm for the factor structure of executive functioning in empirical research; however, a three-factor model of executive functioning has only recieived minimal validation with a clinical sample of children (Avirett, 2011). Therefore, the six-factor model in this study incorporated Miyake and Friedman's work to build upon previous SEM findings and to guide the structure of the model. For the six-factor model, inhibition was represented with the domain of impulse control and self-regulation. Further, set shifting was described with the domain of mental flexibility and utilization of feedback, while updating/working memory was simply called working memory. Three additional factors were added (i.e., deployment of attention; initiation, planning, and organization; problem solving) to extend Miyake and Friedman's work and allow for representation of additional aspects of executive functioning commonly identified in the literature. It was also necessary to include additional factors to allow for comparison between the different models. Executive skills that were included in each of the domains of the six-factor model will be described in the following sections along with support for their inclusion in the model. A graphic representation of the six-factor model can be found in Chapter 3.

Anticipation and deployment of attention. Of the different components of executive functioning, there is the most disagreement and confusion about which aspects of attention are truly executive functions (Gioia et al., 2001). This problem is based partly on the different terms used to represent attention in the various theories. Popular terms, such as attentional set shifting and executive attention, illustrate this phenomenon. Various types of attention are frequently cited in journal articles and are commonly used to measure different facets of executive function (see Anderson & Reidy, 2012; Friedman et al., 2007; Leve et al., 2013; Logue & Gould, 2013; Loher & Roebers, 2013). Most researchers agree that attention serves as either a requisite skill for successful higher-order functioning (Miller, 2013) or is itself a component of executive functions (Anderson, 2008). The majority of support for the relationship between attention and executive function has been based on evidence that children with ADHD often display signs of executive dysfunction (Willcutt et al., 2005). The correlation between executive dysfunction and attention problems has also been established in typically developing children. Overall, attentional difficulties in early childhood are predictive of executive dysfunction in the adolescent years (Friedman et al., 2007).

The interrelationship between attention and executive function is further supported by research on sustained attention (Loher & Roebers, 2012). In order to focus for a longer period of time, a child must also remember and hold the details about what they are to be doing in their mind while also inhibiting distractors. Research on the connections between sustained attention, working memory, and inhibition indicates that they may share a similar developmental trajectory that is based on age, suggesting common underlying processes support these skills (Loher & Roebers, 2012). When a child is asked to complete a task that is focused on goals or future success, focused attention, sustained attention, shifting, and inhibition are typically recruited (Anderson, 2008). Based on this literature, the attention factor in the six-factor model was representative of focused attention, sustained attention, and attentional control.

Impulse control and self-regulation. At a theoretical level, this factor represented aspects of both behavioral (i.e., hot) and cognitive (i.e., cool) self-control (Anderson, 2008; Zelazo & Carlson, 2012). Behavioral self-regulation involves controlling actions and impulses in real-world settings, and is typically measured using behavioral rating scales. This study only focused on the cognitive portion of self-regulation and impulse control, which was operationally defined as inhibition. Inhibition is also one of the three factors included in Miyake and Friedman's (2012) three-factor model. Cognitive inhibition is a well-established factor of executive functioning that is frequently included in theoretical models (Anderson, 2008; Gioia et al., 2001; Hunter & Sparrow, 2012). It is considered the ability to suppress a dominant response and replace it with a less common one. Cognitive inhibition requires an individual to consciously use executive control to override a conditioned response pattern, which is a necessary skill for impulse control and regulation.

Initiation, planning, and organization. The initiation, planning, and organization factor is a combination of two executive skills described by Anderson (2008). It is representative of neuroscience research suggesting that individuals with executive dysfunction or brain damage to specific regions of the PFC, particularly the dlPFC, struggle to start tasks (Hale & Fiorello, 2004). These individuals also have significant difficulty planning and organizing the steps needed for completion of a goal. Initiation requires that an individual have sufficient motivation to attempt a task or action (Anderson, 2008). Planning and organization are then necessary to ensure that the task is completed in an efficient manner. Individuals with poor initiation, planning, and organization often give up easily on tasks, take longer to reach a goal due to inefficient strategies, or fail to successfully achieve their goal at all.

Problem solving. There is a general consensus that problem-solving skills are an important component of higher-order thinking and functioning (Anderson, 2008). Accurate problem solving is dependent on the ability to correctly represent the problem, pick appropriate strategies, outline the steps needed, and then implement the steps until completion. Strong problem-solving skills also demand that an individual be aware of any mistakes along the way and be able to accurately evaluate performance after the task is finished. Reasoning abilities and concept formation are crucial for this process. The six-factor model incorporated different types of reasoning, concept formation, and decision making to fully represent the problem-solving domain.

Mental flexibility and use of feedback. Another important component of executive functions is the ability to have mental flexibility (Anderson, 2008). This domain is also representative of Miyake and Friedman's (2012) factor of set shifting. Set shifting requires the ability to follow rules of a task and be able to shift between different sets of rules depending on prompts from the environment. As noted in the neuroanatomy section, individuals with shifting difficulties often perseverate on the same task or produce a high number of errors.

Working memory. As previously reviewed in this chapter, there is some disagreement on whether working memory belongs under the umbrella of executive functions or if it is a separate cognitive skill that supports higher-order functions (Dehn, 2008). There is a general consensus that working memory is an integral skill required for completing executive tasks. Working memory is also frequently listed as a type of executive function in empirical research (see McCabe, Roediger, McDaniel, Balota, & Hambrick, 2010; Miyake & Friedman, 2012; Willoughby et al., 2012; Xu et al., 2013). The six-factor model viewed working memory as a separate domain under the overarching factor of executive functions. It was represented by tasks that measure a child's ability to hold information in memory as it is needed for a task, and to alter or manipulate this information while completing the task.

Summary

Recent research highlights the importance of neuroanatomical structures, networks, and brain chemistry for appropriate development of executive skills. Executive dysfunction can have a significant impact on future academic and life success. Executive deficits are frequently cited in clinical disorders commonly found in childhood, and several formal assessments have been created to measure these deficits. Although numerous theories and models have been proposed in the field of neuropsychology, there is no one accepted model that has been consistently tested with children, particularly using a clinical sample. Based on this finding, the primary research question and purpose of this study was to assess the factor structure of executive functioning in a clinical sample of children with various disabilities. This research study used multiple statistical analyses to determine if a single-factor model, the Integrated SNP/CHC model, or a six-factor model best fits the sample data. An in-depth explanation of the research design and method is outlined in the following chapter.

CHAPTER III

METHOD

This chapter outlines the methodology of the research study, including participants, procedure, and materials. Detailed information on the psychometric properties of the measures, statistical procedures used in the analysis, and descriptions of the three models of executive functioning are presented.

Participants

This study utilized an archival data set previously obtained from the KIDS, Inc. School Neuropsychology Post-Graduate Certification Program. Professionals in this program were practicing in states across the United States and licensed psychologists with specialized training in school neuropsychology supervised all individuals who administered test batteries to the participants. As part of the KIDS, Inc. training program, trainees administered batteries of assessments that were tailored for each individual case. Thus, participants in this study comprised a mixed-clinical sample with diagnoses including but not limited to ADHD, ASD, LD, anxiety disorders, mood disorders, TBI, and medical/genetic disorders. The larger data set contained approximately 1,000 cases. The sample for this study totaled 300 participants after cases were removed if they exceeded the age restriction or did not have data belonging to the 29 subtests comprising the models. This number was well within the minimum guideline of 200 as outlined by Meyers, Gamst, and Guarino (2006). The sample consisted of children and adolescents ages 8 to 16 (*M* = 11.37, *SD* = 2.53) from various races and ethnic groups. Both male and female participants were represented in the sample with 186 males (68%) and 114 females (32%). Additional demographic data pertaining to ethnicity, age, gender, and disability status are reported in Chapter 4.

Procedure

An archival data set previously obtained through the KIDS, Inc. School Neuropsychology Post-Graduate Certification Program was used for analysis. Data were collected between 2008 and 2013. Informed consent was granted as part of the assessment procedure. Each licensed professional chose test batteries tailored for the individual case and wrote up the findings in de-identified neuropsychological reports. Test scores from each report were then extracted and entered into the larger data set. The data for this study were drawn from the larger data set. Cases were included if they fell within the chosen age range and also had test data belonging to at least one of the four measures used in the models.

Measures

A variety of assessment procedures were administered to answer the individual referral questions relevant to each specific case. The data set for this study included demographic information as well as 29 subtests selected from the WJ III COG NU, NEPSY-II, TEA-Ch, and D-KEFS, which were used to represent the variables of executive functioning outlined in the three models. These assessments were chosen because of their psychometric properties, ability to measure latent variables, and strong representation with a high number of participants. The Integrated SNP/CHC model

(Miller, 2013) was used as the primary source for inclusion or exclusion of subtests into the research study based upon its previous validation with a clinical population of children.

Validity and Reliability

In selecting which assessment measures to include, basic criteria for reliability and validity were evaluated. Reliability indicators describe the level of consistency for an assessment tool when it is measured in different ways (Cozby, 2009). The types of reliability pertinent to the research study included test-retest reliability, internal consistency, and split-half reliability. Internal consistency reliability evaluates the consistency of an assessment tool across all items using Cronbach's alpha, while split half divides the measure it into halves and compares the two scores using the Spearman-Brown formula. Reliability coefficients relating to split-half or internal consistency are represented as $r_{11.}$ Test-retest reliability occurs when the same sample of participants is measured over two different points in time. Reliability is considered to be high when the Pearson product-moment correlation between the two time points is at least .80; however, test-retest reliability may be influenced by practice effects, and thus an alternative form of the same assessment measure is sometimes used during the second administration (Cozby, 2009). Test-retest reliability coefficients are represented with $r_{12.}$ When available, all three types of reliability are described in this chapter to support the appropriateness of the subtests included in the current study.

Measures of test validity are equally important as criteria to support the inclusion of the specific assessments in the research study. Validity indicators note how well an assessment represents the variables or constructs it sets out to measure (Cozby, 2009). While numerous types of validity exist, construct/content validity, predictive validity, convergent validity, and discriminant validity are the most relevant to the current study. Content validity describes how well specific test items measure the construct they intend to represent. Construct validity uses the established body of research to support the construct. Construct validity can be further assessed through predictive, convergent, and discriminant validity. Predictive validity indicates how well a specific measure predicts a related behavior, such as executive dysfunction. Predictive validity can also be established by showing that a test expected to measure attention problems shows differential results for individuals with a diagnosed attention problem compared to a typically developing sample. Convergent validity is measured by comparing scores on the target measure to other measures that claim to assess the same construct. This type of validity is often established by comparing a new assessment instrument to similar batteries that have been in existence for some time, such as other measures of intelligence. In contrast, discriminant validity is used to confirm that the measure does not correlate with assessments targeting different or opposing variables (Cozby, 2009).

Woodcock Johnson Test of Cognitive Abilities, Third Edition, Normative Update (WJ III COG NU)

Test development and theory. The WJ III COG NU is a well-known measure of cognitive ability based on the CHC theory of intelligence (McGrew et al., 2007). Elements of CHC theory are drawn from both Carroll's (1997) three-stratum theory and Cattell's Gf-Gc theory (Cattell et al., 1941). Carroll's (1997) three-stratum theory was created from an exploratory factor analysis (EFA) derived from multiple data sets. He postulated that cognitive abilities should be organized hierarchically by different levels, or stratums. Carroll divided intelligence into three stratums. Stratum I outlines over 70 narrow abilities representing very specific factors of intelligence. These narrow abilities are further organized into clusters at Stratum II. Stratum III represents the overall intelligence quotient or general intelligence of an individual. The second contributor to present-day CHC theory stemmed from Gf-Gc theory created by Cattell and Horn approximately 60 years ago (Horn & Cattell, 1966). Initially, the theory proposed a dichotomy between Gf and Gc as two separate but related indicators of overall intelligence. CHC theory has now expanded to include nine factors of intelligence, which are included in Stratum II as broad factors of intelligence (McGrew et al., 2007).

Content of test. The WJ III COG NU is divided into a standard battery, extended battery, and diagnostic supplement, and consists of 31 tests that measure related cognitive abilities and intellectual functioning (McGrew et al., 2007). All tasks on the WJ III COG NU are designed for individuals ranging from ages 5 to 95 years old. This assessment provides a general intellectual ability (GIA) score, as well as seven broad factor scores in the areas of Gc, Glr, Gv, Ga, Gf, Gs, and Gsm. Each broad factor is comprised of at least two subtests measuring different narrow abilities. Of particular importance to the proposed study is Gf, which measures higher-order thinking skills such as inductive and deductive reasoning. This cluster is comprised of the Concept Formation, Analysis-Synthesis, and Planning subtests.

Additionally, the WJ III COG NU provides interpretive clusters to assess specific cognitive deficits and abilities, such as the broad attention and executive processes clusters. The broad attention cluster looks at four different types of attention and includes the constructs of working memory (i.e., Numbers Reversed and Auditory Working Memory), sustained attention (i.e., Pair Cancellation), and selective attention (i.e., Auditory Attention). The executive processes cluster measures executive skills, such as cognitive set shifting, planning, and inhibition. The subtests that make up the executive processes cluster are Pair Cancellation, Concept Formation, and Planning (McGrew et al., 2007). Output from the WJ III COG NU produces test scores in the form of W scores, standard scores, and z-scores; however, only standard scores were included in the statistical analysis of this study. A full list of included subtests can be found in Table 1.

Reliability and validity. The WJ III COG NU was normed using a sample of 8,782 subjects originally representative of the 2000 United States census (McGrew et al., 2007). The normative update was used in this research study and is compiled from a sample representative of the 2005 United States census. All tests comprising the WJ III COG NU battery were normed on a diverse set of participants from groups representing the United States population by geographic location, age, race/ethnicity, and SES.

The WJ III COG NU demonstrates strong psychometric properties as illustrated though good evidence of validity and reliability ($p < .05$; McGrew et al., 2007; Schrank, Miller, Wendling, & Woodcock, 2010). Statistical analyses for test validity on the WJ III COG NU provided data on content validity, convergent validity, divergent validity, and criterion validity as referenced in the technical manual (McGrew et al., 2007). Content validity is based upon the theoretical nature of CHC theory and the historical context of intelligence test development. Test specificity was determined through previous experimental research, factor analyses, and expert opinion, thus providing strong theoretical foundation for tasks. For instance, former factor analytic studies have demonstrated that the three stratums of abilities factor together as outlined in CHC theory. Pearson product-moment correlations indicate that individual tests are related to intelligence, but are separate broad factors with only moderate shared variance. Finally, criterion validity compared the GIA to other general intelligence scores on six separate cognitive measures and confirmed that they were highly correlated with *r* values .70 or higher (Schrank et al., 2010). Validity studies on predictive validity have also been conducted with the clinical groups of anxiety, ADHD, depressive disorders, head injury, LD, ASD, language disorders, ID, and gifted children (McGrew et al., 2007).

Reliability was established for tests of the WJ III COG NU through split-half reliability, inter-rater reliability, and test-retest procedures (McGrew et al., 2007). The majority of tasks were measured using split-half reliability comparing odd and even items with the Spearman-Brown correction formula. The exception to this was for tests measuring speed and those with multiple scoring procedures, such as Pair Cancellation and Planning. Instead, Rasch analysis procedures were utilized for these tasks using test-retest reliability after a one-day duration. The Fluid Reasoning, Broad Attention, and Executive Processes cluster scores all had reliability coefficients above .94 (McGrew et al., 2007). Individual test reliability coefficients for ages 8 to 16 are listed in the test descriptions below.

Table 1

Subtests Included from the Woodcock-Johnson Tests of Cognitive Abilities, Third Edition, Normative Update (WJ III COG NU)

Test – Subtest	Area Measured (other influencing factors)
WJ III COG NU - Auditory Attention	Auditory Processing (attention, knowledge)
WJ III COG NU - Concept Formation	Inductive Reasoning (visuospatial, self-monitoring, learning)
WJ III COG NU - Analysis/Synthesis	Deductive/Sequential Reasoning (visuospatial, self-monitoring, learning)
WJ III COG NU - Planning	Planning/Reasoning (motor ability, attention, initiation, visuospatial)
WJ III COG NU - Pair Cancellation	Processing Speed (visual scanning, motor ability, attention, number sense)
WJ III COG NU - Memory for Words	Short-Term Memory (language/auditory processing, attention)
WJ III COG NU - Auditory Working Memory	Working Memory (language/auditory processing, attention)
WJ III COG NU - Numbers Reversed	Working Memory (number sense, language, attention)

Note. Adapted from "Technical Manual of the Woodcock-Johnson III Normative Update" by K. S. McGrew, F. A. Schrank, & R. W. Woodcock. Copyright 2007 by Riverside Publishing.

Descriptions and psychometrics of subtests.

Auditory Attention. This subtest is considered a broad measure of auditory attention. It is categorized as a narrow ability for speech-sound discrimination. Individuals are asked to listen to words presented aurally and to point to a corresponding picture; however, background noise increases in volume to heighten task difficulty. Auditory attention requires a high degree of selective or focused attention. Correlation coefficients provide support for high reliability for this task with coefficients ranging from .83 to .90.

Concept Formation. Concept Formation is categorized under the broad factor of fluid reasoning, and is included in the executive processes interpretive cluster. This test involves the use of inductive, or categorical reasoning to take in specific pieces of information and then determine the general rule that applies. Test creators secondarily consider it a measure of set shifting and cognitive flexibility. Concept Formation is considered a good measure of fluid reasoning because it does not have a strong reliance on memory skills. Further, Concept Formation allows the administrator to acknowledge or correct responses, which helps assess for use of feedback. Reliability coefficients were above .93 for all ages included in the current study, demonstrating strong reliability.

Analysis-Synthesis. This test is also considered another measure of fluid reasoning; it assesses the narrow ability of deductive, or sequential reasoning. Analysis-Synthesis provides an individual with a broad spectrum of information and requires the examinee to formulate the specific information needed to complete the sequence. Again, the examiner gives corrective feedback for the majority of the items. Reliability coefficients demonstrated strong reliability and ranged from .88 to .92.

Planning. The Planning test is a combined measure of fluid reasoning and visual spatial thinking. Examinees are asked to trace shapes with varying complexity, but are not allowed to pick up their pencil or retrace any lines. Planning provides information on an individual’s ability to plan out and problem solve a path in advance. It also illustrates executive dysfunction when participants struggle with impulsive responding or have difficulty maintaining rules by lifting their pencil or retracing. Planning had acceptable reliability, with coefficients slightly lower than other tests in the battery (r_{11} = .69 to r_{11} = .78).

Pair Cancellation. This task is designed as a broad measure of processing speed. This test secondarily measures the narrow ability of attention and concentration. Pair Cancellation is three minutes long and sustained attention is required to continue to focus for the duration of the task. Executive function is also measured as individuals are required to infer relationships between items by quickly scanning various pictures to identify objects that go together. Reliability for Pair Cancellation was computed using test-retest procedures and is considered acceptable with r_{12} = .83 for ages 7 to 11, and r_{12} = .78 for ages 14 to 17.

Memory for Words. Memory for Words is a part of the extended battery on the WJ III COG NU. The test is categorized under the broad factor of short-term memory and primarily measures the narrow ability of auditory memory span. Memory for Words involves listening to a list of words presented at increasing lengths and repeating them back in identical order. Reliability estimates for this task can be considered acceptable to good, ranging from .72 to .86.

Auditory Working Memory. This test requires individuals to listen to a series of words and numbers presented orally and with increasing difficulty. Participants are then asked to mentally sort items and then sequentially list objects together followed by numbers. Auditory Working Memory is categorized as a measure of the broad ability of short-term memory. This test also primarily measures the narrow ability of working memory. Divided attention is simultaneously required to successfully complete the task.

Reliability of Auditory Working Memory ranges from acceptable (r_{11} = .84) to strong (r_{11} = .90) for the target age range.

Numbers Reversed. Numbers Reversed is a traditional measure of working memory where participants are required to listen to a string of numbers and then repeat them in reverse order. The task is primarily a test of the broad ability of short-term memory. Numbers Reversed is also considered a measure of attention and concentration because individuals must focus heavily to retain the correct auditory stimuli. This test displayed acceptable reliability coefficients with r_{11} values ranging from .84 to .88.

A Developmental Neuropsychological Assessment, Second Edition (NEPSY-II)

Development of test and theory. The NEPSY-II is one of the most popular neuropsychological batteries for children based on its unique ability to comprehensively measure numerous neuropsychological domains with one administration (Kemp & Korkman, 2010). The test's theoretical base stems from A.R. Luria's neuropsychological perspective originally developed over 40 years ago from patients with brain damage. Lurian theory conceptualizes brain dysfunction at different functional levels, with each area of the brain responsible for specific actions or behaviors (Luria, 1973). This theory also highlights the integrative nature of brain function. More advanced cognitions (e.g., attention, executive functions, memory) require the use of multiple functional areas. Importantly, Lurian theory acknowledges that the way regions interact is different for children compared to adults. The NEPSY-II was designed with the understanding that dysfunction in certain lower brain functions may also influence related or complex cognitions that rely on that function (Kemp & Korkman, 2010). The purpose of neuropsychological assessment according to this theory is to identify the primary deficit that is creating the dysfunction in a secondary area. The NEPSY-II is designed to assess these deficits in order to better understand what is causing a greater (i.e., secondary) deficit (Korkman et al., 2007). The NEPSY-II also utilizes Kaplan's (1988) process approach to understand the method or process a child uses to reach the correct or incorrect answer. Thus, qualitative observations are crucial for diagnosis of neuropsychological impairment and the NEPSY-II prioritizes behavioral observations as a standardized way to obtain more information on a child's deficit.

Content of test. The NEPSY-II consists of 32 subtests that assess six broad neuropsychological domains of attention/executive functions, language, sensorimotor, visuospatial, memory and learning, and social perception (Korkman et al., 2007). The test is approved for use with children ages 3 to 16. The NEPSY-II is designed to allow flexibility in administration and provides specific referral batteries depending on the child's need. This assessment is unique in that it can be used to measure all core areas of neuropsychological functioning and associated deficits.

The NEPSY-II has a general referral battery that covers the main subtests in each neuropsychological area as well as diagnostic referral batteries for learning disabilities, attention problems, behavior management, perceptual and motor delays, language disorders, school readiness, and social or interpersonal skills. The subtests can be administered in a flexible order as well. The NEPSY-II does not provide domain or cluster scores. Subtest scores on the NEPSY-II are reported in standard scores, scaled scores, and percentile bands. Process scores provide the opportunity for error analysis, and composite scores are an overall indicator of a child's performance obtained by combining scores representing multiple components of the task. Contrast scores allow an examiner to see how a child performed on different components of a task when compared to the other elements. The goal of these scores is to identify dysfunction, and therefore they do not often expand above the average range (Korkman et al., 2007). Selected subtests for this study were measured with scaled scores. A list of the NEPSY-II subtests included in the analysis can be found in Table 2.

Table 2

Subtests Included from A Developmental Neuropsychological Assessment, Second Edition (NEPSY-II)

Test – Subtest	Area Measured (other influencing factors)
NEPSY-II Inhibition- Inhibition	Inhibition (initiation, nonverbal fluency, cognitive flexibility)
NEPSY-II Inhibition - Switching	Set Shifting (processing speed, inhibition)
NEPSY-II Auditory Attention	Attention (verbal fluency, processing speed)
NEPSY-II Response Set	Set Shifting (verbal fluency, attention, inhibition, processing speed)
NEPSY-II Animal Sorting	Concept Generation (processing speed, working memory, problem solving)
NEPSY-II Clocks	Planning (motor control, memory, initiation)
NEPSY-II Narrative Memory Free Recall	Short-Term Memory (attention, language, processing speed)
NEPSY-II Word List Interference	Working Memory (language, attention, verbal processing)

Note. Adapted from "NEPSY-II: A developmental neuropsychological assessment by M. Korkman, U. Kirk and S. Kemp. Copyright 2007 by The Psychological Corporation.

Reliability and validity. The NEPSY-II is the second edition of the original NEPSY (Korkman et al., 2007). The NEPSY-II was born out of the NEPS, which was developed by Korkman in Finland. The NEPS was a brief measure with one to two subtests per domain; however, the assessment was psychometrically weak and additional subtests were added to produce the original NEPSY (Korkman et al., 1998). This version underwent three phases of test development and standardization before being released in 1998 in the United States. The NEPSY-II was published in 2007 and included several changes in test content, with subtests removed and added in the second edition. The psychometric properties of the NEPSY-II were intentionally targeted for improvement with the second test version. This change also increased the age span that the NEPSY-II can reach and expanded specific domains.

Additionally, the test developers removed domain or cluster scores, and instead focused on subtest-level scores (Korkman et al., 2007). The change most relevant to the current study is the addition of three new subtests to the executive functioning domain (i.e., Animal Sorting, Clocks, Inhibition). Normative data for the NEPSY-II was improved to include updated census data from the 2003 United States census. Test developers also expanded floors and ceilings to strengthen the measure psychometrically. The standardization sample of 1,200 children was stratified to represent the United States population according to age, sex, race, and parent education. The sample was also pulled proportionately from geographic regions representative of the 2003 census. The normative sample included diagnostic studies with children from a wide range of neurodevelopmental disorders.

Several different types of validity were established with the second edition of the NEPSY (Korkman et al., 2007). The test authors claim that content validity exists through the extension of the NEPSY (Korkman et al., 1998), strong theoretical backing in

Lurian theory, utilization of empirical research, and alteration of the test through multiple standardization phases. Construct validity was supported through correlational analysis between subtests. The majority of the subtests were moderately connected with other tasks in the same neuropsychological domain. Separate research studies assessed concurrent validity between the NEPSY-II, the original NEPSY, the CMS (Cohen, 1997), and the D-KEFS (Delis et al., 2001). Additionally, the NEPSY-II was highly correlated with measures of intelligence, such as the WISC-IV (Wechsler, 2003) and the DAS-2 (Elliott, 2007). The clinical utility of the NEPSY-II was established through validity studies demonstrating the sensitivity of the NEPSY with clinical populations (Korkman et al., 2007). Clinical validity was determined using a sample of 260 children with a wide variety of disorders, including ADHD, ASD, emotional disturbance, hearing impairments, ID, LD, and TBI.

Reliability for the NEPSY-II subtests was determined using internal consistency measures, test-retest reliability, and inter-rater reliability with the alpha level set at .05 (Korkman et al., 2007). Split-half reliability was used for all subtests with the exception of Auditory Attention and speeded tasks, which were assessed with test-retest reliability. Decision consistency scores were utilized to determine reliability with combined scores, which combine multiple aspects of an individual's performance. These reliability coefficients may be highly influenced by practice effects and thus tended to be lower. Overall, the majority of the NEPSY-II subtests produced reliability coefficients that were adequate to high; however, process scores and error scores sometimes lacked enough variability in the sample due to task simplicity for typically developing children (Korkman et al., 2007).

Description and psychometrics of subtests.

Inhibition-Inhibition. This subtest is included in the attention/executive functioning domain and is divided into three parts: Inhibition-Naming, Inhibition-Inhibition, and Inhibition-Switching. All three parts are administered to children ages 5 to 16. Examinees are asked to quickly read a page of symbols (e.g., arrows) and to verbally state the shape depending on the condition. Inhibition-Inhibition requires that children inhibit the dominant response of the shape (e.g., up for an up arrow) and say the opposite (e.g., down for an up arrow). This condition can be compared to the other two conditions to see if an examinee has difficulty inhibiting dominant responses. The primary score used from the Inhibition tasks in this study was the combined score. Reliability for Inhibition was determined using decision consistency, which produced adequate (r = .73) to high coefficients (r = .96), with reliability decreasing slightly for adolescents.

Inhibition-Switching. This task is the third component of the inhibition subtest and requires an individual to participate in set switching. A child must also hold the task rules in his or her mind for the duration of the test. These rules indicate that the examinee must state the dominant response for shapes in one color, but give the novel response (i.e., the opposite shape – circle for square) for shapes in white. Thus, the individual must also inhibit dominant responses for these items. Reliability for Inhibition-Switching was consistently strong as all ages with coefficients above .85.

Auditory Attention. Auditory Attention is another subtest with multiple components categorized under the broad domain of auditory attention and executive functioning. This first component, Auditory Attention, is administered to children ages 5 to 16. Examinees are presented a sheet of paper with four circles. An audio recording of various words is presented while the child is asked to point only when one word color is read. This task requires the participant to focus and sustain his or her attention for approximately 3 minutes. It also includes some element of inhibition as the individual is not to point to any color except for one. The score used in this research study was a combined score that considers number of errors and overall completion time. Reliability for this score varied in the normative sample from adequate (r = .71) to high (r = .91).

Response Set. This task is the second portion of Auditory Attention and is primarily a measure of set switching and inhibition. Response Set requires the child to maintain different set rules for certain colors. For two of the colored circles, the examinee is asked to point to the opposite color when the target word is spoken on an audio recording. For another color the individual is asked to point to the same colored circle as the word. All other words are to be inhibited by the respondent. Set shifting mandates that the examinee hold different rules for target words and successfully shift between these rules throughout the time period. Individuals with executive dysfunction often struggle with this task. Response Set can be administered to children ages 7 to 16. Reliability coefficients for Response Set demonstrated adequate to high reliability using combined scores with all coefficients above .83.

Animal Sorting. Animal Sorting is a variation of a classic sorting task that assesses executive functions in the areas of concept formation, problem solving, and reasoning. Individuals are provided with different animal cards and are asked to sort them into two groups based on commonalities. This task also provides data on how many different ways a child can sort the items without repeating or violating rules (i.e., not having equal sets of cards). Animal Sorting is appropriate for individuals ages 7 to 16. The combined score, which was used in this analysis, produced high reliability for the Animal Sorting task with all coefficients above .90.

Clocks. This subtest is a very traditional task assessing executive dysfunction that has been used in the medical field for years (Korkman et al., 2007). Clocks is categorized under the attention and executive function domain on the NEPSY-II. Children are asked to draw and copy clocks displaying different times. This task provides information not only on a child's concept of time, but also on his or her ability to plan and organize information. Individuals with brain damage display atypical drawing patterns, such as only creating one half of a clock. This subtest can be administered to children ages 7 to 16, and was represented in this study with the Clocks Total Score. Clocks produced questionable reliability coefficients that ranged from .63 to .87, with the majority of ages falling below .80.

Narrative Memory Free Recall. Narrative Memory is part of the memory and learning domain on the NEPSY-II and is administered to children ages 3 to 16. Examinees are read a story narrative and are asked to immediately repeat the story back. Details that are not immediately remembered are cued to see if the respondent can answer with additional prompting. Finally, any components of the story that are not recalled are asked again with recognition questions allowing the examinee to choose between two options. Narrative Memory measures a child's short-term memory skills, but also allows the examiner to break down memory through cued recall and recognition. The component to be included in this study was Narrative Memory Free Recall. Narrative Memory had reliability estimates that ranged from low (r = .56) to adequate (r = .73).

Word List Interference. Word List Interference is primarily a test of verbal working memory that requires individuals to listen to a list of words followed by a separate list of words. The examinee must hold the original list in his or her mind while also remembering the second list. Word List Interference belongs to the memory and learning domain and can be administered to children ages 7 to 16. Secondary skills required for this task include auditory processing and recall. The recall score from this task was used in the analysis, which produced low (r = .57) to adequate (r = .77) reliability coefficients. According to the technical manual, the decreased reliability coefficients for Narrative Memory and Word List Interference may be explained by the test-retest procedure used.

Test of Everyday Attention for Children (TEA-Ch)

Development of test and theory. The TEA-Ch is a neuropsychological test developed to measure the components of attention including sustained attention, selective attention, divided attention, and attentional switching or control (Manly et al., 1999). Similar to other measures, the TEA-Ch was originally designed for an adult population and was later adapted for use with children. The authors acknowledge the complexity of the construct of attention and note that measuring a pure construct of attention is difficult based on its relationship with other cognitive tasks (Manly et al., 2001). Another issue when measuring attention is its indirect nature, which may be more problematic for children than adults based on developmental differences. To reduce these limitations, the TEA-Ch was developed to intentionally decrease the demand of memory, motor speed, and language.

Content of test. The authors of the TEA-Ch intentionally modeled subtests to be "game-like" and the full battery of nine subtests can be administered to children ages 6 to 16 (Manly et al., 1999). The TEA-Ch is comprised of two versions, A and B, which can be used to retest the same child for the purposes of progress monitoring. Administration of the full battery takes 55 to 60 minutes on average. The nine subtests on the TEA-Ch are categorized according to the three types of attention measured. Selective attention is measured with Sky Search and Map Mission; attentional control/switching is measured with Creature Counting-Timing and Opposite Worlds; and sustained attention is assessed with Score!, Code Transmission, Walk-Don't Walk, Score Dual Task (DT), and Sky Search DT. Subtests selected for analysis in the models of this study are listed in Table 3.

Reliability and validity. Validity and reliability were determined using a normative sample of 293 typically developing children from Melbourne, Australia (Manly et al., 1999). The standardization group was stratified based on SES, age, and gender. No participants scored a 0 on any subtest with the exception of Creature Counting, thus supporting the strong floors and instructions of the assessment. No gender effects were noted. Validity studies were also performed during the standardization procedures with the alpha level set at .05 (Manly et al., 1999). The authors argue that construct validity was established through previous research of neural models of attention and the original version of the TEA (Robertson et al., 1994) for adults.

Several of the subtests of the TEA-Ch were adapted from previous neuropsychological attention measures, which test authors state further confirms its content validity (Manly et al., 1999). For instance, Code Transmission is a form of a CPT. Convergent validity was established by comparing scores of 96 participants on the TEA-Ch to other attention measures, such as the Stroop test (Golden & Freshwater, 2002), TMT Version A and B (Spreen & Strauss, 1991), and Matching Familiar Figures Test - Errors (MFFT; Arizmendi, Paulson, & Domino, 1981). The MFFT is commonly seen as a measure of inhibition. Partial correlations with age removed indicated that significant correlations existed between these assessments and Code Transmission and Sky Search. Creature Counting (i.e., accuracy) was significantly correlated with the Stroop test and MFFT errors. Sky Search DT demonstrated a significant positive correlation with Trails Version A, while Walk, Don't Walk was significantly correlated with Trails Version B and MFFT errors (Manly et al., 2001). When compared to IQ scores and achievement measures, there were no statistically significant correlations with the TEA-Ch. The test authors indicate this is supportive of discriminant validity because IQ and attention are separate cognitive functions. Additional information on test validity was explored using SEM analysis (Manly et al., 2001). Modeling indicated that subtests were related to the previously listed variables of attention (i.e., selective attention, attentional control/switching, and sustained attention). All values of fit were .90 or higher, indicating that the model was a strong fit for the data used. No age related differences were found when the sample group was divided by age.

Fifty-five children in the standardization sample participated in a reliability study using test-retest procedures after 5 to 20 days (Manly et al., 2001). Age was removed from the correlation to decrease unrealistically high coefficients. The Pearson product-moment correlations generally ranged from adequate to good; however, as noted by other researchers, test-retest procedures are more sensitive to practice effects, which therefore should be considered when determining the appropriateness of a measure. Further, three tasks had ceiling effects which rendered the test-retest formula unusable. For these tasks, the manual provides the percentage of agreement in scores within the first standard deviation. The only task included in the current study with percentage of agreement used was Walk, Don't Walk.

Several limitations to the psychometric stability of the TEA-Ch have been noted by researchers, such as the complex array of skills (e.g., motor performance, processing speed) required for attention tasks, the sample data from children from Australia, and the lack of data from children with disabilities (Manly et al., 2001); however, support for inclusion of the TEA-Ch subtests in the proposed model is provided through additional standardization and validity studies. The TEA-Ch has now been validated with a United States sample of 158 children (Belloni, 2012) as well as a Chinese sample of 232 children using CFA (Chan et al., 2008). Chan and colleagues (2008) supported the three-factor structure with their sample of Chinese children without ADHD. They further confirmed reliability using test-retest over four weeks, and discriminant validity with children with ADHD performing more poorly than the normative sample.

Table 3

Subtests Included from the Test of Everyday Attention for Children (TEA-Ch)

Test – Subtest	Area Measured (other influencing factors)
TEA-Ch Creature Counting (Timing)	Attentional Control (initiation, nonverbal fluency, cognitive flexibility)
TEA-Ch Walk, Don't Walk	Sustained Attention (motor control, auditory processing, motoric inhibition)
TEA-Ch Code Transmission	Sustained Attention (auditory processing, number sense)
TEA-Ch Sky Search (Attn. Score)	Selective Attention (motor control, visual scanning)
TEA-Ch Sky Search DT	Sustained Attention (motor control, visual scanning, language, inhibition, set shifting)

Note. Adapted from *The Test of Everyday Attention for Children* by T. Manly, I. H., Robertson, V. Anderson, and I. Nimmo-Smith, copyright 1999 by Harcourt Assessment.

Subtest descriptions and psychometrics.

Code Transmission. This subtest is considered to be a measure of sustained attention (Manly et al., 1999). The task requires vigilance as children are asked to listen to a continual stream of numbers to identify when two specific numbers are spoken together (e.g., 7, 7). When the child hears these two numbers together, he or she must then identify the number that was spoken prior to the target sequence. This process occurs over a 7-minute time period and thus demands continual focused attention over a longer duration of time than the other measures of sustained attention on the TEA-Ch. The demand for sustained attention is higher due to the task lacking engagement and lasting for a longer duration than other tasks. Reliability coefficients for Code Transmission indicated adequate reliability with $r_{12} = .78$.

Walk, Don't Walk. Walk, Don't Walk provides children with different paths containing 14 squares (Manly et al., 2001). Two different tones are presented, one indicating the child should move forward one space, and the other communicating that the child should not make any movement on the path. Movement forward is indicated by drawing a line over a box using a washable marker. Walk, Don't Walk is an adapted version of traditional neuropsychological go and no-go tasks. Target tones increase in speed and require that the child respond quickly, but inhibit the desire to keep marking when tones are not presented. Walk, Don't Walk demonstrated ceiling effects and thus the percentage of agreement between the first standard deviation were used for reliability. Approximately 71% of children performed similarly on this subtest. Walk, Don't Walk was able to discriminate between boys with ADHD who performed significantly more poorly when compared to matched controls.

Creature Counting. This task is considered a measure of attentional control, as it requires individuals to switch back and forth between tasks and rules (Manly et al., 2001). In the executive function literature, Creature Counting may also be categorized as a set-shifting task. On this activity, children are asked to count pictures of creatures as they fall along a path; arrows pointing up or down change the course of counting. Examinees must count out loud and shift focus as each arrow arises. Scores are provided on overall time and accuracy of counting across multiple trials. Of all of the TEA-Ch subtests, Creature Counting had the highest relationship with IQ score, suggesting that cognitive ability may mediate performance on this task. Test-retest reliability indicated adequate reliability ($r_{12} = .71$) for the accuracy score on Creature Counting.

Sky Search. Sky Search is categorized by the developers of the TEA-Ch as a selective attention task (Manly et al., 2001). Individuals are required to focus on circling targets of paired spaceships on a laminated sheet of paper. Children are required to focus attention on the paired ships, and avoid distractor items that may look similar. One strength of Sky Search is that the task itself is visual and does not require a verbal- or language-heavy response. Sky Search produces scores on overall completion time, speed, and accuracy. Scores are compared to a motor task, which allows the examiner to confirm that slowed responses are not due to a motor impairment. Sky Search Attention Score was used in the current analysis, which has appropriate reliability using test-retest procedures ($r_{12} = .75$).

Sky Search Dual Task (DT). This subtest is a version of Sky Search that combines the original task with an additional auditory task. While counting targets, children are also asked to listen to sounds on an audio recording and count the total number of tones per segment. Sky Search DT is considered a test of divided attention. The test also involves working memory and set shifting between the two different task requirements. Scores are taken together to combine how well a child quickly searches for targets with his or her accuracy of counting tones. Sky Search DT has good reliability as evidenced by a correlation coefficient of .81.

Delis-Kaplan Executive Function System (D-KEFS)

Development of test and theory. The D-KEFS is a comprehensive measure of executive functioning that contains numerous traditional neuropsychological tasks, such as the TMT, the Stroop test (Golden & Freshwater, 2002), and the Tower of Hanoi (Delis et al., 2001). The D-KEFS was also the first standardized measure to assess higher-order cognition in both children and adult populations. While the D-KEFS does not have a strong theoretical base, test developers used research on frontal-lobe dysfunction to conceptualize executive functions and create test items. The authors of the D-KEFS also identify with a cognitive-process approach that uses qualitative information, such as perseverative errors, as test data. There is some variability in the degree of basic skills required to complete more complex tasks on this measure, and D-KEFS subtests frequently build upon each other (e.g., identify letters and numbers before switching between them; Delis et al., 2001).

Content of test. The D-KEFS is comprised of nine individual subtests. The battery contains traditional measures of executive functions as well as unique tasks created by the test developers (Delis et al., 2001). While the test authors argue that the D-KEFS represents the construct of executive function fully, the nine subtests in the battery do not produce an overall composite score or factor. Instead, the individual subtests can be administered in any order and examiners are allowed to pick and choose tasks for each assessment. Administration of the full battery takes approximately 90 minutes. Subtests on the D-KEFS represent both verbal and nonverbal components of executive functioning. All of the tasks can be administered to children and adults ages 8 to 89 with the exception of Proverbs, which cannot be given to individuals under age 16. Numerous scores are produced on the D-KEFS, including total achievement, total correct responses, total accuracy, and error scores. All of these scores are represented with scaled scores. Some error scores are provided in cumulative percentage ranks; however, all of the scores for this research study were scaled scores. The table below lists the subtests from the D-KEFS that were included in the models.

Table 4

Subtests Included from the Delis-Kaplan Executive Function System (D-KEFS)

Test – Subtest	Area Measured (other influencing factors)
D-KEFS - Verbal Fluency Condition 3	Set Shifting (verbal fluency, word retrieval)
D-KEFS - Trail Making Condition 4	Set Shifting (visual scanning, motor control)
D-KEFS - Sorting Condition 1 Confirmed Correct Sorts	Concept Generation (self-monitoring, knowledge, working memory)
D-KEFS - Sorting Conditions 1 + 2 Description	Concept Generation (self-monitoring, knowledge, working memory, expressive language)
D-KEFS - Twenty Questions	Reasoning/Problem Solving (knowledge, long-term memory)
D-KEFS - Word Context	Deductive Reasoning (language/knowledge, working memory)
D-KEFS - Tower Total Achievement	Planning, Motoric Inhibition (visual attention, working memory)
D-KEFS - Color Word Interference - Condition 3	Set Shifting (inhibition, language, attention, processing speed)

Note. Adapted from *Delis-Kaplan Executive Function System Examiner's Manual* by D. C. Delis, E. Kaplan & J. H. Kramer. Copyright 2001 by the Psychological Corporation.

Reliability and validity. The D-KEFS standardization sample was comprised of 1750 individuals, 875 of which were ages 8 to 19 (Delis et al., 2001). The sample was split evenly between men and women and was representative of the 2000 U.S. Census data. Additionally, race, ethnicity, education, and geographical regions were divided to fit the census. There was a slight performance decline in average scores for children ages 8 to 10, thus resulting in larger standard deviations for this age range; however, this pattern was likely related to the developmental nature of executive functions. Generally, the sample population was normally distributed, with the exception that error rates tended to be decreased and skewed in the negative direction. Additionally, nonclinical responses in the normative group may be lacking lower scores in the distribution as the D-KEFS is designed to identify executive function deficits in clinical groups (Delis et al., 2001).

Support for strong reliability for the D-KEFS exists in the form of internal consistency and test-retest reliability (Delis et al., 2001). Internal consistency was measured using split-half reliability procedures. The alpha level was reported at .05 for all coefficients. The test authors acknowledge that reliability coefficients may be lower because practice effects on tasks with repeated trials negatively impact internal consistency. Test-retest reliability was established using 101 individuals from representative ages at an average of 25 days between assessments; the general pattern demonstrated slight improvement between administrations. Individual coefficients for subtest reliability are reported below for ages 8 to 19.

Test validity for the D-KEFS is supported by intercorrelations between subtests, validity studies with specific disability samples, and convergent validity established through test comparisons (Delis et al., 2001). Correlational analyses using the standardization sample are provided to highlight the relationships between subtests. It is important to note that no factor analyses have been computed with the D-KEFS. Previous validity studies suggest that the D-KEFS can discriminate between clinical groups. Mattson, Goodman, Caine, Delis, and Riley (1999), using Color-Word Interference, Trail Making, Tower, and Word Context, found that children with FAS performed differently from typically developing peers. In adults with frontal lobe lesions, Baldo, Shimamura, Delis, Kramer, and Kaplan (2001) noted that performance was decreased for individuals with lesions compared to normal participants on both Design Fluency and Verbal Fluency.

Construct validity on the D-KEFS was individually established through correlations between the total achievement scores of individual subtests (Delis et al., 2001). Tasks measuring similar constructs generally correlated together, while only low positive correlations were found between tasks measuring different components of executive functions. Test authors noted that these correlations varied for age ranges due to the development of executive function abilities as children age. Thus, each subtest is hypothesized to measure different aspects of executive functioning even when there is shared variance. Divergent validity was measured by comparing the D-KEFS subtests to the California Verbal Learning Test-Second Edition (CVLT-II; Delis, Kramer, Kaplan, & Ober, 2000). Low positive correlations were documented, with the majority of the subtests lacking significance. Similarly, the WCST (Berg, 1948; Heaton et al., 1993) displayed moderate correlations with some of the D-KEFS tasks; however, there were low correlations for the shared variance for other tasks indicating that the tests may measure different aspects of executive functioning.

Subtest descriptions and psychometrics.

Verbal Fluency Condition 3. This task is the third condition of the Verbal Fluency subtest on the D-KEFS. The first two conditions are measures of retrieval fluency where examinees are asked to recall as many words as possible from either a semantic or letter category. Condition 3 is predominantly a verbal measure of set shifting. Children are asked to switch between listing pieces of furniture and fruits. This task lasts 1 minute in duration and provides scores for total number of items listed as well as a child's successful ability to switch between categories. The primary score for Verbal Fluency Condition 3 is a measure of the total number correct. Internal consistency scores for children and adolescents ranged from .37 to .62, which indicates that there may be some reliability issues when measuring switching. The test-retest reliability value was .65.

Trail Making Test Condition 4. This task is also one condition in a set of five activities under the TMT (Delis et al., 2001). Trail Making has strong roots in neuropsychology and is a traditional test of executive functioning. Conditions 1, 2, 3, and 5 provide comparative information to help examiners determine if a weak score in condition 4 is related to cognitive set shifting and flexibility, or if it is a motor or sequencing delay. On condition 4, individuals use a pencil to draw a line connecting alternative stimuli of a number and then a letter. Children must follow the appropriate sequencing (i.e., numerical and alphabetic order) until they reach Z. In addition to cognitive flexibility and set shifting, this task requires attention and working memory to hold the appropriate place in sequence in the mind until it is time to switch back. The main score for Trail Making is completion time. Internal consistency scores were not provided for condition 4; however, test-retest reliability was low ($r_{12} = .20$).

Sorting Conditions 1 and 2 Description. The sorting subtest on the D-KEFS is another adaptation of a traditional neuropsychological measure used with adults. Examinees are given a set of cards containing different words, shapes, and patterns. The individual is asked to sort the cards into two separate piles with an equal number of cards in each pile. The D-KEFS adds an additional component to this task because children are also required to explain how the two piles are sorted. This task is repeated again with a second set of cards. Sorting Conditions 1 and 2 Combined is the overall score provided, which includes whether or not the sort was correct as well as the appropriateness and accuracy of the individual's verbal response. This task is primarily a measure of concept formation and generation. It also requires creativity, problem solving, maintenance of task rules, and sustained attention. Internal consistency for this subset was produced using split-half reliability, with r values ranging from .55 to .82 suggesting moderate to high validity. The sample size for younger ages for sorting subtests was decreased, which may impact reliability data.

Sorting Condition 1 Confirmed Correct Sorts. This task is another score provided in the sorting subtest of the D-KEFS. The test assesses the number of times an individual correctly sorts both sets of the cards; however, the Confirmed Correct Sorts condition removes the requirement of a correct verbal explanation of how the cards were sorted. Thus, it is a nonverbal measure of concept formation and generation. There is no specific reliability or validity information available for this score as it is not included in the standardization sample.

Twenty Questions. Twenty Questions is a subtest unique to the D-KEFS and is based upon a childhood game. This task occurs in four series where children are allowed to ask questions to the examiner to deduce the target item. A visual tool displaying the possible items in picture form assists the examinee. To successfully complete this task, an individual must be able to use problem solving and reasoning to eliminate items that do not fit the answers and to produce questions that will help them determine the word. Scores provided on this task help the examiner see how quickly a child is able to guess based on how many questions the child needed as well as how frequently the child was able to correctly identify the target word. The Total Achievement score was used in the current study. Reliability is influenced by rate of learning through the multiple trials. Internal consistency data was not provided for the Total Achievement score, but test-retest reliability was .62.

Word Context. Word Context is another subtest that is unique to the D-KEFS. For this task, an individual is presented with a verbal and visual nonsense word. Cues are provided in steps that use the word in a sentence to help explain its meaning. The examinee is allowed to guess at each phase. Scores explain whether the word was correctly defined, how many cues were needed, and if the individual changed back to an incorrect answer after more cues were given. Word Context is primarily a measure of reasoning and problem solving. This task also highlights how well an individual remembers previous information and can hold it in working memory long enough to integrate the cues. The main score provided from this task is Total Consecutively Correct. Internal consistency scores using the Spearman-Brown correction for split-half reliability ranged from .47 to .71, with the majority of the items below .60. Test-retest reliability was $r_{12} = .58$.

Tower. The Tower subtest is an adaptation of the Tower of Hanoi activity that has been in use for many years (Delis et al., 2001). This version of the task measures planning, problem solving, and behavioral inhibition. Individuals are asked to move rings from one peg to another until they have created the target image and the rings are in the correct final location. Rule violations are monitored as a participant is not allowed to put a larger ring on top of a smaller one and can only move one ring at a time. The number of moves is also counted to see how well the individual is able to plan out his or her moves ahead of time. Nine scores are combined to produce the Tower Total Achievement score. Using the Spearman-Brown formula to measure split-half reliability, internal consistency values ranged from poor ($r_{12} = .43$) to good ($r_{12} = .84$), with the majority of the scores being .60 or below. Test-retest reliability was .51.

Color Word Interference Condition 3. This task is similar to the well-known Stroop task (Golden & Freshwater, 2002). Although there are several conditions, Condition 3 assesses how well an individual can inhibit the dominant task of saying the color of the item and instead read the word above the color. This condition is compared to the other conditions to rule out verbal retrieval or fluency issues. The main measure of this subtest is total completion time. Internal consistency was not provided for Color Word Interference Condition 3, but test-retest reliability was .90.

Data Analysis

The purpose of this study was to examine the factor structure of executive functioning using three models that represent divergent theoretical perspectives currently found in the field of school neuropsychology. Findings from this study contribute to a better understanding of the role of executive functioning in children with disabilities. The three models used in the analysis are described in more detail below.

Descriptive Statistics

Sample selection. The sample used in the analysis was drawn from the larger dataset based on the inclusion of at least one of the 29 subtests used in the analysis. Cases were removed if the participant's age did not fall within the required age range of 8- to 16-years-old. Data were determined to be missing at random (MAR) and full information maximum likelihood (FMIL) was used to adjust for missing values. Additional detail on the process for handling missing values is discussed later in this chapter.

Demographics. The next phase of data analysis was to obtain general demographic information about the sample. Frequency counts and percentages were computed on the categorical variables of gender, disability category, and race/ethnicity. Frequency counts, box plots, and scatterplots were created for the continuous variables of age and subtest scores; data were also gathered on the mean, median, mode, range, and standard deviation for both dichotomous and continuous variables. The range of scores helped to identify outliers with extreme scores on the assessments and to visually scan the data to identify any unusual or problematic figures (e.g., ages or subtest scores outside of the allowed range). The output regarding the distribution of subtest scores was used to inform the researcher on the representation of subtests included in the analysis. Further, scatterplots and box plots assisted in assessing whether assumptions were met, such as normality of data.

Addressing Issues with the Data

Range restriction and outliers. All subtest scores were entered into the analysis as discrete scores, as decimals were not possible for these variables (Schumacker & Lomax, 2010). Histograms, scatterplots, and box plots were used to visually inspect the data for outliers, which are scores that are extremely atypical from other data points. Two scores that did not make logical sense were removed from the analysis because they were outside of the range allowed by the test statistics. These outliers might have occurred because of human error during data entry into the data set or into the report shell. These scores might also have been the result of examination error due to poor test administration. Outliers identified as high or low subtest scores were allowed to remain in the analysis under the assumption that these scores appropriately represented the true nature of the clinical sample. All but four subtests demonstrated range spanning at least 15 scaled points so that the distribution was wide enough to display variance (Schumacker & Lomax, 2010). The exception to this were the NEPSY-II Response Set, TEA-Ch Code Transmission, TEA-Ch Creature Counting, and D-KEFS Color Word Condition 3 subtests. These tasks were allowed to remain in the analysis as they displayed ranges that spanned 13 to 14 scaled points, still demonstrating large variance.

Missing data values. The missing data were first checked to determine if there was a pattern. In general, data can be missing completely at random (MCAR), MAR, or not missing at random (NMAR; Meyers et al., 2006). Variables MCAR are almost impossible and occur when the missing values are not in any way related to the target variables being assessed. MAR patterns are more likely to exist in data. The assumption for data MAR is met if the pattern for missing data can be explained by a specific pattern or variable included in the data. Many subtests used in the models measured similar consturcts, and values were likely missing because most examiners do not give duplicate subtests during the assessment process. Thus, data were determined to be MAR with 52 percent of data missing. Large amounts of missing data are common in applied research, particularly for data gathered over a longer period of time (Acock, 2005; Peugh & Enders, 2004). Due to the large amount of missing data, an advanced statistical procedure, such as FIML, was necessary to accommodate for missing values. Experts in the field note that advanced methods of handling missing data are still effective with 50% of data missing.

The two most appropriate ways to handle missing data are FIML and multiple imputation (MI; Kline, 2010). MI predicts missing values using similar data available for the item, and them compares estimates through a series of multiple iterations. Instead of filling in missing data points with estimated values, FIML predicts statistics based upon all available information in the data set (Tomarken & Waller, 2005). FIML accounts for the pattern of missing values by utilizing all available scores in the data grid to predict test statistics. While both methods of handling missing values are appropriate in SEM, FIML was chosen for the primary analysis because of its ability to produce more consistent results when a high degree of values are missing (Enders, 2001). FIML is also less affected by bias in non-normal samples, although some increases in rejection rates have been observed. The dataset was imputed with MI for specific preliminary analyses because of sample size limitations using raw data. The first versions of the models were computed using both MI and FIML for comparison. No differences were noted for type of imputation during the initial modeling phase.

Linearity and non-normality. Checks for the assumptions of linearity and normality were conducted using scatterplots that displayed the data points graphically and through tests of skewness and kurtosis. Visual scanning of scatterplots indicated that subtests generally displayed linearity. Frequency tables illustrated that 21 of the 29 subtests demonstrated slight deviation from normality. A negative skew was observed for these items due to a higher number of children who performed below average on these subtests. This pattern can be explained by the clinical nature of the sample. Tests of skewness and kurtosis indicated that all subtests fell within the acceptable range (i.e., plus or minus 2 for skewness, plus or minus 7 for kurtosis; Rhu, 2011) with the exception of WJ III COG NU Planning subtest. Previous research on complex modeling procedures suggests that the deviations of normality observed in the sample data are below the cutoff rate for Type 1 errors. Although data transformation procedures are a common method for handling non-normal data, transforming data comes with significant drawbacks (Kline, 2010); it is often challenging to identify which transformation is appropriate for the sample. Data transformation also alters how variables are scaled and thus makes it difficult to generalize findings to the raw data. Further, data transformations were not appropriate based on the fact that the research question was focused on studying a clinical sample of children.

Bivariate Correlations

The next step in data analysis was to conduct bivariate correlations between all of the observed variables to measure the degree of relationship between them (Meyers et al., 2006). The Pearson product-moment correlation (*r*) is typically the statistical test used to measure the degree of similarity between continuous variables. The Pearson product-moment correlation is very sensitive to outliers and deviations in normality. Thus, Spearman rank-order correlations were computed to adjust for the slight deviations in normality on some of the subtest scores. The Spearman rank-order correlations established how much variance was shared between two scores by ranking them in order from one to 29. First, the imputed dataset was utilized to explore the relationship between demographic and continuous variables, such as age and subtest scores. These bivariate correlations helped the researcher better understand the sample characteristics and were used to explain findings during interpretation.

The Spearman rank-order correlations were also put into a correlation matrix organized by factor loadings of the models. These correlations were computed with non-imputed data to allow for direct comparison during model testing. Data from the matrix highlighted the degree of relationship between assessment subtests hypothesized to be in the same factor of a model. The correlation matrix was also used to explore what relationships between subtests looked like when not predetermined to be in a model.

Another use of correlation data was to produce the correlation-covariance matrix that outlined the structural coefficients of each latent factor (Meyers et al., 2006). The factor matrix displayed a weighted composite of how much each variable, or subtest, contributed to the overall variance. This information provided support for model specification to determine if observed variables loaded on their hypothesized latent factors. It also informed future steps during the primary analysis when deciding what model modifications were appropriate.

Structural Equation Modeling (SEM)

General information. Structural equation modeling (SEM) is a complex form of factor analysis with the goal of measuring how well theoretical models fit with sample data (Schumacker & Lomax, 2010). In contrast with other statistical procedures, SEM permits the measurement of latent, or unobserved, variables (Meyers et al., 2006). In general, SEM allows researchers to quantitatively test theoretical models by assessing how observed variables represent constructs, as well as how broader constructs are related to each other (Schumacker & Lomax, 2010). Models used in SEM must be built upon previous research and existing theories. SEM was the chosen method of analysis for the current study because it is a sophisticated statistical technique allowing for measurement and comparison of complex theories. It was also the preferred method of analysis because it is able to better represent how variables are related in the real world and can more appropriately account for measurement error (Schumacker & Lomax, 2010).

The statistical analysis in SEM involves the testing of both a measurement model and a structural model (Meyers et al., 2006). The measurement model is produced by the observed (i.e., indicator) variables that represent different aspects of the latent variables in the theory or model. It was measured by CFA. Experts suggest that each latent construct be comprised of at least two to five observed or measured variables. The structural model represents the overall theoretical model and is defined by the relationships between the latent variables.

Another way of conceptualizing constructs in SEM is by categorizing variables as endogenous or exogenous (Meyers et al., 2006). Endogenous variables are defined as those that are described by the model and take on the role of dependent or criterion variables. In contrast, exogenous variables help to explain endogenous variables and are completely independent of other variables. They are also defined as independent or predictor variables. For the models tested in this study, the latent variables representing executive functioning on the far left of the model diagram were considered exogenous, while the subtests and second-level latent variables were endogenous.

Model fit was assessed during the modeling process (Schumacker & Lomax, 2010). A general fit index provided overall information on how well both the measurement model and structural model fit the data; however, this index is not adequate as the sole criterion for model fit. It is possible to have a good overall fit index even though specific aspects of the model are not a strong representation of the data. Thus, multiple measures of fit were used to determine if both the measurement model and structural model are a good fit. These techniques will be described in more detail in the following sections. Statistical significance for all tests was set with an alpha level of .05, which required that there was only a 5 percent likelihood that the findings were due to chance or error.

Sample size. Numerous competing standards exist as suggestions for appropriate sample size when using SEM. According to Meyers and colleagues (2006), statistical techniques, number of factors, and number of assessments influence the minimum sample of participants required to achieve power. In general, they suggest that a minimum of 200 participants is necessary for factor analysis. Another way to estimate appropriate sample size is to have a minimum of 10 cases per measurement variable. The models in the current analysis were comprised of 29 subtests that functioned as observed variables. Thus, the sample size of 300 participants met the criteria for minimum sample size (i.e., 290 cases).

Steps for SEM. Because it is driven by theory, SEM is confirmatory in nature as it sets out to test specific models that are previously created based on research. It is also exploratory because the model with the best fit may need to be adjusted following the initial results. The five steps of SEM are: model specification, model identification, model estimation, model testing, and model modification. The Statistical Packages for the Social Sciences (SPSS) software (version 19) was initially used to obtain descriptive statistics, check for assumptions, and to compute the correlations both before and after the CFA. Next, the laaven package of R was used to conduct the primary analysis (Rossel, 2012). Laaven in R is a statistical package increasing in popularity due to its ability to easily switch between common commercial software, such as SPSS, and its intuitive nature for complex statistical analysis (Rossel, 2012). R is also considered a strong statistical tool because it has a high number of support programs that increase its usability, such as add-on modules (Kline, 2010).

Model specification. The first step in the primary analysis was model specification, which occurs when a researcher outlines the model using previous research and sound theory (Schumacker & Lomax, 2010). The process of model specification determines the variables that will be included as well as excluded in the study. It also involves identifying relationships between variables and the parameters to be measured in the research. The structure coefficients representing the paths between exogenous and endogenous variables, correlation coefficients between latent variables, factor loadings, and estimates of shared or predicted error variance are all examples of parameters in SEM (Meyers et al., 2006). Careful construction of models is important to ensure that they are not misspecified. Specification error occurs when the model does not have accurate parameter estimates that occur in the data, such that the researcher made an assumption about fixing a relationship that is not true. While specification error is unavoidable, good theory and use of previous research should decrease the amount of error in the model.

One of the main components of model specification is visually diagraming the models to be tested (Schumacker & Lomax, 2010). This step determines how the models are structured and defines the hypothesized relationships between variables. SEM procedures dictate that ovals represent latent factors, rectangles represent observed factors, and arrows indicate the direction or relationship between variables. Arrows in the models point away from the independent or exogenous variables and toward the dependent or endogenous variables. Detailed diagrams of the model paths can be found in Chapter 4.

Model identification. Model identification was then conducted to confirm that the theorized model could actually be tested with sample data (Schumacker & Lomax, 2010). Model identification must ensure that there is enough data for each unknown parameter to be estimated. The identification rule determines how parameters will be measured in later phases of analysis in hopes that a unique set of parameters exists. Parameter estimates of the population are initially unknown. During model identification, all parameters are counted, including the correlation matrices, structure coefficients, and correlation coefficients. Overall, parameters can be free (i.e., unknown and requiring estimation), fixed (i.e., previously set to 0 or 1), or constrained (i.e., unknown but tied to other parameters). Model identification requires that the researcher use SEM to create parameters to represent the structural model. Additionally, the identification rule suggests that the measurement model have at a minimum two observed variables that are not too highly correlated representing each latent variable (Schumacker & Lomax, 2010).

Several mathematical calculations to confirm model identification must also be satisfied before proceeding to the next step (Schumacker & Lomax, 2010). Two examples of these checks, the *t*-rule and the rank condition rule, were assessed during this phase of the analysis. Laaven in R has statistical techniques built in to identify models using rank tests and an information matrix (Rossel, 2012). The *t*-rule, which is also referred to as the order rule, states that there must be a higher proportion of non-redundant (i.e., known) parameters than unknown parameters in the models (Meyers et al., 2006). The difference between non-redundant elements and unknown parameters was computed. Non-redundant elements make up the number of distinct values in the *S* variance-covariance matrix, which can be calculated for each model using the formula V (V + 1)/2, where V represents the number of measured variables in each model, including error paths. Unknown or free model parameters were then determined by adding the latent factor variance and covariance, prediction error variances, structure coefficients, measurement error variance and covariance, and the factor loadings (Schumacker & Lomax, 2010). These elements are presented in the Σ variance-covariance matrix. It is important that the model have a higher number of data points in the *S* variance-covariance matrix than estimated parameters in the Σ variance-covariance matrix for the structural model. The degrees of freedom were then calculated by subtracting the difference between the known and unknown parameters. The order condition is confirmed when all of the parameters are established and the degrees of freedom is a positive number (Meyers et al., 2006).

There are three outcomes in model identification: the overall model can either be just-identified, over-identified, or under-identified (Schumacker & Lomax, 2010). Over-identified models have a positive value for the degrees of freedom indicating that there is adequate information in the *S* matrix and thus there are multiple possibilities to estimate the parameters. A model must be over-identified before the next step of SEM can be completed. Just-identified models have zero for the degrees of freedom. These models have the same number of free parameters as known values, so there is barely enough information provided by the *S* matrix. Under-identified models are not able to identify all of the parameters because the data in the *S* matrix is lacking. If a model is under- or just-identified, it can be improved by fixing a metric in the model. This process requires that the researcher fix at least one path from a latent to an observed variable before model testing begins. Typically, the structure coefficient is given a value of one at the beginning of the analysis. This parameter is then referred to as the reference variable. After other parameters are set, an iterative process occurred and eventually these scores were allowed to be free to vary (Schumacker & Lomax, 2010). For this study, the first observed variable or subtest of each latent variable was fixed to 1 during the first iteration of specification.

Model estimation. During model estimation, all of the unknown parameters in the proposed models were officially estimated (Meyers et al., 2006). Model estimation attempts to determine the different options for parameters of the Σ variance-covariance matrix (i.e., the theorized model) to ensure that it closely matches the *S* variance-covariance matrix of the indicator variables in the sample (Schumacker & Lomax, 2010). Model estimation occurs by using fit to decrease the variance between the *S* and Σ matrices. It is complete when the theorized model can repeat or match the sample matrix. Maximum likelihood estimation was chosen for the analysis as it is the preferred estimation procedure for laaven in R. All of the theoretical models went through multiple iterations and were found to be appropriately identified and estimated during both the first analysis phase and the model modification phase.

Model testing. The next phase of analysis was model testing, which determined how well the sample data actually fit with the proposed model (Schumacker & Lomax, 2010). Model testing occurred for both the measurement model and structural model. During this step, the proposed parameters produced correlation and covariance data that was then compared to the observed sample data. Multiple statistical measures were utilized to determine model fit. The researcher looked at the global fit of the model using omnibus tests as well as the individual coefficients related to the specific model parameters.

There is no preferred global fit index accepted by all experts in SEM. Multiple fit indices from different subtypes were calculated during model testing based upon the guidelines of Kline (2010) and the seminal work of Hu and Bentler (1998). Fit indices are generally divided into model test statistics and approximate fit indices (Kline, 2010). The chi-square test is universally seen as the main model test statistic and was used in this analysis based upon its popularity in the field. It is considered an exact fit because it tests for possible differences between the model co-variances and those in the population. A non-significant chi-square suggests that the model is generally consistent with the sample data (Kline, 2010); however, the chi-square is vulnerable to sample sizes, larger correlations between variables, and produces more Type 1 errors when normality is violated. The adjusted chi-square accounts for sample size by dividing the statistic by the degrees of freedom in a model. The adjusted chi-square is considered good if it is under 3.

Because of the limitations to the chi-square statistic, researchers suggest using a combination of approximate fit indices for comparison (Kline, 2010). Approximate fit indices can be further categorized as absolute fit, incremental or relative fit, and parsimony-corrected fit. Similarly, Hu and Bentler (1998) suggested a two-index strategy, which includes the standardized root mean squared residual (SMSR) along with another measure of approximate fit.

Absolute fit indices compare interrelationships between variables of the proposed and measured models as evidenced by the correlation/covariance matrix (Hooper, Coughlan, & Mullen, 2008). They are different from model test indices because they do not have a clear cut off determined by level of significance, but instead are gradations of fit (Kline, 2010). Most absolute fit indices are built off of the chi-square formula and thus are susceptible to the same problems as the chi-square statistic. The SMSR was chosen as the absolute fit because unlike the chi-square it is based on residuals. The SRMR adjusts the covariance matrices into standardized correlation matrices and provides information on the difference between expected and observed correlation matrices produced by the sample data. The SRMR is historically a very popular fit index and was also incorporated into this study because of its ability to handle moderate specification errors (Hu & Bentler, 1998). The residual SRMR is considered good it if is under .08 (Kline, 2010).

Another aspect of fit that was measured is incremental fit (Kline, 2010). Incremental fit is an indicator of baseline or relative fit, which assesses the difference between the independence and saturated models (Meyers et al., 2006). The independence model is created by assuming that none of the model variables have significant relationships. In contrast, the saturated model represents a perfect fit between all variables. The comparative fit index (CFI) was used to measure relative fit in this study because it is less likely to be impacted by sample size or model misspecification (Hooper et al., 2008). The CFI was also chosen because of its sensitivity to specification errors related specifically to the factor loadings themselves (Kline, 2010). Scores greater than .90 were considered good fit for the model.

Finally, the root mean square error of approximation (RMSEA) was used to represent a parsimony-corrected index, particularly because it provides a confidence interval to assist in interpretation (Kline, 2010). The RMSEA is also a non-central measure because it accounts for degrees of freedom. It was chosen for analysis based on its positive reputation and "sensitivity to the number of estimated parameters in the model" (Hooper et al., 2008, p. 54). Values produced by the RMSEA should fall between 0 and 1, with a lower number more ideal. The RMSEA was considered a good indicator of fit if it fell between 0 and 0.08.

In addition to assessing measures of fit, model testing involved analyzing the specific model parameters produced by the CFA (Schumacker & Lomax, 2010). The parameter estimates, critical values, and standard errors were all created by the output during model testing. Critical values illustrated whether a factor parameter or structure coefficient was significantly different from zero. Structure coefficients provided information on the relationship (i.e., magnitude and direction) between the different latent variables (Meyers et al., 2006). Significant structure coefficients that were positive in direction and had *r* values greater than .40 were considered good. Ultimately, a good overall measure of fit index as well as statistically significant structural coefficients between the different types of variables were used to determine the theoretical model with the best fit.

Model modification. This phase was necessary because none of the three theorized models demonstrated a strong fit with the sample data after model testing, which is not uncommon (Schumacker & Lomax, 2010). The two most appropriate models, the Integrated SNP/CHC model and the six-factor proposed model, had similar fit indices and required additional modification. Computer generated specification suggestions produced by the modification index (MI) of laaven in R were used to support decision making in the model modification phase. Only changes that were theoretically supported by research were allowed. After model modifications were complete, another CFA was conducted on each model to determine which had the most appropriate fit. Although this practice is commonplace, it should be noted that model modification increases the likelihood of having a Type 1 error. Specific modifications of the models are described in Chapter 4.

Description and diagram of each model.

Single-factor model. The single-factor model was the most simple of the three models and represented the idea that executive function is one large neuropsychological construct. As mentioned in Chapter 2, one trend in the field of school neuropsychology has been to conceptualize executive function as a unitary higher-order function (Flanagan & Harrison, 2012; Goldberg, 2001). Statisticians also suggest that a simple comparison model be used in the analysis procedures when conducting SEM (Schumacker & Lomax, 2010). In the single-factor model, all 29 subtests from the aforementioned measures were included under one latent variable titled executive function. The single-factor model is outlined fully in Figure 1.

Figure 1. Original single-factor model

Integrated SNP/CHC model. The second model that was tested in the research study was the Integrated SNP/CHC model (Miller, 2013). The Integrated SNP/CHC model functions as a framework to structure evaluations based upon cross-battery neuropsychological assessment procedures. This model was created as a way to hierarchically organize data with a purpose of connecting assessment results with appropriate interventions. The Integrated SNP/CHC model incorporates social-emotional, cognitive, achievement, and neuropsychological testing data into one overarching model. Its theoretical base is a combination of Lurian theory outlining neurocognitive strengths and weaknesses, the process approach, cross-battery assessment procedures, and traditional neuropsychological principles, such as Baddeley and Hitch's (2000) model of working memory and Mirsky's (Mirsky, Pascualvaca, Duncan, & French, 1999) conceptualization of attention. This model is represented visually in Figure 2.

Model adjustments. The model analyzed slightly altered the Integrated SNP/CHC model in a number of ways. First, the model only included subtests that comprised the executive function, working memory, and attention domains. Broad domains that did not apply to this study, such as sensorimotor functioning, were excluded from the analysis. The number of subtests selected to represent the latent variables in the Integrated SNP/CHC model was also reduced significantly by removing subtests that did not have strong representation in the archival data set. Thus, only subtests found on the D-KEFS, NEPSY-II, TEA-Ch, and WJ III COG NU were used in the analysis. Additionally, the current model removed processing speed from the facilitator/inhibitor latent variable. Evidence from recent factor analytic research supports the decreased role of processing speed in relation to executive functions (Fournier, 2014; McCabe et al., 2010). Subtests measuring processing speed were also removed from the analysis to ensure that the sample size was attainable by keeping the number of subtests in the model at a reasonable level.

Another alteration to the Integrated SNP/CHC structure was that the research model only represented classifications at the second-order level. The researcher needed to combine third-order classifications to ensure that there were an appropriate number of observed variables for each latent construct; however, an attempt was made to include a variety of third-order classification types so that multiple aspects of the skill were represented. While qualitative information and behavioral/emotional data are included in the Integrated SNP/CHC model, they were removed from this study based on the behavioral nature of those measures. Similarly, process scores were excluded from the analysis to ensure that similar types of scores were being compared. This should also decrease error and increase the likelihood that the model can be identified and tested (Schumacker & Lomax, 2010). Specific subtests from the chosen measures that were not incorporated into the current study can be found in Table 5.

Attention. Miller (2013) divides the facilitator/inhibitor factor of attention into selective/focused attention, sustained attention, and attentional control. These three aspects of attention were collapsed into one latent factor in the current study; however, every attempt was made to represent all three dimensions of attention, with a particular emphasis on including both auditory and visual formats when possible. Selective/focused attention involves the ability to attend to one salient piece of information or input when needed. Sustained attention requires that an individual continue to focus on important information or input for a longer duration of time. Subtests that measure selective/focused and sustained attention in the Integrated SNP/CHC model utilize auditory, visual, and combined auditory-visual formats. This aspect of attention was represented by the following subtests: Auditory Attention on the NEPSY-II; Code Transmission, Sky Search, and Sky Search DT on the TEA-Ch; and Pair Cancellation on the WJ III COG NU.

Attentional capacity is conceptualized in the Integrated SNP/CHC model as the amount of information that can be held in one's mind, thus measuring how much an individual can attend to during one period of time (Miller, 2013). Attentional capacity includes the third-tier classifications of memory span and meaningful memory. Both attentional capacity and sustained attention are categorized under the CHC broad classification of attention/concentration (AC). Subtests representing attentional capacity in the current model were Memory for Words on the WJ III COG NU and Narrative Memory Free Recall on the NEPSY-II.

Working memory. The facilitator/inhibitor of working memory measures how well an individual can hold information in his or her mind while manipulating it in some way (Miller, 2013). Working memory is conceptualized in CHC theory under the broad domain of Gsm. In the Integrated SNP/CHC model, working memory is measured in both visual and verbal formats. Subtests that assess working memory in the Integrated SNP/CHC model that were included in the current study are: Word List Interference on the NEPSY-II, Auditory Working Memory on the WJ III COG NU, and Numbers Reversed on the WJ III COG NU.

*Executive functions***.** In the Integrated SNP/CHC model, executive functions are classified as a separate basic cognitive process (Miller, 2013). This domain is made up of cognitive flexibility or set shifting; concept formation; problem solving, planning, and reasoning; and response inhibition. Cognitive flexibility is defined as an individual's ability to stop one task and then shift his or her focus to another task. This aspect of executive functioning was measured in the model with Color Word Interference Condition 4, Verbal Fluency Condition 3, and Trail Making Condition 4 on the D-KEFS; Inhibition-Switching and Response Set on the NEPSY-II; Creature Counting on the TEA-Ch; and Auditory Attention on the WJ III COG NU.

Another domain of executive functioning in the Integrated SNP/CHC model is concept formation (Miller, 2013). This skill is conceptualized as the ability to recognize concepts or patterns from various types of information. It also requires an individual to generate or represent concepts through classification of test stimuli. The latent variable of concept formation was measured in the research study by the D-KEFS Sorting Conditions 1 + 2 Description and Free Sorting Condition 1 Confirmed Correct Sorts, D-KEFS Twenty Questions, and NEPSY-II Animal Sorting tasks.

The third domain of executive functioning outlined in the Integrated SNP/CHC model combined the second order-classification of planning, problem solving, and fluid reasoning tasks (Miller, 2013). Fluid reasoning involves the ability to solve complex or novel problems using reasoning or logic. It is also the prime CHC measure of executive functioning (McGrew et al., 2007). Problem solving and inductive/deductive reasoning were represented in the analysis using scores from the D-KEFS Word Context, D-KEFS Tower, NEPSY-II Clocks, WJ III COG NU Concept Formation, and the WJ III COG NU Analysis/Synthesis subtests. This factor also included planning, which assesses how well a person can control initial behavioral responses and formulate strategies to complete a task or solve a problem in advance. Planning was represented in the current study by the Planning subtest on the WJ III COG NU.

Table 5

Subtests Removed from all Models for the Purposes of this Study

Test – Subtest	Reason for Removal
D-KEFS - Design Fluency Condition 3	Poor reliability, anticipated high collinearity
D-KEFS - Color Word Condition 4	Anticipated high collinearity, similar to NEPSY
D-KEFS - Proverbs	Age limit too high
D-KEFS - Twenty Questions - Initial Abstraction	Anticipated high correlation between task scores
D-KEFS - Twenty Questions - Total Questions	Anticipated high correlation between task scores
NEPSY-II - Statue	Age limit too low
NEPSY-II - Sentence Repetition	Age limit too low
TEA-Ch - Map Mission	Low reliability
TEA-Ch - Opposite Worlds	Anticipated high collinearity
TEA-Ch - Score	Ceiling effects, high collinearity
TEA-Ch - Score Dual Task (DT)	Ceiling effects, language, high collinearity
WJ III COG DS - Number Matrices	Too few cases available
WJ III COG DS - Number Series	Too few cases available
WJ III COG DS - Memory for Sentences	Too few cases available

Note. The TEA-Ch subtests were intentionally selected to include at least one subtest from each of test developers' designated three factors of attention.

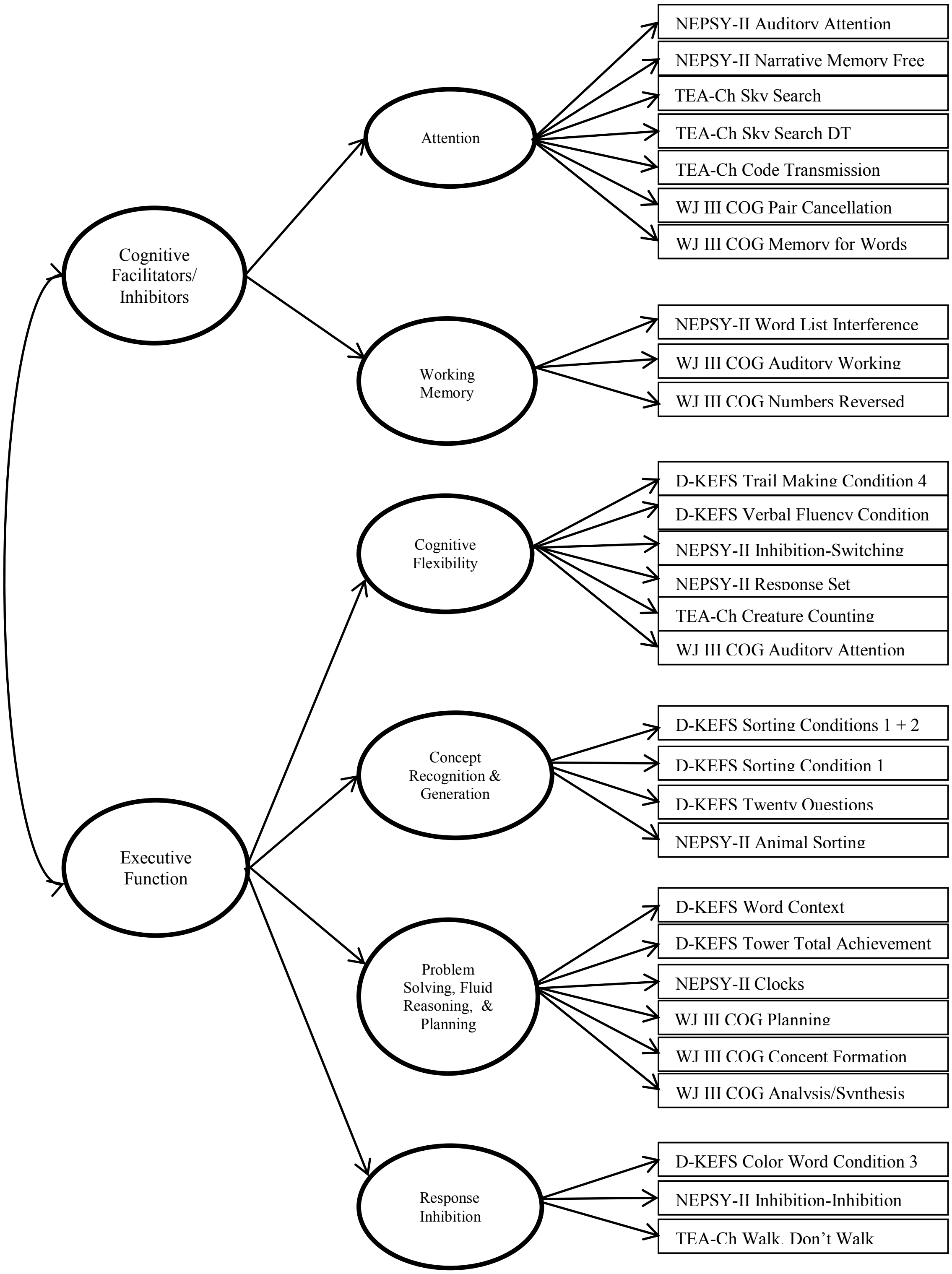

Figure 2. Original integrated SNP/CHC model

The final factor included in the executive functioning domain of the Integrated SNP/CHC model is response inhibition (Miller, 2013). Response inhibition measures the ability to inhibit one's natural inclination to produce a dominant response in favor of a less typical, or non- dominant response. Response inhibition was measured in verbal formats (i.e., D-KEFS Color Word Inhibition Condition 3, NEPSY-II Inhibition-Inhibition) and motoric tasks (i.e., TEA-Ch Walk, Don't Walk).

Six-factor model of executive functioning. The third model tested in the current study was a hybrid of multiple existing theories drawn from current research in executive functioning. As reviewed in Chapter 2, it is difficult to find comprehensive models of executive functioning that are testable and clearly delineated. A six-factor model was created by the researcher based on the overarching body of neuropsychological research on the topic, and not one specific theory. Anderson's (2008) key elements of executive function gleaned from the overall literature were loosely used as a framework for the third model in the research study. He describes executive functions in general terms as "anticipation and deployment of attention, impulse control and self-regulation, initiation of activity, working memory, mental flexibility and use of feedback, planning and organization, and selection of efficient problem-solving strategies" (Anderson, 2008, p. 4).

Additional support for the six-factor model was provided by previous research using SEM to examine the factor structure of executive functioning. The current study aimed to continue the work of Miyake and Friedman (2012) who analyzed the factor structure of executive functioning as defined by the three variables of set shifting, updating/monitoring working memory, and inhibition. Findings suggested that these components of executive function were distinct variables that still factored together as one latent factor. Miyake and Friedman noted that inhibition and set shifting may be more primary or pure components of executive function.

Research validating Miyake and Friedman's (2012) three-factor model has been primariliy conducted with college students and typically developing children. A three-factor model of executive functioning has only recieived minimal validation with a clinical sample of children (Avirett, 2011). Statisticians suggest that SEM models begin with simple models incorporating the fewest relevant factors and become more complex as future research is continued (Schumacker & Lomax, 2010). Thus, the six-factor model set out to expand the variables included in Miyake and Friedman's model to determine if other components of executive functioning (e.g., attention, planning, problem-solving) may contribute to the model using a clinical nature of children. Additional factors were also included to allow for comparison between the six-factor model and the Integrated SNP/CHC model. It was the hope of this researcher that the six-factor model would serve as a bridge connecting Miyake and Friedman's (2012) work to future studies.

The six-factor model was also created to include the variables of attention and working memory under the broad factor of executive function. These two constructs continue to be intensely debated by researchers in the field of neuropsychology who disagree on their role in higher-order cognition (see Baddeley & Hitch, 2000; Barkley, 1997; Dehn, 2008; Hunter & Sparrow, 2012; Norman & Shallice, 1980; Zhou, Chen, & Main, 2012). A review of the debate on the role of attention and working memory in executive functioning can be found in Chapter 2. The six-factor model conceptualized attention and working memory as separate variables under the latent factor of executive functions, which was in contrast to the idea of facilitators/inhibitors in the Integrated SNP/CHC model. The subtests chosen to represent the six latent variables in the third model were categorized using previous theoretical research and empirical support of what each individual subtest measures. Assessment subtests were also included based upon their role in the Integrated SNP/CHC model to allow for appropriate comparison. The six-factor model is diagrammed in Figure 3.

Impulse control and self-regulation. Impulse control and self-regulation are divided in the executive function literature between cognitive and behavioral components (Anderson, 2008; Hunter & Sparrow, 2012). Behavioral impulse control is generally observed in real-life settings and involves the ability to inhibit behavioral responses. It is sometimes referred to as hot cognition because it involves regulation of emotion; however, behavioral components of executive function or dysfunction are difficult to quantitatively measure in neuropsychological assessment. Instead, this factor was represented by tests measuring the cognitive ability of inhibition, which requires an individual to choose a non-dominant response over a dominant one. The following subtests were included in the latent factor of impulse control and self-regulation: D-KEFS Color Word Condition 3, NEPSY-II Inhibition-Inhibition, and TEA-Ch Walk, Don't Walk.

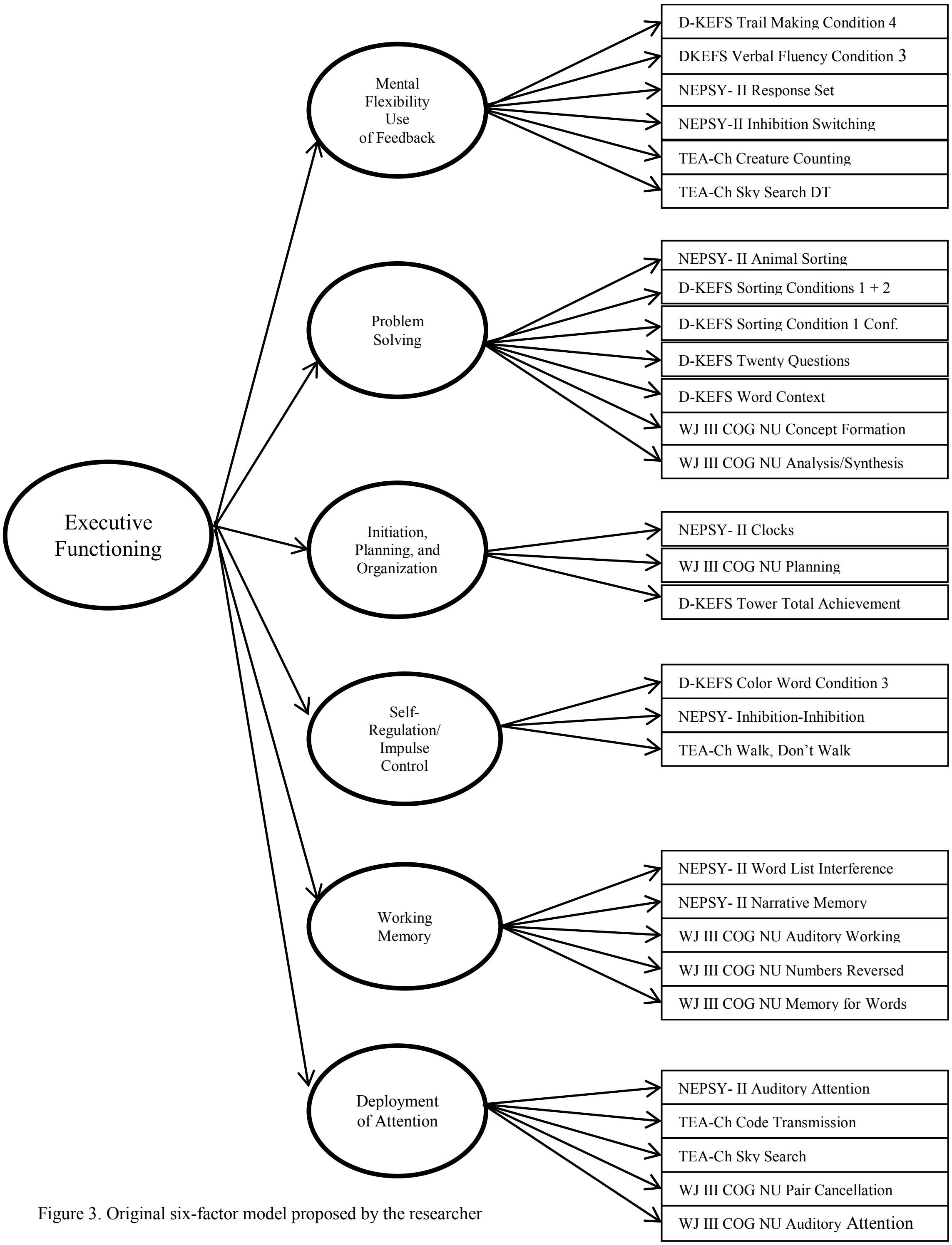

Figure 3. Original six-factor model proposed by the researcher

Initiation, planning, and organization. This domain represented the executive functioning skills required to complete tasks in an organized and successful way (Anderson, 2008). Initiation involves having the motivation to start an activity or goal. It is difficult to directly measure during formal assessment, but can be observed by completion of activities that require effort, planning, and organization. Similarly, planning and organization are executive skills that allow for efficient task completion. The initiation, planning, and organization domain was measured in the current study by the NEPSY-II Clocks, WJ III COG NU Planning, and D-KEFS Tower subtests. The NEPSY-II Clocks and WJ III COG NU Planning tasks require executive skills because individuals must think critically about the drawings or figures they need to produce before beginning the task if they are to be successful. On the WJ III COG NU, inability to plan and organize decreases the child's score because points are not awarded for lines that are traced twice or not traced at all. Finally, the D-KEFS Tower subtest measures these skills as individuals must plan out and produce moves that follow task rules by stacking the tower pieces appropriately. Poor planning and organization increases the number of moves and time required to create the final tower.

Problem solving. Problem solving is a complex concept that requires an individual be able to identify the problem, choose effective strategies, complete the appropriate steps to solve the problem, and evaluate self performance (Anderson, 2008; Zelazo, Carter, Reznick, & Frye, 1997). Examples of problem solving measured by this domain include inductive and deductive reasoning, concept formation, and decision-making. Inductive reasoning is a bottom up approach that involves applying a given rule to similar situations, whereas deductive reasoning is a top-down approach that requires a person determine the overall or general rule based on a set of specific information (Flanagan & Harrison, 2012). Reasoning skills were primarily represented by the WJ III COG NU Analysis/Synthesis and Concept Formation tests as well as the D-KEFS Twenty Questions and Word Context subtests. Another aspect of problem solving included in this domain is concept formation. Concept formation involves recognizing patterns and producing groups of items based on specific characteristics or rules. The DKEFS Sorting Conditions 1 + 2 Description and Condition 1 Confirmed Correct Sorts as well as the NEPSY-II Animal Sorting subtests represented this aspect of problem solving and decision-making.

Mental flexibility and use of feedback. The domain of mental flexibility and use of feedback represented the skills needed to incorporate and follow task rules that require an individual shift between activities or responses based on feedback (Anderson, 2008). This concept is also referred to as set shifting. Subtests incorporated into this variable were chosen to represent verbal, auditory, and motoric aspects of mental flexibility and use of feedback. On the D-KEFS Verbal Fluency Condition 3 task, individuals must quickly retrieve and produce words by switching back and forth between two semantic categories. The NEPSY-II Inhibition-Switching and TEA-Ch Creature Counting subtests use visual stimuli to prompt verbal responses based on the set rule. The D-KEFS Trail Making Condition 4 and TEA-Ch Sky Search subtests both have motoric components that require fine-motor skills while switching between different tasks or rules. Importantly, the D-KEFS Trail Making Condition 4 subtest also incorporates explicit feedback as individuals are not allowed to move on until a mistake identified by the examiner is corrected.

Working memory. Traditionally, working memory is conceptualized as the ability to mentally hold and manipulate various pieces of information over a brief period of time (Dehn, 2008). Disagreement exists on whether short-term memory and working memory are the same executive process. Both types of memory were incorporated into the domain of working memory in the six-factor model. The NEPSY-II Word List Interference, WJ III COG NU Auditory Working Memory, and WJ III COG NU Numbers Reversed tests were used to measure an individual's ability to manipulate information held in memory. In contrast, the WJ III COG NU Memory for Words and NEPSY-II Narrative Memory Free Recall subtests represented basic short-term memory processes. All of the tasks comprising the working memory domain were primarily auditory in nature.

Deployment of attention. The final domain included in the six-factor model was deployment of attention, which was used to represent multiple aspects of the construct of attention. Thus, sustained attention, focused/selective attention, and attentional control were all combined in this factor. The NEPSY-II Auditory Attention, TEA-Ch Code Transmission, TEA-Ch Sky Search, WJ III COG NU Pair Cancellation and Auditory Attention tasks were chosen to represent the attention factor. They are primarily measures of auditory attention; however, Sky Search and Pair Cancellation involve motoric responses.

Research Question

Various research procedures and statistical techniques were used to answer the following research question:

Which theory best describes the factor structure of executive functioning using a mixed-clinical sample of children?

a. A one-factor model?

b. A model based upon the Integrated SNP/CHC model?

c. A six-factor model proposed by the researcher?

Hypotheses

Three hypotheses were predicted based upon previous research on executive functioning using similar modeling and theoretical structures. First, the researcher expected that the one factor model would not fit the data well and would not be the most representative model using a clinical sample. This hypothesis was based on prior research supporting the notion that executive functioning is more complex than a one-factor model allows. One-factor models are also statistically unlikely to fit sample data based upon the multiple relationships (i.e., collinearity) between observed variables (Schumacker & Lomax, 2010). Instead, the Integrated SNP/CHC model was hypothesized as the proposed model of executive function that would be most representative of the sample data. This hypothesis was based upon research supporting working memory and attention as facilitators of more complex thinking documented in previous factor analytic studies using a clinical sample of children (Miller, 2013).

The third hypothesis was that the six-factor model would fit the data, but to a lesser degree than the Integrated SNP/CHC model. The six-factor model derived its backing from a wide body of neuropsychological research and prior SEM analyses using Miyake and Friedman's (2012) factor structure. Although many researchers still consider attention and working memory to be core components of executive function (Anderson, 2008), the expectation that the six-factor model would not be the best fit stemmed from the lack of factor analytic research studies specifically examining this model compared to the Integrated SNP/CHC model. The six-factor model was also constructed by the researcher, and thus may have been impacted more by research limitations than the Integrated SNP/CHC model.

Conclusion

This chapter outlined the methodology used in the research study with particular focus on participant characteristics, details about the measurements utilized, and specific components of the three models of executive functioning that were tested. This chapter also reviewed the data analysis procedure, specifically describing in detail the steps required for analysis using structural equation modeling. Additional information on the statistical procedures and findings are reviewed in more detail in the following chapter.

CHAPTER IV

RESULTS

The purpose of this study was to examine the factor structure of executive functioning using three theoretical models chosen to represent current views in the field of neuropsychology. This chapter presents the results of the statistical analyses. First, descriptive statistics and preliminary data analysis methods are presented, then a discussion of correlation, analysis of variance (ANOVA), and multivariate analysis of variance (MANOVA) is provided, and finally the primary SEM analyses are discussed.

Data Analysis

Data Selection

Data utilized in this study were drawn from a larger archival data set. Cases were selected for use in the analysis if they included scores for at least one of the 29 subtests in the models. Cases without any subtest data or that were outside of the identified age range of 8- to 16-years were removed. This resulted in a total of 300 cases for the preliminary and primary analyses.

Preliminary Analysis

Preliminary analyses were conducted using SPSS version 19, and included descriptive information such as participant demographics as well as bivariate correlations. Additionally, ANOVAs and MANOVAs were conducted to understand the impact of demographic variables on the neuropsychological measures. The specific results of the preliminary analyses are outlined below.

Outliers and missing values. The first phase of data analysis was to identify any possible outliers, specifically data points that fell outside of the acceptable range. As previously noted, this included removal of participants whose ages were not in the targeted age range. Two subtest scores were also removed prior to computing the preliminary analysis as they were beyond the possible range allowed on the measures (e.g., a 22 on a subtest only allowing scores between 1 and 19). Next, a missing values analysis indicated that 36.63% of all possible values were determined to be missing. Missing data for individual assessment subtests ranged from 25% to 74% and totaled 52% overall.

Based on the large amount of missing data, the researcher determined that a specific procedure for handling missing values in data analysis was necessary. Missing data are typically adjusted through either FIML or MI (Meyers et al., 2006). While MI uses multiple iterations to predict and then impute data into missing values, FIML skips over these values and instead incorporates all available information in a data set to simultaneously produce statistics (Allison, 2003). FIML was chosen during the modeling phase because of its ability to handle minor variations in normality as well as larger amounts of missing data (Enders, 2001). Spearman rank-order correlations between subtests were computed with non-imputed data to allow for comparison during the modeling phase; however, other preliminary analyses, such as the ANOVAs and

MANOVAs, were conducted with imputed data using MI because of sample size limitations.

Descriptives. Descriptive statistics were conducted to better understand the demographic characteristics of the sample used in the primary analysis. Frequency counts, percentages, and histograms were computed for all demographic variables. The sample was comprised of 300 participants overall. Sixty-two percent of the participants identified as male (n = 186), while 38% identified as female (n = 114). The majority of the children in the sample were from a Caucasian or European background (65.1%, n = 188). The remaining participants identified as Latino(a)/Hispanic (14.5%, n = 42), African American (8.0%, n = 23), Asian/Pacific Islander (2.4%, n = 7), Native American (1.0%, n = 3), and Other (9.0%, n = 26). In 3% of cases (n = 11), participant ethnicity was unknown.

Due to an imbalance between ethnicities in the sample, some categories were consolidated before conducting the preliminary analyses. The original groups of Caucasian and Latino(a)/Hispanic were retained, and an updated category of African American/Other was created from the remaining categories. The Latino(a)/Hispanic and African American/Other categories were intentionally kept separate to allow for possible language differences that may have existed between the two groups. The updated African American/Other category totaled 20.4% of the sample (n = 59). Additional information on ethnicity/race and gender can be found in Table 6.

Table 6

Frequencies and Percentages for Categorical Demographic Variables Ethnicity and Gender

	n	%
Ethnicity (Original)		
Caucasian/European	188	65.1
African American	23	8.0
Asian/Pacific Islander	7	2.4
Hispanic/Latino(a)	42	14.5
Native American	3	1.0
Other	26	9.0
Ethnicity (Consolidated)		
Caucasian/European	188	65.1
Hispanic/Latino	42	14.5
African American/Other	59	20.4
Gender		
Female	114	38.0
Male	186	62.0

Note. Frequencies not summing to N = 300 and percentages not summing to 100 reflect missing data.

The sample was also comprised of individuals with various disabilities, including many participants diagnosed with more than one disability. To better understand participant disability status, individuals were first placed into disability types regardless of possible co-morbid disabilities. This sorting procedure allowed for participants to belong to multiple groups. The majority of participants had received a diagnosis of a learning disability (59.0%, n = 177) and/or ADHD (49.3%, n = 148). Additional diagnoses included a neurological impairment (16.7%, n = 50), an emotional disability (e.g., depression, anxiety; 24.7%, n = 74), a language disability (11.7%, n = 35), an intellectual disability (4.7%, n = 14), an autism spectrum disorder (10.0%, n = 30), a generic medical condition (e.g., diabetes; 11.3%, n = 34), and another impairment not previously identified (.3%, n = 1).

The category of disability was then recoded to allow participants to belong to only one category each, since category overlap is not allowed in linear statistical analysis (Meyers et al., 2006). The following demographic variables were utilized in the preliminary analysis: learning disability (14.3%, n = 43), neurological impairment (8.3%, n = 25), ADHD (8%, n = 24), another single disability (8.7%, n = 26), ADHD plus a learning disability (14.3%, n = 43), other two disabilities (25.3%, n = 76), and three or more disabilities (21%, n = 63). Frequencies and percentages for both categories of disability type are listed in Table 7.

Table 7

Frequencies and Percentages for Disability Variables

	n	%
Learning Disability		
No Disability	123	41.0
Has Disability	177	59.0
Language Disability		
No Disability	265	88.3
Has Disability	35	11.7
Intellectual Disability		
No Disability	286	95.3
Has Disability	14	4.7

(Continued)

Neurological Impairment		
No Disability	250	83.3
Has Disability	50	16.7
Attention-Deficit/Hyperactivity Disorder		
No Disability	152	50.7
Has Disability	148	49.3
Autism Spectrum Disorder		
No Disability	270	90.0
Has Disability	30	10.0
Emotional Disability		
No Disability	226	75.3
Has Disability	74	24.7
Generic Medical Condition		
No Disability	266	88.7
Has Disability	34	11.3
Other Impairment		
No Disability	299	99.7
Has Disability	1	.3
Disability (Consolidated)		
Learning Disability	43	14.3
Neurological Impairment	25	8.3
Attention-Deficit/Hyperactivity Disorder	24	8.0
Other Single Disability (Not Already Listed)	26	8.7
ADHD and LD	43	14.3
Other Two Disabilities	76	25.3
Three or More Disabilities	63	21.0

Note. Frequencies not summing to $N = 300$ and percentages not summing to 100 reflect missing data.

Additional descriptive statistics were computed for the continuous variables of age and assessment subtest scores, including mean, standard deviation, and range. Participants in the sample ranged from ages 8 to 16 (*M* = 11.37, *SD* = 2.54). Frequency tables for the variable of age demonstrated that the distribution of the sample was slightly negatively skewed with the highest percentage of participants identified as 8 years of age. Demographics on participant age can be found in Table 8.

Table 8

Means and Standard Deviations for Continuous Demographic Variable Age

	N	*M*	*SD*	Min	Max
Age	300	11.37	2.54	8	16

The majority of the subtest scores demonstrated a span of 15 points or larger, which is the desired range to allow enough variance to include a variable in SEM (Schumacker & Lomax, 2010); however, four subtests included in the analysis (i.e., NEPSY-II Response Set, TEA-Ch Code Transmission, TEA-Ch Creature Counting, and D-KEFS Color Word Interference Condition 3) had scores that ranged 13 to 14 points. Overall, the majority of the mean subtest scores fell within the average range (e.g., scaled scores between 7 and 12) as outlined in the test manuals. The following subtests had raw mean scores outside of the expected range of performance: NEPSY-II Inhibition-Switching (*M* = 6.63, *SD* = 3.57), NEPSY-II Inhibition-Inhibition (*M* = 6.84, *SD* = 3.43), NEPSY-II Word List Interference (*M* = 6.98, *SD* = 3.74), TEA-Ch Code Transmission (*M* = 5.80, *SD* = 3.52), TEA-Ch Sky Search DT (*M* = 6.08, *SD* = 4.18), and D-KEFS

Trail Making Condition 4 (M = 6.17, SD = 3.87). Means and standard deviations of the imputed scores were found to be highly consistent with the raw data. Descriptive statistics outlining the imputed and non-imputed means and standard deviations of the 29 subtest scores are located in Table 9.

Table 9

Non-Imputed and Imputed Means and Standard Deviations for the Woodcock Johnson Tests of Cognitive Abilities, Third Edition, Normative Update (WJ III COG NU), A Developmental Neuropsychological Assessment, Second Edition (NEPSY-II), the Test of Everyday Attention for Children (TEA-Ch), and the Delis-Kaplan Executive Function System (D-KEFS) Items

	Non-Imputed			*Imputed*		
	n	*M*	*SD*	*n*	*M*	*SD*
WJ III COG NU Pair Cancellation	148	91.38	9.98	300	91.18	10.38
NEPSY-II Auditory Attention	223	7.42	3.95	300	7.19	3.93
TEA-Ch Code Transmission	84	5.80	3.52	300	5.36	3.13
TEA-Ch Sky Search	105	8.14	3.73	300	8.10	4.29
TEA-Ch Sky Search DT	91	6.08	4.16	300	6.27	4.45
WJ III COG NU Memory for Words	106	85.77	16.41	300	85.04	17.11
NEPSY- II Narrative Memory Free Recall	143	8.36	3.63	300	8.59	3.78
WJ III COG NU Numbers Reversed	150	88.02	16.91	300	88.29	17.35

(Continued)

WJ III COG NU Auditory Working Memory	143	91.48	16.44	300	91.41	17.24
NEPSY-II Word List Interference	125	6.98	3.74	300	7.11	3.75
WJ III COG NU Auditory Attention	133	93.12	16.39	300	91.38	18.03
NEPSY-II Response Set	216	7.76	3.51	300	7.63	3.63
NEPSY-II Inhibition-Switching	204	6.63	3.57	300	6.99	3.73
TEA-Ch Creature Counting	95	7.68	3.51	300	7.59	3.54
D-KEFS Verbal Fluency Condition 3	209	8.02	3.44	300	7.98	3.35
D-KEFS Trail Making Condition 4	224	6.17	3.87	300	5.93	3.87
NEPSY-II Animal Sorting	145	7.75	3.99	300	7.63	4.17
D-KEFS Sorting Conditions 1 + 2 Description	137	7.68	3.45	300	7.53	3.38
D-KEFS Sorting Condition 1 Confirmed Correct Sorts	143	8.47	3.18	300	8.29	3.10

(Continued)

D-KEFS Twenty Questions	143	8.82	3.84	300	8.50	3.88
WJ III COG NU Planning	77	91.87	14.38	300	89.26	14.52
NEPSY-II Clocks	113	7.69	4.26	300	7.83	4.66
D-KEFS Tower Total Achievement	130	9.56	3.16	300	9.49	3.29
WJ III COG NU Concept Formation	162	92.04	16.08	300	91.25	15.41
WJ III COG NU Analysis/Synthesis	144	91.33	16.45	300	91.42	16.66
D-KEFS Word Context	134	7.35	3.62	300	7.06	3.71
NEPSY-II Inhibition-Inhibition	193	6.84	3.43	300	7.01	3.50
TEA-Ch Walk, Don't Walk	80	8.63	5.05	300	8.79	5.12
D-KEFS Color Word Condition 3	205	7.44	3.71	300	7.23	3.70

Note. *N*s not equal to 300 reflect missing data.

The assumptions of normality and linearity were examined visually in scatterplots and box plots as well as through tests of skewness and kurtosis. All of the subtests displayed levels of skewness below 2 and kurtosis below 3 with the exception of WJ III COG NU Planning. Although these numbers are higher than more conservative estimates, Rhu (2011) examined SEM models with deviations from normality and noted that the cutoff range for Type 1 errors in modeling is 2 or below for skewness and 7 or below for kurtosis. Visual inspection of data indicated that some variables had minor deviations from normality, which is consistent with the slight negative skew previously described by subtest mean scores in the low average range. This pattern is explained by the clinical nature of the data set as children with disabilities often perform below average on tasks of executive functioning (Hunter & Sparrow, 2012). Some researchers suggest transforming data to decrease issues related to non-normality (Meyers et al., 2006). Even so, data transformation of only certain variables in an analysis makes it difficult to compare items in a model as they become scaled differently (Kline, 2010). Further, transformation decreases the researcher's ability to make generalizations regarding the sample data. Thus, data were not transformed so that the subtest variables represented the true neuropsychological performance of children with disabilities. Additionally, SEM is a robust statistical technique and is capable of handling slight deviations from normality.

Preliminary analyses were computed to obtain information on the relationship between the demographic variables of gender, ethnicity, and sex. Spearman rank-order correlations, ANOVAs, and MANOVAs were conducted to examine any performance differences between demographic variables (e.g., ethnicity, gender) and continuous variables, such as age and subtest score. The alpha level for all preliminary analyses was set at .05. Cross-tabulations using the chi-square statistic documented no significant relationship between ethnicity and gender ($\chi^2(2, n = 300) = 2.32, p = .313$), gender and disability type ($\chi^2(6, n = 300) = 4.46, p = .614$), or ethnicity and type of disability ($\chi^2(12, n = 300) = 10.84, p = .542$).

Results from a one-way ANOVA found no significant age differences between ethnic groups ($F(2, 297) = .946$, $p = .390$) or between genders ($F(1, 298) = .147$, $p = .701$) confirming that the distribution of age was consistent across both ethnicity and gender. Further, a one-way ANOVA comparing age and disability type indicated a significant difference between groups ($F(6, 293) = 4.02$, $p = .001$). Tukey's post-hoc analysis confirmed that children with a neurological impairment were significantly older than children in all other disability types. These findings are illustrated in Table 10.

Table 10

Means and Standard Deviations for Age by Disability

	n	*M*	*SD*	*F*	*p*
Disability				4.02	.001
Learning Disability	43	11.09	2.64		
Neurological Impairment*	25	13.32	2.58		
Attention-Deficit/Hyperactivity Disorder	24	10.04	2.18		
Other Single Disability (Not Already Listed)	26	11.12	2.61		
ADHD and LD	43	11.16	2.53		
Other Two Disabilities	76	11.53	2.43		
Three or More Disabilities	63	11.33	2.32		

Note. *Mean age of neurological impairment significantly different from all other disability types.

Spearman rank-order correlations were conducted to determine the degree of relationship between each of the different subtests representing the four neuropsychological measures. Spearman rank-order correlations are less impacted by violations in normality making them the preferred statistic for this analysis (Meyers et al., 2006). Moderate positive correlations ranging from .30 to .50 were observed between many subtests comprising latent variables in the preliminary analyses. Additional strong correlations were observed between subtests in the models. Notable strong positive correlations were observed between subtests on the WJ III COG NU, including Auditory Working Memory and Memory for Words ($r = .61$, $p < .001$), Auditory Working Memory and Concept Formation ($r = .50$, $p < .001$), and Concept Formation and Analysis/Synthesis ($r = .50$, $p < .001$). The only other strong positive correlations noted between subtests on the same measure were between the D-KEFS Sorting Conditions 1 + 2 Description and D-KEFS Condition 1 Confirmed Correct Sorts subtests ($r = .85$, $p < .001$). Spearman rank-order correlations can be found in Tables 11 through 14.

Other significant positive correlations indicated that tests from the WJ III COG NU were highly related to subtests from other measures. For example, strong positive correlations were noted between the WJ III COG NU Memory for Words test and the NEPSY-II Word List Interference subtest ($r = .58$, $p < .001$), the TEA-Ch Code Transmission subtest ($r = .51$, $p < .001$), and TEA-Ch Sky Search DT ($r = .53$, $p < .001$). Additionally, strong correlations were noted between the WJ III COG NU Concept Formation test and NEPSY-II Clocks ($r = .53$, $p < .001$), WJ III COG NU Concept Formation and TEA-Ch Creature Counting ($r = .51$, $p < .001$), WJ III COG NU Analysis/Synthesis and TEA-Ch Creature Counting ($r = .53$, $p < .001$), and WJ III COG NU Concept Formation with D-KEFS Sorting Conditions 1 + 2 Description ($r = .69$, $p < .001$) as well as D-KEFS Sorting Condition 1 Confirmed Correct Sorts ($r = .63$, $p < .001$).

Significant positive correlations were also observed between subtests on other measures including strong relationships between the NEPSY-II Animal Sorting task and the D-KEFS Sorting Conditions 1 + 2 Description ($r = .57$, $p < .001$) as well as the D-KEFS Sorting Condition 1 Confirmed Correct Sorts subtest ($r = .55$, $p < .001$). Non-significant negative correlations were also observed during the preliminary analysis; however, there were no negative correlations observed between subtests comprising the factors of the final Integrated SNP/CHC model or the six-factor model proposed by the researcher. Spearman rank-order correlations comparing items between different measures can be found in Tables 15 through 20. All subtests were initially allowed inclusion in the models.

Table 11

Spearman Rank-Order Correlations Among Items on the Test of Everyday Attention for Children (TEA-Ch)

	Code Transmission	Walk, Don't Walk	Creature Counting	Sky Search	Sky Search DT
Code Transmission	---				
Walk, Don't Walk	.357**	---			
Creature Counting	.308**	.024	---		
Sky Search	.111	.147	.209*	---	
Sky Search DT	.198	.189	.355**	.294**	---

Note. *$p < .05$, **$p < .01$

Table 12

Spearman Rank-Order Correlations Among Items on the Woodcock Johnson Tests of Cognitive Abilities, Third Edition, Normative Update (WJ III COG NU)

	Auditory Attention	Memory for Words	Numbers Reversed	Auditory Working Memory	Concept Formation	Analysis/ Synthesis	Pair Cancellation	Planning
Auditory Attention	---							
Memory for Words	.326**	---						
Numbers Reversed	.226**	.404**	---					
Auditory Working Memory	.081	.610**	.412**	---				
Concept Formation	.172	.501**	.312**	.452**	---			
Analysis/Synthesis	.288**	.382**	.462**	.460**	.503**	---		
Pair Cancellation	.137	.284**	.294**	.238*	.326**	.487**	---	
Planning	.377**	.183*	.368**	.338*	.398**	.324**	.216	---

Note. $^{*}p < .05$, $^{**}p < .01$

Table 13

Spearman Rank-Order Correlations Among Items on A Developmental Neuropsychological Assessment, Second Edition (NEPSY-II)

	Auditory Attention	Response Set	Inhibition-Inhibition	Inhibition-Switching	Clocks	Word-List Interference	Narrative Memory	Animal Sorting
Auditory Attention	---							
Response Set	.413**	---						
Inhibition-Inhibition	.310**	.256**	---					
Inhibition-Switching	.211**	.226**	.447**	---				
Clocks	.263**	.294**	.165	.167	---			
Word-List Interference	.154	.214*	.304**	.212*	.155	---		
Narrative Memory-Free Recall	.004	.098	.048	.165	.347**	.168	---	
Animal Sorting	.244**	.071	.154	.141	.274*	.133	.192	---

Note. $*p < .05$, $**p < .01$

Table 14

Spearman Rank-Order Correlations Among Items on the Delis-Kaplan Executive Function System (D-KEFS)

	Verbal Fluency Condition 3	Trail Making Test	Sorting Conditions 1 + 2	Sorting Confirmed Correct	Twenty Questions	Word Context	Tower Total Achievement	Color Word Condition 3
Verbal Fluency Condition 3	---							
Trail-Making Test Condition 4	.257**	---						
Sorting Conditions 1 + 2 Description	.384**	.247**	---					
Sorting Confirmed Correct Sorts	.381**	.240**	.847**	---				
Twenty Questions	.227	.190*	.368**	.371**	---			
Word Context	.305**	.209*	.375**	.426**	.371**	---		
Tower Total Achievement	.125	.089	.147	.118	.176	.240*	---	
Color Word Condition 3	.335**	.321**	.282**	.236**	.099*	.074	.012	---

Note. *$p < .05$, **$p < .01$

Table 15

Spearman Rank-Order Correlations Between Items on the Woodcock Johnson Tests of Cognitive Abilities, Third Edition, Normative Update (WJ III COG NU) and A Developmental Neuropsychological Assessment, Second Edition (NEPSY-II)

	NEPSY-II Auditory Attention	NEPSY-II Response Set	NEPSY-II Inhibition-Inhibition	NEPSY-II Inhibition-Switching	NEPSY-II Clocks	NEPSY-II Word-List Interference	NEPSY-II Narrative Memory	NEPSY-II Animal Sorting
WJ III COG NU Auditory Attention	.312**	.171	.171	.233*	-.032	.228	.174	.248*
WJ III COG NU Memory for Words	.226*	.238*	.357**	.309**	.296*	.576**	.232	.315*
WJ III COG NU Numbers Reversed	.190*	.137	.440**	.365**	.169	.269*	-.009	.255*
WJ III COG NU Auditory Working Memory	.057	.050	.267**	.203*	.361**	.415**	.217	.412**
WJ III COG NU Concept Formation	.335**	.213*	.404**	.207*	.525**	.447**	.317**	.488**
WJ III COG NU Analysis/Synthesis	.159	.050	.455**	.336**	.447**	.298*	.309*	.477**
WJ III COG NU Pair Cancellation	.299*	.253**	.358**	.391**	.308*	.429**	.184	.230*
WJ III COG NU Planning	.275*	.159	.224	.279*	.194	.061	.073	.434**

Note. $*p < .05$, $**p < .01$

Table 16

Spearman Rank-Order Correlations Between Items on the Woodcock Johnson Tests of Cognitive Abilities, Third Edition, Normative Update (WJ III COG NU) and Test of Everyday Attention for Children (TEA-Ch)

	TEA-Ch Code Transmission	TEA-Ch Walk, Don't Walk	TEA-Ch Creature Counting	TEA-Ch Sky Search	TEA-Ch Sky Search DT
WJ III COG NU Auditory Attention	.100	.179	.052	.018	.264
WJ III COG NU Memory for Words	.510**	-.096	.369*	.113	.531**
WJ III COG NU Numbers Reversed	.315*	.465**	.322*	.047	.316*
WJ III COG NU Auditory Working Memory	.388*	-.129	.426**	.136	.345*
WJ III COG NU Concept Formation	.364*	.208	.509**	.284*	.314*
WJ III COG NU Analysis/Synthesis	.283	.074	.525**	.225	.144
WJ III COG NU Pair Cancellation	.236	.121	.296	.456**	.248
WJ III COG NU Planning	.390	.241	.072	.384	.318

Note. $^{*}p < .05$, $^{**}p < .01$

Table 17

Spearman Rank-Order Correlations Between Items on the Woodcock Johnson Tests of Cognitive Abilities, Third Edition, Normative Update (WJ III COG NU) and Delis-Kaplan Executive Function System (D-KEFS)

	D-KEFS Verbal Fluency Condition 3	D-KEFS Trail Making Test	D-KEFS Sorting Conditions 1 + 2	D-KEFS Sorting Confirmed Correct	D-KEFS Twenty Questions	D-KEFS Word Context	D-KEFS Tower Total Achievement	D-KEFS Color Word Condition 3
WJ III COG NU Auditory Attention	.081	.236*	.124	.007	.095	.014	.034	.273**
WJ III COG NU Memory for Words	.275*	.317**	.501**	.383**	.245	.472**	.309*	.147
WJ III COG NU Numbers Reversed	.193*	.378**	.271*	.314*	.363**	.265*	.101	.205*
WJ III COG NU Auditory Working Memory	.393**	.317**	.387**	.327**	.420**	.404**	.329*	.057
WJ III COG NU Concept Formation	.343**	.358**	.686**	.626**	.397**	.362**	.247*	.293**
WJ III COG NU Analysis/Synthesis	.286**	.305**	.271*	.134	.279*	.306**	.010	.188
WJ III COG NU Pair Cancellation	.355**	.289**	.142	.136	.058	.088	.014	.390**
WJ III COG NU Planning	.063	.051	.188	.182	.308	.262	.264	.363*

Note. $*p < .05$, $**p < .01$

Table 18

Spearman Rank-Order Correlations Between Items on A Developmental Neuropsychological Assessment, Second Edition (NEPSY-II) and the Test of Everyday Attention for Children (TEA-Ch)

	NEPSY-II Auditory Attention	NEPSY-II Response Set	NEPSY-II Inhibition-Inhibition	NEPSY-II Inhibition-Switching	NEPSY-II Clocks	NEPSY-II Word-List Interference	NEPSY-II Narrative Memory	NEPSY-II Animal Sorting
TEA-Ch Code Transmission	.106	.120	.269*	.340*	.175	.351	.015	.235
TEA-Ch Walk, Don't Walk	.356*	.220	.413**	.310*	.184	.271	.150	.407*
TEA-Ch Creature Counting	.145	.062	.314*	.455**	.298	.321	.131	.311*
TEA-Ch Sky Search	.330**	.126	.171	.224	.044	.191	.245	.280
TEA-Ch Sky Search DT	-.019	.187	.448**	.355**	.043	.420*	.244	.335*

Note. *$p < .05$, **$p < .01$

Table 19

Spearman Rank-Order Correlations Between Items on A Developmental Neuropsychological Assessment, Second Edition (NEPSY-II) and the Delis-Kaplan Executive Function System (D-KEFS)

	NEPSY-II Auditory Attention	NEPSY-II Response Set	NEPSY-II Inhibition-Inhibition	NEPSY-II Inhibition-Switching	NEPSY-II Clocks	NEPSY-II Word-List Interference	NEPSY-II Narrative Memory	NEPSY-II Animal Sorting
D-KEFS Verbal Fluency Condition 3	.073	.040	.179*	.151	.107	.459**	.176	.300**
D-KEFS Trail Making Test Condition 4	.114	.154*	.412**	.191*	.267*	.126	.027	.269**
D-KEFS Sorting Conditions 1 + 2 Description	.125	.122	.223	.235*	.253	.333*	.311*	.568**
D-KEFS Sorting Condition 1 Confirmed Correct	.175	.131	.172	.311**	.224	.245	.197	.554**
D-KEFS Twenty Questions	.250*	.128	.192	.238*	.114	.088	-.051	.261*
D-KEFS Word Context	-.068	-.088	.236*	.192	.202	.371**	.210	.413**
D-KEFS Tower Total Achievement	.126	.089	.293*	.194	.108	.172	.201	-.048
D-KEFS Color Word Condition 3	.129	.208	.378**	.247**	.003	.200	-.015	.187

Note. *$p < .05$, **$p < .01$

Table 20

Spearman Rank-Order Correlations Between Items on the Test of Everyday Attention for Children (TEA-Ch) and the Delis-Kaplan Executive Function System (D-KEFS)

	D-KEFS Verbal Fluency Condition 3	D-KEFS Trail Making Test	D-KEFS Sorting Conditions 1 + 2	D-KEFS Sorting Confirmed Correct	D-KEFS Twenty Questions	D-KEFS Word Context	D-KEFS Tower Total Achievement	D-KEFS Color Word Condition 3
TEA-Ch Code Transmission	.308*	.356**	.250	.227	.183	.179	-.032	.141
TEA-Ch Walk, Don't Walk	.243*	.276*	.172	.232	.320*	.061	.103	.314*
TEA-Ch Creature Counting	.041	.129	.222	.216	.235	.231	.166	.003
TEA-Ch Sky Search	.343**	.271**	.270*	.192	.032	.050	.304*	.336**
TEA-Ch Sky Search DT	.189	.258*	.290*	.321*	.057	.173	-.025	.329**

Note. $*p < .05$, $**p < .01$

Spearman rank-order correlations were also conducted to determine the degree of relationship between age and subtest scores. Age was significantly negatively correlated with three subtests, the WJ III COG NU Pair Cancellation ($r = -.33$, $p < .001$), D-KEFS Verbal Fluency Condition 3 ($r = -.14$, $p = .040$), and D-KEFS Color Word Condition 3 ($r = -.18$, $p = .010$), indicating that older participants scored significantly lower on these items compared to younger children. Significant positive correlations were found between age and the TEA-Ch Sky Search ($r = .30$, $p = .004$) and WJ III COG NU Auditory Attention ($r = .19$, $p = .028$) subtests. Older participants tended to perform better on these subtests. Correlations between age and subtests are listed in Table 21.

Table 21

Spearman Rank-Order Correlations for the Woodcock Johnson Tests of Cognitive Abilities, Third Edition, Normative Update (WJ III COG NU), A Developmental Neuropsychological Assessment, Second Edition (NEPSY-II), the Test of Everyday Attention for Children (TEA-Ch), and the Delis-Kaplan Executive Function System (D-KEFS) Subtests by Age

Subtest	Age
WJ III COG NU Auditory Attention	.190*
WJ III COG NU Memory for Words	.084
WJ III COG NU Numbers Reversed	.063
WJ III COG NU Auditory Working Memory	-.151

(Continued)

WJ III COG NU Concept Formation	-.028
WJ III COG NU Analysis Synthesis	-.161
WJ III COG NU Pair Cancellation	-.327**
WJ III COG NU Planning	-.082
NEPSY-II Auditory Attention	.058
NEPSY-II Response Set	.080
NEPSY-II Inhibition-Inhibition	-.010
NEPSY-II Inhibition-Switching	-.020
NEPSY-II Clocks	.018
NEPSY-II Word List Interference	-.110
NEPSY-II Narrative Memory Free Recall	-.030
NEPSY-II Animal Sorting	-.108
TEA-Ch Code Transmission	.178
TEA-Ch Walk, Don't Walk	-.036
TEA-Ch Creature Counting	.194
TEA-Ch Sky Search	.033
TEA-Ch Sky Search Dual Task	.296**

(Continued)

D-KEFS Verbal Fluency Condition 3	-.142*
D-KEFS Trail Making Condition 4	-.003
D-KEFS Sorting Conditions 1 + 2 Description	.036
D-KEFS Sorting Condition 1 Confirmed Correct Sorts	.090
D-KEFS Twenty Questions	-.075
D-KEFS Word Context	-.030
D-KEFS Tower Total Achievement	-.075
D-KEFS Color Word Condition 3	-.180*

Note. $*p < .05$, $**p < .01$

Additional preliminary analyses were conducted to compare the mean subtest scores of each measure in the sample with the categorical variables of age, gender, ethnicity, and disability type. MANOVAs comparing subtest scores for male and female participants indicated a significant multivariate effect (Wilks' $\lambda = .762$, $F(29, 270) = 2.910$, $p < .001$, $\eta^2_p = .238$). Univariate ANOVAs confirmed that males performed more poorly than females on the NEPSY-II Word List Interference ($F(1, 298) = 4.043$, $p = .045$, $\eta^2_p = .013$) and NEPSY-II Animal Sorting ($F(1, 298) = 5.220$, $p = .023$, $\eta^2_p = .017$) subtests. In contrast, female participants received lower scores than males on TEA-Ch Sky Search DT ($F(1, 298) = 17.669$, $p < .001$, $\eta^2_p = .056$).

Nonparametric Kruskal-Wallis tests were computed for comparison and produced the same results as the parametric tests. Mean subtest scores by gender along with the results of univariate ANOVAs can be found in Table 22.

Table 22

Means and Standard Deviations for the Woodcock Johnson Tests of Cognitive Abilities, Third Edition, Normative Update (WJ III COG NU), A Developmental Neuropsychological Assessment, Second Edition (NEPSY-II), the Test of Everyday Attention for Children (TEA-Ch), and the Delis-Kaplan Executive Function System (D-KEFS) Items by Gender

	n	*M*	*SD*	*F*	*p*
WJ III COG NU Auditory Attention				1.11	.316
Female	114	92.71	18.49		
Male	186	90.56	17.74		
WJ III COG NU Memory for Words				.00	.989
Female	114	85.03	16.32		
Male	186	85.05	17.62		
WJ III COG NU Numbers Reversed				.11	.742
Female	114	87.87	17.06		
Male	186	88.55	17.56		
WJ III COG NU Auditory Working Memory				.15	.704
Female	114	91.89	18.63		
Male	186	91.11	16.37		
WJ III COG NU Concept Formation				1.57	.211
Female	114	92.68	15.03		
Male	186	90.38	15.61		

(Continued)

WJ III COG NU Analysis/Synthesis				3.02	.083
Female	114	93.54	17.33		
Male	186	90.11	16.15		
WJ III COG NU Pair Cancellation				.63	.426
Female	114	90.57	11.23		
Male	186	91.55	9.83		
WJ III COG NU Planning				.19	.663
Female	114	88.79	15.47		
Male	186	89.54	13.94		
NEPSY-II Auditory Attention				1.60	.207
Female	114	7.55	3.87		
Male	186	6.96	3.96		
NEPSY-II Response Set				2.76	.098
Female	114	8.07	3.64		
Male	186	7.35	3.61		
NEPSY-II Inhibition-Inhibition				.19	.665
Female	114	6.89	3.79		
Male	186	7.06	3.31		
NEPSY-II Inhibition-Switching				.21	.645
Female	114	6.86	3.90		
Male	186	7.06	3.62		
NEPSY-II Clocks				.63	.426
Female	114	7.55	4.79		
Male	186	7.99	4.58		

(Continued)

NEPSY-II Word List Interference				4.04	.045
Female	114	7.67	3.75		
Male	186	6.77	3.72		
NEPSY-II Narrative Memory Free Recall				.08	.784
Female	114	8.67	3.65		
Male	186	8.54	3.87		
NEPSY-II Animal Sorting				5.22	.023
Female	114	8.32	4.12		
Male	186	7.20	4.16		
TEA-Ch Code Transmission				2.43	.120
Female	114	5.74	3.12		
Male	186	5.12	3.40		
TEA-Ch Walk, Don't Walk				1.25	.265
Female	114	8.37	4.92		
Male	186	9.05	5.24		
TEA-Ch Creature Counting				3.20	.074
Female	114	8.05	3.44		
Male	186	7.30	3.58		
TEA-Ch Sky Search				.39	.562
Female	114	7.92	4.56		
Male	186	8.22	4.05		
TEA-Ch Sky Search DT				17.67	< .001
Female	114	4.93	3.95		
Male	186	7.10	4.55		

(Continued)

D-KEFS Verbal Fluency Condition 3				.78	.378
Female	114	8.20	3.01		
Male	186	7.85	3.56		
D-KEFS Trail Making Condition 4				2.06	.152
Female	114	6.34	4.02		
Male	186	5.68	3.77		
D-KEFS Sorting Conditions 1 + 2				.18	.673
Female	114	7.42	3.31		
Male	186	7.59	3.48		
D-KEFS Sorting Condition 1 Confirmed Correct Sorts				2.57	.110
Female	114	7.92	3.11		
Male	186	8.51	3.09		
D-KEFS Twenty Questions				.22	.638
Female	114	8.63	3.74		
Male	186	8.41	3.98		
D-KEFS Word Context				.33	.568
Female	114	6.90	3.64		
Male	186	7.16	3.76		
D-KEFS Tower Total Achievement				.81	.370
Female	114	9.27	3.47		
Male	186	9.62	3.18		
D-KEFS Color Word Condition 3				2.48	.117
Female	114	6.80	3.52		
Male	186	7.49	3.79		

Note. Significant Multivariate Effect: Wilks' $\lambda = .762$, $F(29, 270) = 2.910$, $p < .001$, $\eta^2_p = .238$.

Consistent with gender, significant differences in performance were observed between ethnic groups (Wilks' $\lambda = .448$, $F(58, 538) = 4.587$, $p < .001$, $\eta^2_p = .331$) using Tukey's post-hoc comparisons. Children from a Caucasian/European background demonstrated higher performance on several subtests compared to the other two ethnicities sampled. On the WJ III COG NU Planning ($F(2, 297) = 3.501$, $p = .031$, $\eta^2_p = .023$) and NEPSY-II Word List Interference tasks ($F(2, 297) = 3.379$, $p = .035$, $\eta^2_p = .022$), participants who identified as Latino(a)/Hispanic obtained scores that were significantly lower than those from a Caucasian/European background. Similarly, both African American/Other and Latino(a)/Hispanic participants demonstrated decreased performance compared to Caucasian/European children on the D-KEFS Twenty Questions ($F(2, 287) = 7.588$, $p = .001$, $\eta^2_p = .049$) and WJ III COG NU Concept Formation $F(2, 287) = 10.190$, $p < .001$, $\eta^2_p = .064$) subtests. On two subtests, NEPSY-II Animal Sorting ($F(2, 287) = 5.461$, $p = .005$, $\eta^2_p = .035$) and D-KEFS Word Context ($F(2, 287) = 4.516$, $p = .012$, $\eta^2_p = .030$), the African American/Other group performed significantly more poorly than the Caucasian/European group.

Three other subtests yielded significant results among ethnic groups. On the WJ III COG NU Memory for Words task ($F(2, 287) = 4.832$, $p = .009$, $\eta^2_p = .032$), Latino(a)/Hispanic children scored well below both the African American/Other and Caucasian/European groups. Finally, participants who identified as Latino(a)/Hispanic performed better than African American/Other and Caucasian/European participants on TEA-Ch Code Transmission ($F(2, 287) = 10.675$, $p < .001$, $\eta^2_p = .067$), and better than

Caucasian/European children on WJ III COG NU Numbers Reversed subtest (F(2, 287) = 5.942, p = .003, η^2_p = .038). Nonparametric tests computed for ethnicity and test performance indicated similar patterns of performance. A full list of the univariate results by ethnicity can be found in Table 23.

Table 23

Means and Standard Deviations for the Woodcock Johnson Tests of Cognitive Abilities, Third Edition, Normative Update (WJ III COG NU), A Developmental Neuropsychological Assessment, Second Edition (NEPSY-II), the Test of Everyday Attention for Children (TEA-Ch), and the Delis-Kaplan Executive Function System (D-KEFS) Items by Ethnicity

	n	*M*	*SD*	*F*	*p*
WJ III COG NU Auditory Attention				1.48	.231
Caucasian/European	190	91.13	17.73		
Hispanic/Latino	44	88.25	20.11		
African American/Other	66	94.17	17.29		
WJ III COG NU Memory for Words				4.83	.009
Caucasian/European	190	86.03	17.51		
Hispanic/Latino	44	77.80	14.67		
African American/Other	66	87.03	16.44		
WJ III COG NU Numbers Reversed				5.94	.003
Caucasian/European	190	85.81	17.57		
Hispanic/Latino	44	94.48	16.46		
African American/Other	66	91.32	15.95		
WJ III COG NU Auditory Working Memory				9.77	< .001
Caucasian/European	190	94.65	16.84		
Hispanic/Latino	44	86.50	15.38		

(Continued)

African American/Other	66	85.35	17.37		
WJ III COG NU Concept Formation				10.19	< .001
Caucasian/European	190	94.22	14.27		
Hispanic/Latino	44	86.52	15.70		
African American/Other	66	85.88	16.34		
WJ III COG NU Analysis/Synthesis				1.99	.139
Caucasian/European	190	92.70	16.46		
Hispanic/Latino	44	91.02	16.99		
African American/Other	66	87.98	16.78		
WJ III COG NU Pair Cancellation				2.03	.133
Caucasian/European	190	90.76	9.71		
Hispanic/Latino	44	94.07	9.68		
African American/Other	66	90.47	12.34		
WJ III COG Planning				3.50	.031
Caucasian/European	190	90.84	13.13		
Hispanic/Latino	44	85.09	15.81		
African American/Other	66	87.47	16.75		
NEPSY-II Auditory Attention				1.21	.298
Caucasian/European	190	7.44	3.77		
Hispanic/Latino	44	6.52	4.19		
African American/Other	66	6.89	4.20		
NEPSY-II Response Set				.29	.752
Caucasian/European	190	7.74	3.38		
Hispanic/Latino	44	7.57	3.71		
African American/Other	66	7.35	4.26		

(Continued)

NEPSY-II Inhibition-Inhibition				.85	.427
Caucasian/European	190	7.10	3.52		
Hispanic/Latino	44	7.32	3.41		
African American/Other	66	6.53	3.50		
NEPSY-II Inhibition-Switching				.39	.675
Caucasian/European	190	6.98	3.55		
Hispanic/Latino	44	7.39	3.97		
African American/Other	66	6.74	4.07		
NEPSY-II Clocks				.05	.951
Caucasian/European	190	7.87	4.51		
Hispanic/Latino	44	7.89	5.13		
African American/Other	66	7.67	4.81		
NEPSY-II Word List Interference				3.38	.035
Caucasian/European	190	7.38	3.68		
Hispanic/Latino	44	5.77	4.17		
African American/Other	66	7.24	3.53		
NEPSY-II Narrative Memory Free Recall				2.26	.106
Caucasian/European	190	8.49	3.60		
Hispanic/Latino	44	9.66	4.04		
African American/Other	66	8.17	4.05		
NEPSY-II Animal Sorting				5.46	.005
Caucasian/European	190	8.14	4.31		
Hispanic/Latino	44	7.57	3.54		
African American/Other	66	6.20	3.86		
TEA-Ch Code Transmission				10.68	< .001
Caucasian/European	190	4.94	3.05		
Hispanic/Latino	44	7.41	3.69		

(Continued)

African American/Other	66	5.18	3.31		
TEA-Ch Walk, Don't Walk				.21	.811
Caucasian/European	190	8.65	5.06		
Hispanic/Latino	44	9.16	5.44		
African American/Other	66	8.94	5.16		
TEA-Ch Creature Counting				.50	.605
Caucasian/European	190	7.67	3.54		
Hispanic/Latino	44	7.09	3.28		
African American/Other	66	7.68	3.73		
TEA-Ch Sky Search				1.84	.161
Caucasian/European	190	7.84	4.30		
Hispanic/Latino	44	7.91	3.69		
African American/Other	66	8.98	4.39		
TEA-Ch Sky Search DT				.17	.846
Caucasian/European	190	6.26	4.65		
Hispanic/Latino	44	6.59	3.96		
African American/Other	66	6.09	4.23		
D-KEFS Verbal Fluency Condition 3				1.38	.253
Caucasian/European	190	8.23	3.38		
Hispanic/Latino	44	7.64	3.08		
African American/Other	66	7.52	3.42		
D-KEFS Trail Making Condition 4				.59	.553
Caucasian/European	190	6.11	3.80		
Hispanic/Latino	44	5.77	3.85		
African American/Other	66	5.53	4.10		
D-KEFS Sorting Conditions 1 + 2 Description				1.42	.245
Caucasian/European	190	7.69	3.46		

(Continued)

Hispanic/Latino	44	7.73	2.52		
African American/Other	66	6.91	3.63		
D-KEFS Sorting Condition 1 Confirmed Correct Sorts				1.96	.143
Caucasian/European	190	8.47	3.10		
Hispanic/Latino	44	8.50	2.68		
African American/Other	66	7.62	3.32		
D-KEFS Twenty Questions				7.59	.001
Caucasian/European	190	9.13	3.55		
Hispanic/Latino	44	6.98	4.58		
African American/Other	66	7.70	3.93		
D-KEFS Word Context				4.52	.012
Caucasian/European	190	7.54	3.59		
Hispanic/Latino	44	6.11	3.44		
African American/Other	66	6.30	4.02		
D-KEFS Tower Total Achievement				.47	.626
Caucasian/European	190	9.38	3.16		
Hispanic/Latino	44	9.91	3.18		
African American/Other	66	9.53	3.73		
D-KEFS Color Word Condition 3				.14	.871
Caucasian/European	190	7.14	3.75		
Hispanic/Latino	44	7.41	3.53		
African American/Other	66	7.35	3.72		

Note. Significant Multivariate Effect: Wilks' λ = .448, $F(58, 538) = 4.587$, $p < .001$, $\eta^2_p = .331$

A final MANOVA was conducted to examine the impact of disability type on subtest performance across the four neuropsychological measures. Findings confirmed a significant multivariate effect between subtest and disability (Wilks' λ = .079, F(174,

1569) = 4.867, $p < .001$, $\eta^2_p = .345$). Univariate tests with Tukey's post-hoc analysis indicated that disability type had a significant impact on performance for 23 of the 29 subtests included in the analysis. As with other comparisons, no differences were noted for results using nonparametric tests. Means and standard deviations for subtest performance of each disability type are listed in Table 24.

While results varied, some consistent patterns were noted. Children with a neurological impairment performed more poorly than other clinical groups on several subtests. For example, the neurological impairment group had significantly lower scores than children with ADHD, ADHD plus a learning disability, and three plus disabilities on the WJ III COG NU Memory for Words subtest ($F(6, 293) = 3.643$, $p = .002$, $\eta^2_p = .069$), while they performed lower than all other disability types on WJ III COG NU Auditory Working Memory test ($F(6, 293) = 5.238$, $p < .001$, $\eta^2_p = .097$). On the NEPSY-II Word List Interference task, the neurological impairment group had significantly lower scores than the ADHD, two plus disabilities, and three plus disabilities groups ($F(6, 293) = 3.203$, $p = .005$, $\eta^2_p = .062$), and also performed more poorly than the learning disability and ADHD participants on NEPSY-II Animal Sorting ($F(6, 293) = 3.785$, $p = .001$, $\eta^2_p = .072$).

Children with a neurological impairment also displayed significantly lower mean scores than the three plus disabilities group on TEA-Ch Sky Search DT ($F(6, 293) = 2.286$, $p = .036$, $\eta^2_p = .045$), and lower scores than the two plus disability group on the D-KEFS Trail Making Task Condition 4 ($F(6, 293) = 2.143$, $p = .049$, $\eta^2_p = .042$). Post-hoc tests illustrated that both the learning disability and the neurological impairment groups obtained lower scores on the TEA-Ch Walk, Don't Walk subtest than the other disability type groups ($F(6, 293) = 3.435$, $p = .003$, $\eta^2_p = .066$). Finally, the neurological impairment group demonstrated poorer performance than the learning disability, ADHD, and the other single disability category groups on the D-KEFS Word Context subtest ($F(6, 293) = 3.629$, $p = .002$, $\eta^2_p = .069$).

Another pattern documented in the univariate analysis of disability type was children with a learning disability performed better than other groups on several subtests. On the WJ III COG NU Concept Formation subtest ($F(6, 293) = 2.896$, $p = .009$, $\eta^2_p = .056$), children with a learning disability displayed better performance than the two disabilities group. Similarly, children with a learning disability outperformed the other single disability group, the two plus disability group, and the neurological impairment group on the WJ III COG NU Cancellation subtest ($F(6, 293) = 6.757$, $p < .001$, $\eta^2_p = .122$).

Participants with learning disabilities also obtained significantly higher scores on the NEPSY-II Response Set subtest ($F(6, 293) = 4.804$, $p < .001$, $\eta^2_p = .090$) compared to children with a neurological impairment, ADHD, and a learning disability plus ADHD. The learning disability group outperformed the learning disability plus ADHD group as well as the three plus disability group on NEPSY-II Narrative Memory Free Recall subtest ($F(6, 293) = 4.018$, $p = .001$, $\eta^2_p = .076$), and obtained higher scores the three plus disability group on the TEA-Ch Creature Counting subtest ($F(6, 293) = 3.516$, $p = .002$, $\eta^2_p = .067$).

Results also identified certain subtests where children with ADHD outperformed other disability categories. For instance, the ADHD group scored significantly higher than children with one other disability, two or more, and three or more disabilities on the WJ III COG NU Analysis/Synthesis task ($F(6, 293) = 3.129$, $p = .005$, $\eta^2_p = .060$) and had significantly higher mean scores on the TEA-Ch Sky Search subtest ($F(6, 293) = 2.639$, $p = .036$, $\eta^2_p = .051$) compared to the three plus disability group. The ADHD group outperformed the neurological impairment and two plus disability groups on the WJ III COG NU Pair Cancellation subtest ($F(6, 293) = 6.757$, $p < .001$, $\eta^2_p = .122$).

Similarly, the ADHD group had significantly better performance on the D-KEFS Color Word Condition 3 task ($F(6, 293) = 3.265$, $p = .002$, $\eta^2_p = .063$) compared to the learning disability, other single disability, and two plus disability groups. Both the ADHD and single learning disability categories demonstrated higher scores than the other single disability group on the D-KEFS Tower Total Achievement score ($F(6, 293) = 3.522$, $p = .002$, $\eta^2_p = .067$). Lastly, the learning disability plus ADHD group outperformed the learning disability alone, neurological impairment, two plus disabilities, and three plus disabilities categories on D-KEFS Twenty Questions task ($F(6, 293) = 3.515$, $p = .002$, $\eta^2_p = .067$).

Table 24

Means and Standard Deviations for the Woodcock Johnson Tests of Cognitive Abilities, Third Edition, Normative Update (WJ III COG NU), A Developmental Neuropsychological Assessment, Second Edition (NEPSY-II), the Test of Everyday Attention for Children (TEA-Ch), and the Delis-Kaplan Executive Function System (D-KEFS) Items by Disability

	n	*M*	*SD*	*F*	*p*
WJ III COG NU Auditory Attention				1.51	.175
Learning Disability	43	93.53	15.27		
Neurological Impairment	25	84.84	19.77		
ADHD	24	97.54	15.02		
Other Single Disability (Not Already Listed)	26	92.19	18.02		
ADHD and LD	43	94.02	17.60		
Other Two Disabilities	76	89.13	20.02		
Three or More Disabilities	63	90.71	17.37		
WJ III COG NU Memory for Words				3.64	.002
Learning Disability	43	81.51	12.94		
Neurological Impairment	25	74.20	13.29		
ADHD	24	90.46	16.65		
Other Single Disability (Not Already Listed)	26	86.31	20.14		
ADHD and LD	43	91.05	14.35		
Other Two Disabilities	76	83.71	18.61		
Three or More Disabilities	63	86.68	17.52		
WJ III COG NU Numbers Reversed				3.21	.005
Learning Disability	43	85.95	16.15		
Neurological Impairment	25	93.28	19.54		
ADHD	24	95.83	16.30		
Other Single Disability (Not Already Listed)	26	97.27	16.61		
ADHD and LD	43	84.40	13.27		

(Continued)

Other Two Disabilities	76	85.82	18.20		
Three or More Disabilities	63	86.97	17.55		
WJ III COG NU Auditory Working Memory				5.24	< .001
Learning Disability	43	96.02	10.44		
Neurological Impairment	25	77.64	13.18		
ADHD	24	95.21	14.56		
Other Single Disability (Not Already Listed)	26	92.96	16.98		
ADHD and LD	43	98.16	16.40		
Other Two Disabilities	76	88.97	20.35		
Three or More Disabilities	63	89.97	16.60		
WJ III COG NU Concept Formation				2.90	.009
Learning Disability	43	96.42	13.40		
Neurological Impairment	25	88.28	14.64		
ADHD	24	97.50	11.63		
Other Single Disability (Not Already Listed)	26	88.12	17.87		
ADHD and LD	43	93.95	12.43		
Other Two Disabilities	76	87.51	18.55		
Three or More Disabilities	63	90.49	13.29		
WJ III COG NU Analysis/Synthesis				3.13	.005
Learning Disability	43	94.26	15.78		
Neurological Impairment	25	89.48	13.73		
ADHD	24	102.88	13.97		
Other Single Disability (Not Already Listed)	26	87.54	19.39		
ADHD and LD	43	93.44	15.80		
Other Two Disabilities	76	89.45	17.82		
Three or More Disabilities	63	88.48	15.48		

(Continued)

WJ III COG NU Pair Cancellation				6.76	< .001
Learning Disability	43	97.19	8.68		
Neurological Impairment	25	84.84	9.83		
ADHD	24	97.25	8.62		
Other Single Disability (Not Already Listed)	26	89.19	10.90		
ADHD and LD	43	91.14	8.74		
Other Two Disabilities	76	89.01	11.70		
Three or More Disabilities	63	90.75	8.64		
WJ III COG NU Planning				1.37	.226
Learning Disability	43	92.14	10.81		
Neurological Impairment	25	88.92	17.37		
ADHD	24	85.75	11.05		
Other Single Disability (Not Already Listed)	26	84.08	13.86		
ADHD and LD	43	87.53	15.53		
Other Two Disabilities	76	90.84	15.63		
Three or More Disabilities	63	90.16	14.54		
NEPSY-II Auditory Attention				1.46	.191
Learning Disability	43	8.02	3.91		
Neurological Impairment	25	5.76	4.59		
ADHD	24	6.96	4.24		
Other Single Disability (Not Already Listed)	26	7.96	3.63		
ADHD and LD	43	7.21	3.95		
Other Two Disabilities	76	6.62	3.80		
Three or More Disabilities	63	7.62	3.72		
NEPSY-II Response Set				4.80	< .001
Learning Disability	43	9.30	3.23		
Neurological Impairment	25	5.08	4.06		
ADHD	24	6.42	3.37		
Other Single Disability (Not Already Listed)	26	7.50	3.74		

(Continued)

ADHD and LD	43	7.02	3.00		
Other Two Disabilities	76	8.05	3.68		
Three or More Disabilities	63	7.90	3.46		
NEPSY-II Inhibition-Inhibition				.91	.486
Learning Disability	43	6.60	2.80		
Neurological Impairment	25	6.84	3.66		
ADHD	24	7.92	3.41		
Other Single Disability (Not Already Listed)	26	7.04	3.97		
ADHD and LD	43	7.23	3.18		
Other Two Disabilities	76	7.39	3.84		
Three or More Disabilities	63	6.37	3.48		
NEPSY-II Inhibition-Switching				1.36	.231
Learning Disability	43	7.47	3.66		
Neurological Impairment	25	5.20	3.32		
ADHD	24	7.17	4.25		
Other Single Disability (Not Already Listed)	26	7.88	3.39		
ADHD and LD	43	7.09	3.63		
Other Two Disabilities	76	6.92	3.79		
Three or More Disabilities	63	6.94	3.77		
NEPSY-II Clocks				2.58	.019
Learning Disability	43	8.02	4.36		
Neurological Impairment	25	6.32	4.31		
ADHD	24	7.29	4.10		
Other Single Disability (Not Already Listed)	26	5.23	3.53		
ADHD and LD	43	8.42	4.27		
Other Two Disabilities	76	8.76	5.12		
Three or More Disabilities	63	8.03	4.89		
NEPSY-II Word List Interference				3.20	.005
Learning Disability	43	7.00	3.73		

(Continued)

Neurological Impairment	25	4.56	2.90		
ADHD	24	8.88	3.48		
Other Single Disability (Not Already Listed)	26	6.73	4.08		
ADHD and LD	43	7.00	3.59		
Other Two Disabilities	76	7.25	3.79		
Three or More Disabilities	63	7.60	3.69		
NEPSY-II Narrative Memory Free Recall				4.02	.001
Learning Disability	43	10.40	3.55		
Neurological Impairment	25	7.76	3.26		
ADHD	24	9.54	3.38		
Other Single Disability (Not Already Listed)	26	7.62	3.62		
ADHD and LD	43	7.53	3.33		
Other Two Disabilities	76	9.18	4.16		
Three or More Disabilities	63	7.73	3.62		
NEPSY-II Animal Sorting				3.79	.001
Learning Disability	43	8.95	4.28		
Neurological Impairment	25	5.60	3.24		
ADHD	24	9.33	4.19		
Other Single Disability (Not Already Listed)	26	8.50	4.55		
ADHD and LD	43	8.35	3.44		
Other Two Disabilities	76	7.14	4.32		
Three or More Disabilities	63	6.60	3.99		
TEA-Ch Code Transmission				2.15	.048
Learning Disability	43	5.23	3.72		
Neurological Impairment	25	5.24	3.85		
ADHD	24	6.04	3.03		
Other Single Disability (Not Already Listed)	26	4.42	2.87		
ADHD and LD	43	4.44	3.05		
Other Two Disabilities	76	5.24	3.06		
Three or More Disabilities	63	6.38	3.65		

(Continued)

TEA-Ch Walk, Don't Walk				3.44	.003
Learning Disability	43	7.42	5.16		
Neurological Impairment	25	6.64	5.59		
ADHD	24	9.88	4.81		
Other Single Disability (Not Already Listed)	26	11.15	4.76		
ADHD and LD	43	8.53	4.40		
Other Two Disabilities	76	8.16	4.73		
Three or More Disabilities	63	10.13	5.50		
TEA-Ch Creature Counting				3.52	.002
Learning Disability	43	8.95	3.29		
Neurological Impairment	25	6.44	3.30		
ADHD	24	8.08	2.80		
Other Single Disability (Not Already Listed)	26	8.00	3.71		
ADHD and LD	43	6.88	2.96		
Other Two Disabilities	76	8.21	3.83		
Three or More Disabilities	63	6.48	3.57		
TEA-Ch Sky Search				2.64	.017
Learning Disability	43	8.49	4.38		
Neurological Impairment	25	7.64	3.87		
ADHD	24	10.50	4.40		
Other Single Disability (Not Already Listed)	26	7.65	4.10		
ADHD and LD	43	9.09	4.34		
Other Two Disabilities	76	7.75	4.16		
Three or More Disabilities	63	7.05	4.02		
TEA-Ch Sky Search DT				2.29	.036
Learning Disability	43	5.14	3.96		
Neurological Impairment	25	3.84	3.64		
ADHD	24	6.96	5.05		
Other Single Disability (Not Already Listed)	26	6.54	4.40		

(Continued)

ADHD and LD	43	6.81	4.10		
Other Two Disabilities	76	6.51	4.18		
Three or More Disabilities	63	6.98	5.09		
D-KEFS Verbal Fluency Condition 3				3.43	.003
Learning Disability	43	8.28	2.99		
Neurological Impairment	25	7.04	3.51		
ADHD	24	8.29	3.21		
Other Single Disability (Not Already Listed)	26	8.92	2.91		
ADHD and LD	43	7.58	3.08		
Other Two Disabilities	76	6.97	3.39		
Three or More Disabilities	63	9.14	3.51		
D-KEFS Trail Making Condition 4				2.14	.049
Learning Disability	43	5.63	3.66		
Neurological Impairment	25	4.32	3.49		
ADHD	24	6.17	3.62		
Other Single Disability (Not Already Listed)	26	5.04	3.69		
ADHD and LD	43	5.79	3.56		
Other Two Disabilities	76	7.05	4.30		
Three or More Disabilities	63	5.81	3.76		
D-KEFS Sorting Conditions 1 + 2 Description				2.80	.012
Learning Disability	43	6.88	2.72		
Neurological Impairment	25	6.68	3.89		
ADHD	24	8.67	3.78		
Other Single Disability (Not Already Listed)	26	8.23	4.27		
ADHD and LD	43	8.19	2.62		
Other Two Disabilities	76	6.64	3.40		
Three or More Disabilities	63	8.19	3.16		

(Continued)

D-KEFS Sorting Condition 1 Confirmed Correct Sorts				1.15	.336
Learning Disability	43	8.56	2.64		
Neurological Impairment	25	7.16	3.65		
ADHD	24	8.37	3.36		
Other Single Disability (Not Already Listed)	26	8.08	3.70		
ADHD and LD	43	9.07	1.96		
Other Two Disabilities	76	8.08	3.12		
Three or More Disabilities	63	8.32	3.38		
D-KEFS Twenty Questions				3.52	.002
Learning Disability	43	7.65	4.02		
Neurological Impairment	25	7.44	3.84		
ADHD	24	9.71	3.62		
Other Single Disability (Not Already Listed)	26	8.38	3.44		
ADHD and LD	43	10.58	3.13		
Other Two Disabilities	76	8.03	4.16		
Three or More Disabilities	63	8.22	3.74		
D-KEFS Word Context				3.63	.002
Learning Disability	43	7.70	3.54		
Neurological Impairment	25	4.56	2.38		
ADHD	24	7.63	2.99		
Other Single Disability (Not Already Listed)	26	7.81	3.54		
ADHD and LD	43	8.33	3.48		
Other Two Disabilities	76	6.68	3.93		
Three or More Disabilities	63	6.68	3.97		
D-KEFS Tower Total Achievement				3.52	.002
Learning Disability	43	10.70	2.99		
Neurological Impairment	25	9.16	3.18		
ADHD	24	11.21	3.36		
Other Single Disability (Not Already Listed)	26	8.04	2.43		

(Continued)

ADHD and LD	43	9.02	3.07		
Other Two Disabilities	76	9.22	3.40		
Three or More Disabilities	63	9.32	3.44		
D-KEFS Color Word Condition 3				3.27	.004
Learning Disability	43	6.44	3.78		
Neurological Impairment	25	7.00	3.48		
ADHD	24	9.25	3.07		
Other Single Disability (Not Already Listed)	26	6.15	4.14		
ADHD and LD	43	8.00	3.04		
Other Two Disabilities	76	6.46	3.80		
Three or More Disabilities	63	7.92	3.66		

Note. Significant Multivariate Effect. Wilks' $\lambda = .079$, $F(174, 1569) = 4.867$, $p < .001$, $\eta^2_p = .345$.

Primary Analysis

The primary analysis for this study utilized multiple CFAs to determine which, if any, of the three models of executive functioning best fit the sample data and represented the underlying factor structure of executive functioning in a clinical sample of children. The statistical package of laaven in R (Rossel, 2012) was used to conduct the primary analysis. During the model testing phase, several different fit indices were analyzed to determine goodness of model fit. The chi-square and adjusted chi-square were used for model test fit, while the SRMR, CFI, and RMSEA represented different aspects of approximate fit. Additionally, standardized coefficients illustrated the degree and strength of the relationships between all variables included in the models. Standardized coefficients were used due to their ability to allow for direct comparison between different items. Typically, standardized coefficients range from 0 to 1;

however, some paths between the latent variables in this analysis exceeded 1. Standardized coefficients over 1 can still be valid but may represent an extremely high degree of multicollinearity between latent variables (Schreiber, 2008). This issue is discussed further in this chapter as it relates to the final versions of the Integrated SNP/CHC model and six-factor model proposed by the researcher.

During the model specification phase, the models were diagrammed as CFAs using rectangles to represent the observed variables of subtest scores, and circles to signify the various latent variables. Paths were diagrammed with arrows pointing to the variable being affected (i.e., the dependent or endogenous variable) and a curved line with arrows on both ends to represent co-variances in the model (Meyers et al., 2006). For the primary analysis, the statistical package laaven in R (Rossel, 2012) initially set one path in each latent variable to 1 at the beginning of the analysis. This path was later allowed to vary as the multiple iterations occurred during model analysis. All three models converged appropriately during the model estimation phase.

Single-factor model. As previously mentioned, three separate models of executive functioning were assessed for model fit. The first model, the single-factor model, was hypothesized to represent the poorest fit for the sample data. Results from the analysis indicated that all of the paths connecting the observed variables to the single latent variable of executive functions were significant. The majority of the standardized coefficients were strong ranging from .302 at the lowest (D-KEFS Tower Total Achievement) to .811 at the largest (D-KEFS Sorting Conditions 1 + 2 Confirmed Correct Sorts); however, initial indicators of model fit confirmed that the single-factor model was a poor fit on all fit measures. The chi-square statistic was significant ($\chi^2(377) = 898.40$, $p < .001$) indicating that the model was a poor fit overall. The adjusted chi-square improved after considering degrees of freedom (*adjusted* $\chi^2 =$ 2.38), but was still not desirable due to statistical significance. Two of the approximate fit indices were considered poor, with the SMSR at .124 and the CFI at .616. The exception was the RMSEA, which was deemed acceptable at .068 (90% CI = .06, .07).

Minor modifications were conducted in the second phase of modeling to allow for co-variance between several of the observed variables. Overall, the modified single-factor model fit improved slightly, but was still considered a poor fit for the sample data. The chi-square value remained significant, although the adjusted chi-square after considering degrees of freedom decreased to a value under two ($\chi^2(377) = 707.82$, *adjusted* $\chi^2 = 1.93$, $p < .001$). The RMSEA improved slightly and continued to be at an acceptable level of .056 (90% CI = .05, .06). All remaining approximate fit indices were unacceptable with the CFI staying consistent at .616 and the SMSR decreasingly only slightly to .118. A full description of the original and modified coefficients is listed in Table 25 and 26. The modified single-factor model is depicted in Figure 4.

The Integrated SNP/CHC model. The Integrated SNP/CHC model was hypothesized to represent the best fit of the three models in the analysis. Due to the theoretical nature of the Integrated SNP/CHC model, the third-level latent variables of cognitive facilitators/inhibitors and executive functions were allowed to co-vary in both the initial and modified models. All of the standardized coefficients were significant in the initial model. Four latent variables had coefficients over .85 and the two latent factors of attention and cognitive flexibility displayed standardized coefficients exceeding the value of 1, which indicated overlap or mutlicollinearity. Similarly, the third-level factors of inhibitors/facilitators and executive functions displayed a high degree of co-variance at .975.

Table 25

Standardized Coefficients for the Original Single-Factor Model

	Unstandardized Estimate	Standardized Estimate
Executive Function		
WJ III COG NU Pair Cancellation	1.000	.517
NEPSY-II Auditory Attention	.285	.371
TEA-Ch Code Transmission	.352	.510
TEA-Ch Sky Search	.277	.381
TEA-Ch Sky Search DT	.356	.438
WJ III COG NU Memory for Words	2.245	.703
NEPSY- II Narrative Memory Free Recall	.240	.341
WJ III COG NU Numbers Reversed	1.969	.593
WJ III COG NU Auditory Working Memory	2.055	.641
NEPSY-II Word List Interference	.401	.554
WJ III COG NU Auditory Attention	1.052	.329
NEPSY-II Response Set	.231	.338
NEPSY-II Inhibition-Switching	.295	.427
TEA-Ch Creature Counting	.266	.389
D-KEFS Verbal Fluency Condition 3	.323	.478
D-KEFS Trail Making Condition 4	.301	.396
NEPSY-II Animal Sorting	.421	.555

(Continued)

D-KEFS Sorting Conditions 1 + 2 Description	.568	.811
D-KEFS Sorting Condition 1 Confirmed Correct Sorts	.503	.787
D-KEFS Twenty Questions	.415	.542
WJ III COG NU Planning	1.279	.468
NEPSY-II Clocks	.412	.495
D-KEFS Tower Total Achievement	.187	.302
WJ III COG NU Concept Formation	2.520	.807
WJ III COG NU Analysis/Synthesis	2.107	.659
D-KEFS Word Context	.410	.564
NEPSY-II Inhibition-Inhibition	.347	.521
TEA-Ch Walk, Don't Walk	.457	.464
D-KEFS Color Word Condition 3	.299	.411

Table 26

Standardized Coefficients for the Modified Single-Factor Model

	Unstandardized Estimate	Standardized Estimate
Executive Function		
WJ III COG NU Pair Cancellation	1.000	.526
NEPSY-II Auditory Attention	.276	.364
TEA-Ch Code Transmission	.350	.513
TEA-Ch Sky Search	.284	.397
TEA-Ch Sky Search DT	.353	.439
WJ III COG NU Memory for Words	2.171	.697
NEPSY- II Narrative Memory Free Recall	.247	.356
WJ III COG NU Numbers Reversed	1.966	.602
WJ III COG NU Auditory Working Memory	2.110	.676

(Continued)

NEPSY-II Word List Interference	.404	.566
WJ III COG NU Auditory Attention	1.080	.343
NEPSY-II Response Set	.212	.313
NEPSY-II Inhibition-Switching	.270	.395
TEA-Ch Creature Counting	.294	.431
D-KEFS Verbal Fluency Condition 3	.345	.517
D-KEFS Trail Making Condition 4	.299	.400
NEPSY-II Animal Sorting	.411	.548
D-KEFS Sorting Conditions 1 + 2 Description	.476	.697
D-KEFS Sorting Condition 1 Confirmed Correct Sorts	.413	.670
D-KEFS Twenty Questions	.402	.535
WJ III COG NU Planning	1.306	.489
NEPSY-II Clocks	.444	.532
D-KEFS Tower Total Achievement	.184	.303
WJ III COG NU Concept Formation	2.430	.795
WJ III COG NU Analysis/Synthesis	2.181	.695
D-KEFS Word Context	.406	.567
NEPSY-II Inhibition-Inhibition	.331	.505
TEA-Ch Walk, Don't Walk	.452	.468
D-KEFS Color Word Condition 3	.297	.413
D-KEFS Sorting Conditions 1 + 2 Description		
D-KEFS Sorting Condition 1 Confirmed Correct Sorts	4.387	.728
NEPSY-II Auditory Attention		
NEPSY-II Response Set	4.216	.345
NEPSY-II Inhibition-Switching		
NEPSY-II Inhibition-Inhibition	3.530	.370
WJ III COG NU Auditory Working Memory		
TEA-Ch Walk, Don't Walk	-26.036	-.493

(Continued)

WJ III COG NU Pair Cancellation		
D-KEFS Color Word Condition 3	7.603	.266
D-KEFS Trail Making Condition 4		
NEPSY-II Inhibition-Inhibition	2.192	.210
TEA-Ch Creature Counting		
WJ III COG NU Planning	-20.933	-.541
NEPSY-II Clocks		
D-KEFS Color Word Condition 3	-4.252	-.341
D-KEFS Tower Total Achievement		
WJ III COG NU Analysis/Synthesis	-12.308	-.351
TEA-Ch Creature Counting		
D-KEFS Verbal Fluency Condition 3	-3.179	-.335

The majority of the standardized coefficients comprising the measurement model met the ideal criteria of .40 to .85 (Schumacker & Lomax). There were some exceptions and lower coefficients were considered during the model modification phase. The NEPSY-II Auditory Attention, NEPSY-II Narrative Memory Free Recall, and TEA-Ch Sky Search subtests on the attention factor as well as the WJ III COG NU Auditory Attention and NEPSY-II Response Set subtests on the cognitive flexibility factor were all below .40. The D-KEFS Tower Total Achievement variable also demonstrated a low standardized coefficient of .322 on the problem solving, fluid reasoning, and planning factor. All of the standardized estimates in the original Integrated SNP/CHC model are listed in Table 27.

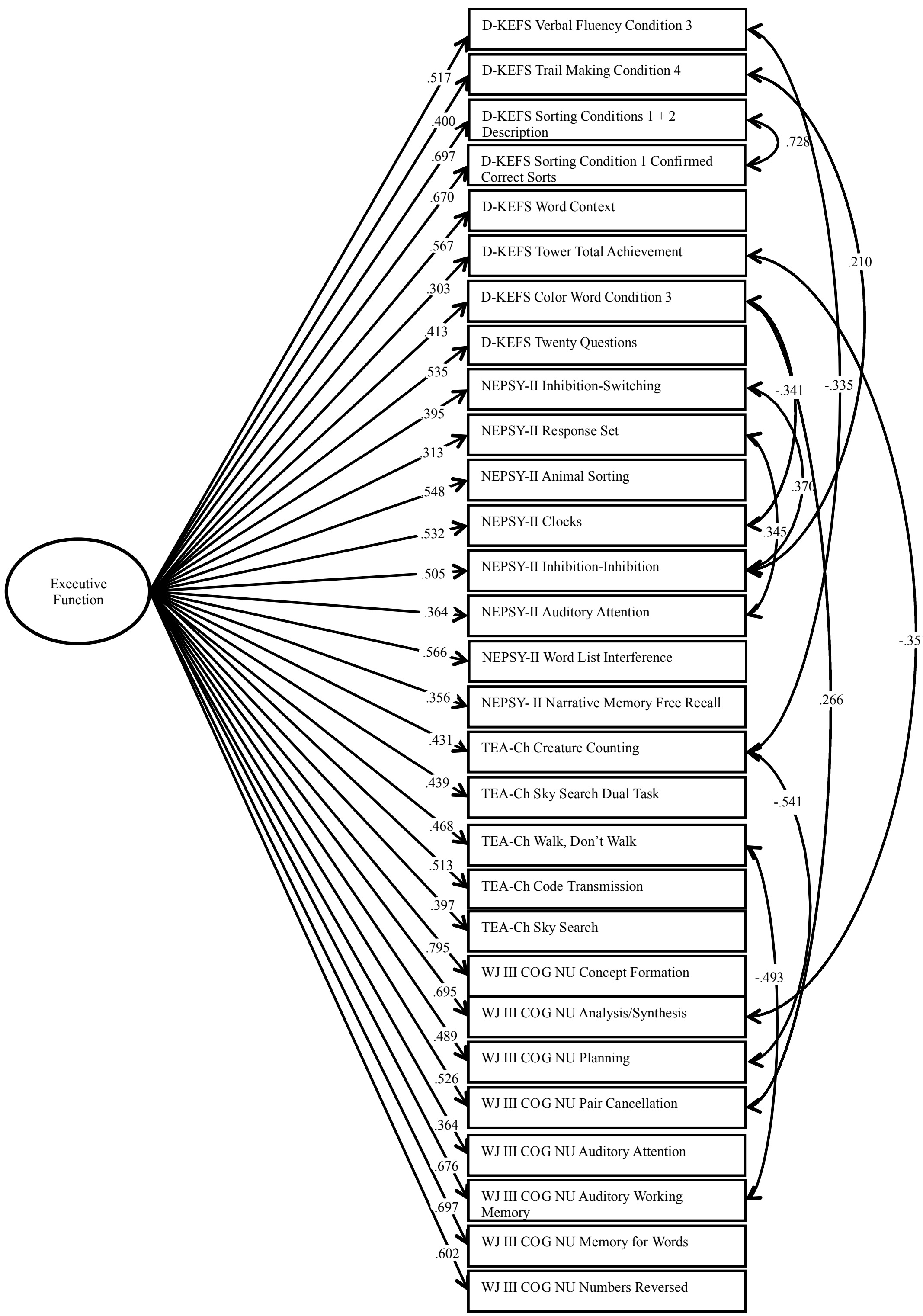

Figure 4. Modified single-factor model

Table 27

Standardized Coefficients for the Original Integrated SNP/CHC Model

	Unstandardized Estimate	Standardized Estimate
Cognitive Facilitators/Inhibitors		
Attention	1.000	1.075
Working Memory	1.765	.944
Executive Function		
Cognitive Flexibility	1.000	1.050
Concept Recognition and Generation	.300	.720
Problem Solving, Fluid Reasoning, and Planning	1.022	.945
Response Inhibition	.332	.775
Attention		
WJ III COG NU Pair Cancellation	1.000	.538
NEPSY-II Auditory Attention	.279	.376
TEA-Ch Code Transmission	.359	.536
TEA-Ch Sky Search	.267	.381
TEA-Ch Sky Search DT	.346	.441
WJ III COG NU Memory for Words	2.087	.687
NEPSY- II Narrative Memory Free Recall	.227	.334
Working Memory		
WJ III COG NU Numbers Reversed	1.000	.629
WJ III COG NU Auditory Working Memory	1.076	.700
NEPSY-II Word List Interference	.216	.619
Cognitive Flexibility		
WJ III COG NU Auditory Attention	1.000	.343
NEPSY-II Response Set	.225	.359

(Continued)

NEPSY-II Inhibition-Switching	.281	.444
TEA-Ch Creature Counting	.252	.403
D-KEFS Verbal Fluency Condition 3	.290	.471
D-KEFS Trail Making Condition 4	.282	.406
Concept Recognition and Generation		
NEPSY-II Animal Sorting	1.000	.634
D-KEFS Sorting Conditions 1 + 2 Description	1.351	.928
D-KEFS Sorting Condition 1 Confirmed Correct Sorts	1.212	.920
D-KEFS Twenty Questions	.767	.487
Problem Solving, Fluid Reasoning, and Planning		
WJ III COG NU Planning	1.000	.458
NEPSY-II Clocks	.362	.539
D-KEFS Tower Total Achievement	.160	.322
WJ III COG NU Concept Formation	2.044	.818
WJ III COG NU Analysis/Synthesis	1.762	.689
D-KEFS Word Context	.300	.517
Response Inhibition		
NEPSY-II Inhibition-Inhibition	1.000	.740
TEA-Ch Walk, Don't Walk	1.220	.606
D-KEFS Color Word Condition 3	.795	.538
Cognitive Facilitators/Inhibitors		
Executive Function	32.774	.975

The original Integrated SNP/CHC model produced variable measures of fit. As with the single-factor model, the Integrated SNP/CHC model had a significant chi-square value ($\chi^2(370) = 799.86$, $p < .001$), which indicated a poor fit and possible specification error. The adjusted chi-square value fell below the cutoff of 3 (*adjusted* χ^2 = 2.16), but was still significant and thus demonstrated that there was a significant difference in the co-variance matrices for the proposed factor structure and sample factor structure. As with the single-factor model, the RMSEA was considered good at .062 (90% CI = .06, .07). The remaining approximate fit indices all fell in the unacceptable range, with the CFI at .684 and SMSR at .121. The high degree of multicollinarity for the majority of the latent variables coupled with the poor fit indices illustrated that the original Integrated SNP/CHC model was not a strong representation of executive functioning in the sample.

Post-hoc model modifications were then conducted in an attempt to improve the fit of the Integrated SNP/CHC model and to decrease possible misspecification. First, the latent variables of response inhibition and cognitive flexibility were collapsed under one factor, thus decreasing the number of second-level latent variables to five instead of six. This decision was based on previous research and other factor analytic studies indicating that cognitive flexibility and inhibition may have significant overlap (Pureza, Jacobson, Oliveira, & Fonseca, 2011). Combining the two latent factors in the modified Integrated SNP/CHC model placed the observed variables of D-KEFS Color Word Condition 3, NEPSY-II Inhibition-Inhibition, and TEA-Ch Walk, Don't Walk onto the same factor as the original subtests belonging to the cognitive flexibility factor. Additionally, several subtests were dropped from the second CFA. These subtests were the WJ III COG NU Memory for Words and NEPSY-II Narrative Memory Free Recall, which were originally a part of the attention factor, and the WJ

III COG NU Auditory Working Memory subtest, which was initially included in the working memory latent variable.

The results of the modified CFA for the Integrated SNP/CHC model indicated that the overall measures of model fit improved slightly although several indices continued to be in the unacceptable range. The chi-square remained significant and thus confirmed a poor fit overall ($\chi^2(293) = 639.82$, $p < .001$). The adjusted chi-square continued to be in the desired range of less than 3 (*adjusted* $\chi^2 = 2.18$) and RMSEA maintained an acceptable level at .063 (90% CI = .06, .07). The CFI increased from .684 to .699. Finally, the SMSR remained the same at .121 and was not in the desired range. Thus, the model modifications did not improve the overall model fit.

In addition to model fit, the model modifications altered some of the standardized coefficients. Improvements were observed for the latent variables of attention and cognitive flexibility as the standardized coefficients decreased to a value below 1; however, these two constructs continued to be highly similar with coefficients over .85. Further, the relationship between the third-level variables of executive functioning and inhibitors/facilitators remained over 1. Collapsing the latent factors to three under the third-level variable of executive functioning allowed them to remain strong and indicated they were good predictors of the construct.

Most changes to the standardized coefficients of the measurement model were minor and the modifications did not greatly improve the magnitude of the relationships between the observed and latent variables. On the attention factor, all of the factor loadings improved to above .40, which is considered good to moderate; the two subtests comprising the working memory factor decreased slightly. On the revised cognitive flexibility and response inhibition factor, approximately half of the coefficients improved slightly while the others decreased; all changes were within .10 in either direction. There were no major improvements for concept recognition and generation, or on the problem solving, fluid reasoning, and planning factors. Overall, the adjusted Integrated SNP/CHC model was unable to fully represent the factor structure of executive functioning without changes that would seriously alter the theoretical integrity of the model. The final version of the Integrated SNP/CHC model with standardized coefficients is outlined in Table 28 and diagrammed in Figure 5.

Table 28

Standardized Coefficients for the Modified Integrated SNP/CHC Model

	Unstandardized Estimate	Standardized Estimate
Cognitive Facilitators/Inhibitors		
Attention	1.000	.939
Working Memory	1.718	.995
Executive Function		
Cognitive Flexibility and Response Inhibition	1.000	.866
Concept Recognition and Generation	.303	.718
Problem Solving, Fluid Reasoning, and Planning	.993	.897
Attention		
WJ III COG NU Pair Cancellation	1.000	.595
NEPSY-II Auditory Attention	.295	.440
TEA-Ch Code Transmission	.325	.539
TEA-Ch Sky Search	.284	.448
TEA-Ch Sky Search DT	.315	.445

(Continued)

Working Memory		
WJ III COG NU Numbers Reversed	1.000	.565
NEPSY-II Word List Interference	.204	.526
Cognitive Flexibility and Response Inhibition		
WJ III COG NU Auditory Attention	1.000	.405
NEPSY-II Response Set	.212	.400
NEPSY-II Inhibition-Switching	.296	.555
TEA-Ch Creature Counting	.172	.328
D-KEFS Verbal Fluency Condition 3	.230	.443
D-KEFS Trail Making Condition 4	.287	.489
NEPSY-II Inhibition-Inhibition	.358	.696
TEA-Ch Walk, Don't Walk	.433	.569
D-KEFS Color Word Condition 3	.299	.532
Concept Recognition and Generation		
NEPSY-II Animal Sorting	1.000	.625
D-KEFS Sorting Conditions 1 + 2 Description	1.354	.920
D-KEFS Sorting Condition 1 Confirmed Correct Sorts	1.236	.928
D-KEFS Twenty Questions	.767	.481
Problem Solving, Fluid Reasoning, and Planning		
WJ III COG NU Planning	1.000	.459
NEPSY-II Clocks	.356	.531
D-KEFS Tower Total Achievement	.150	.302
WJ III COG NU Concept Formation	2.066	.830
WJ III COG NU Analysis/Synthesis	1.750	.684
D-KEFS Word Context	.289	.500
Cognitive Facilitators/Inhibitors		
Executive Function	34.188	1.077

(Continued)

The six-factor model. The final theoretical model examined in this study was the six-factor model proposed by the researcher. It was originally hypothesized that this model would demonstrate good fit, but would not be as strong of a representation of the sample data as the Integrated SNP/CHC model. Examination of the original standardized coefficients comprising the latent variables indicated that three of the six latent variables (i.e., problem solving, self-regulation/impulse control, and working memory) displayed good predictive strength for the executive functioning factor with standardized coefficients ranging from .747 to .843. The other three latent variables of mental flexibility/use of feedback; initiation, planning, and organization; and deployment of attention had factor loadings over .95 which were indicative of possible overlap and poor differentiation between constructs.

The standardized coefficients between the endogenous and exogenous variables were all significant and ranged in strength from .247 to .917 with the majority of the coefficients between the desired range of .40 to .85. The paths of all three observed variables to the initiation, planning, and organization factor were considered low and fell below .30. Additionally, the NEPSY-II Response Set, TEA-Ch Creature Counting, and the NEPSY-II Narrative Memory subtests had lower than anticipated coefficients below .40. The full list of standardized coefficients for the original six-factor model proposed by the researcher can be found in Table 29.

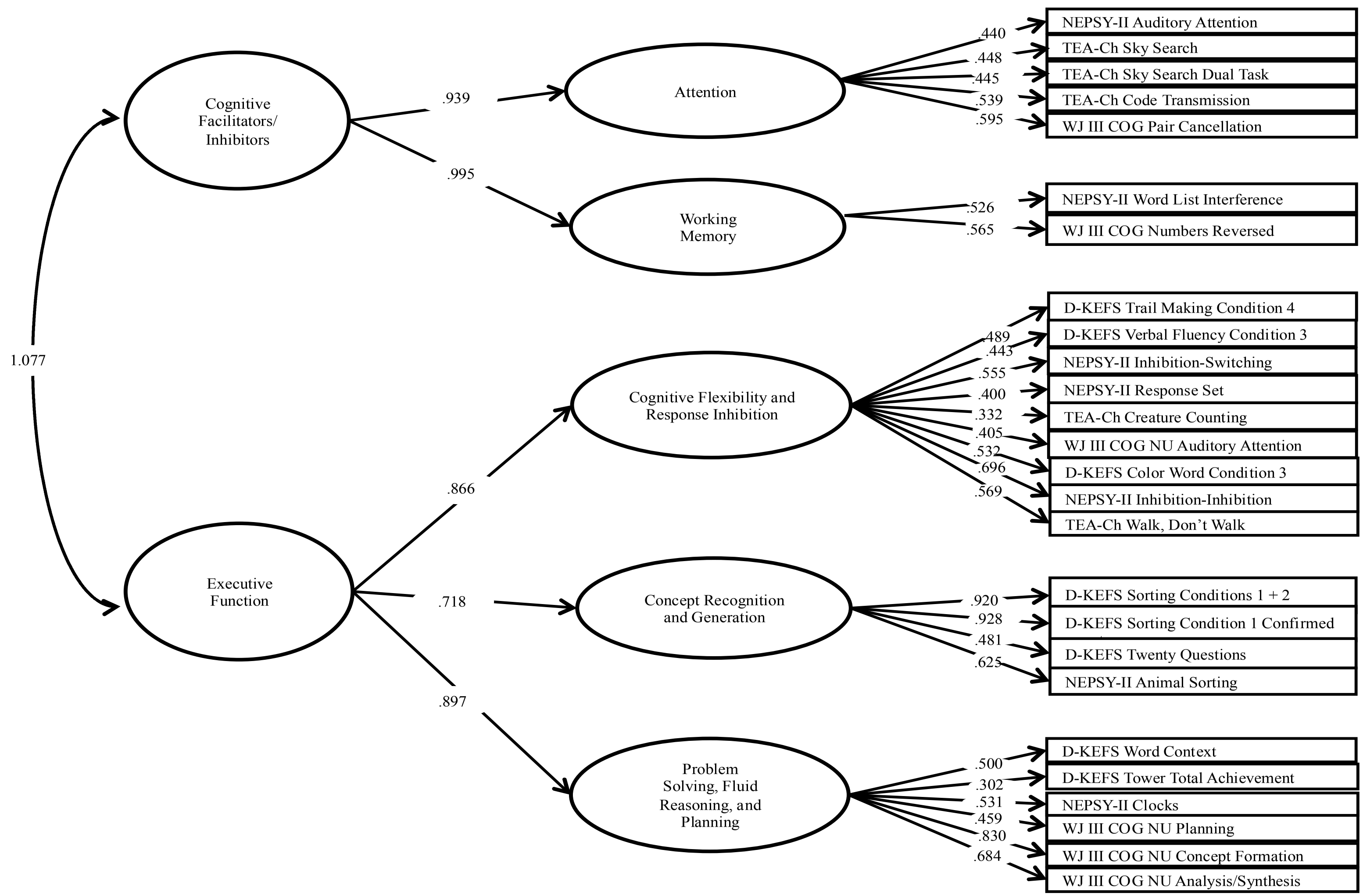

Figure 5. Modified integrated SNP/CHC model

Model fit for the six-factor model proposed by the researcher was also assessed using several fit indices. The original model was determined to be a poor fit as evidenced by the significant chi-square value ($\chi^2(371) = 815.34$, $p < .001$). As with the other models, the adjusted chi-square was under the desired range of below 3 (*adjusted* $\chi^2 = 2.20$), but remained significant indicating that there was a statistically significant difference between the co-variances of the proposed and measured models. The only fit index that was appropriate was the RMSEA at .063 (90% CI = .06, .07). The remaining fit indices indicated poor fit of the model with the CFI at .673 and the SMSR at .124.

In the second phase of the analysis, theoretically sound post-hoc model modifications were conducted to determine if model fit could be improved by adjusting the original six-factor model. First, the second-level constructs were no longer tied to the overall construct of executive functioning but were instead allowed to co-vary. All subtests from the initiation, planning, and organization factor were removed due to low factor loadings altering the proposed model from a six-factor to a five-factor model. The remaining latent variables, with the exception the mental flexibility/use of feedback, demonstrated strong co-variances after these modifications. The mental flexibility/use of feedback factor continued to display a standardized estimate over 1 and individual paths to the subtests under .40, indicating it continued to be problematic in the model; however, the factor was allowed to stay in the analysis because of its historical and theoretical value as a major component of executive functioning.

Other modifications occurred for the observed variables. The D-KEFS Sorting Conditions 1 + 2 Description subtest was allowed to co-vary with D-KEFS Sorting

Condition 1 Confirmed Correct Sorts, thus decreasing its standardized coefficients to appropriate amounts for all paths from the problem solving factor. Additional changes to the proposed model included dropping subtests with low factor loadings, such as the TEA-Ch Creature Counting and the D-KEFS Trail Making Condition 4 subtests, which were both originally on the mental flexibility/use of feedback factor. The NEPSY-II Narrative Memory Free Recall subtest was also dropped from the working memory factor due to low factor loadings. The result was that all paths on the working memory factor were over .60.

Another alteration involved moving several subtests to new factors as suggested during the model modification phase. Specifically, NEPSY-II Inhibition-Switching was moved from mental flexibility to self-regulation/impulse control, while WJ III COG NU Analysis/Synthesis was relocated from problem solving to mental flexibility/use of feedback. These modifications were conducted with the goal of improving the strength of the overall factor of mental flexibility/use of feedback. The final standardized coefficients for self-regulation/impulse control improved slightly and the deployment of attention structural coefficients displayed only minimal changes. All of the standardized coefficients in the model remained statistically significant. The standardized coefficients for the modified five-factor model proposed by the researcher are listed in Table 30.

In addition to changes in the standardized coefficients, the model modifications also improved model fit for most indices. As with the other models, the chi-square statistic remained significant ($\chi^2(218) = 342.78$, $p < .001$); however, the adjusted chi-square decreased to 1.57 and was the lowest of all models tested. Other improvements in the overall model fit occurred for all of the approximate fit indices as the CFI increased from .673 to .897. Although the CFI was still slightly below the ideal rate of .90, it was very close to acceptable and surpassed the other models. Importantly, the SRMR shifted closer to a good fit as it decreased from .124 to .096. Lastly, the RMSEA remained acceptable and improved to .044 (90% CI = .04, .05). The final modified version of the five-factor model proposed by the researcher is diagrammed in Figure 6.

Table 29

Standardized Coefficients for the Original Six-Factor Model Proposed by the Researcher

	Unstandardized Estimate	Standardized Estimate
Executive Functioning		
Mental Flexibility/Use of Feedback	1.000	1.088
Problem Solving	.822	.747
Initiation, Planning, and Organization	3.223	1.231
Self-Regulation/Impulse Control	1.032	.843
Working Memory	5.005	.815
Deployment of Attention	2.848	.962
Mental Flexibility/Use of Feedback		
TEA-Ch Sky Search DT	1.000	.449
NEPSY-II Response Set	.741	.395
NEPSY-II Inhibition-Switching	.904	.479
TEA-Ch Creature Counting	.641	.344
D-KEFS Verbal Fluency Condition 3	.835	.454
D-KEFS Trail Making Condition 4	.878	.423

(Continued)

Problem Solving		
NEPSY-II Animal Sorting	1.000	.584
D-KEFS Sorting Conditions 1 + 2 Description	1.497	.917
D-KEFS Sorting Condition 1 Confirmed Correct Sorts	1.337	.903
D-KEFS Twenty Questions	.915	.527
WJ III COG NU Concept Formation	5.708	.809
WJ III COG NU Analysis/Synthesis	4.214	.577
D-KEFS Word Context	.888	.541
Initiation, Planning, and Organization		
WJ III COG NU Planning	1.000	.382
NEPSY-II Clocks	.300	.377
D-KEFS Tower Total Achievement	.146	.247
Self-Regulation/Impulse Control		
NEPSY-II Inhibition-Inhibition	1.000	.730
TEA-Ch Walk, Don't Walk	1.179	.583
D-KEFS Color Word Condition 3	.826	.554
Working Memory		
WJ III COG NU Memory for Words	1.000	.786
NEPSY- II Narrative Memory Free Recall	.100	.346
WJ III COG NU Numbers Reversed	.852	.628
WJ III COG NU Auditory Working Memory	.940	.718
NEPSY-II Word List Interference	.202	.673
Deployment of Attention		
WJ III COG NU Pair Cancellation	1.000	.611
NEPSY-II Auditory Attention	.295	.451
TEA-Ch Code Transmission	.306	.523
TEA-Ch Sky Search	.279	.454
WJ III COG NU Auditory Attention	1.086	.401

Table 30

Standardized Coefficients for the Modified Six-Factor Model Proposed by the Researcher

	Unstandardized Estimate	Standardized Estimate
Mental Flexibility/Use of Feedback		
TEA-Ch Sky Search DT	1.000	.321
NEPSY-II Response Set	.815	.310
D-KEFS Verbal Fluency Condition 3	.928	.361
WJ III COG NU Analysis/Synthesis	6.071	.507
Problem Solving		
NEPSY-II Animal Sorting	1.000	.568
D-KEFS Sorting Conditions 1 + 2 Description	1.246	.770
D-KEFS Sorting Condition 1 Confirmed Correct Sorts	1.110	.766
D-KEFS Twenty Questions	1.030	.581
WJ III COG NU Concept Formation	6.356	.874
D-KEFS Word Context	.962	.574
Self-Regulation/Impulse Control		
NEPSY-II Inhibition-Inhibition	1.000	.757
TEA-Ch Walk, Don't Walk	1.270	.645
D-KEFS Color Word Condition 3	.783	.545
NEPSY-II Inhibition-Switching	.843	.616
Working Memory		
WJ III COG NU Memory for Words	1.000	.785
WJ III COG NU Numbers Reversed	.848	.626
WJ III COG NU Auditory Working Memory	.981	.750
NEPSY-II Word List Interference	.190	.646

(Continued)

Deployment of Attention		
WJ III COG NU Pair Cancellation	1.000	.653
NEPSY-II Auditory Attention	.267	.435
TEA-Ch Code Transmission	.277	.499
TEA-Ch Sky Search	.273	.469
WJ III COG NU Auditory Attention	1.017	.399
D-KEFS Sorting Conditions 1 + 2 Description		
D-KEFS Sorting Condition 1 Confirmed Correct Sorts	2.907	.628
Mental Flexibility/Use of Feedback		
Problem Solving	3.306	1.130
Self-Regulation/Impulse Control	3.339	.967
Working Memory	19.728	1.175
Deployment of Attention	11.716	1.368
Problem Solving		
Self-Regulation/Impulse Control	3.035	.534
Working Memory	21.678	.785
Deployment of Attention	9.567	.679
Self-Regulation/Impulse Control		
Working Memory	15.166	.465
Deployment of Attention	14.023	.842
Working Memory		
Deployment of Attention	56.461	.698

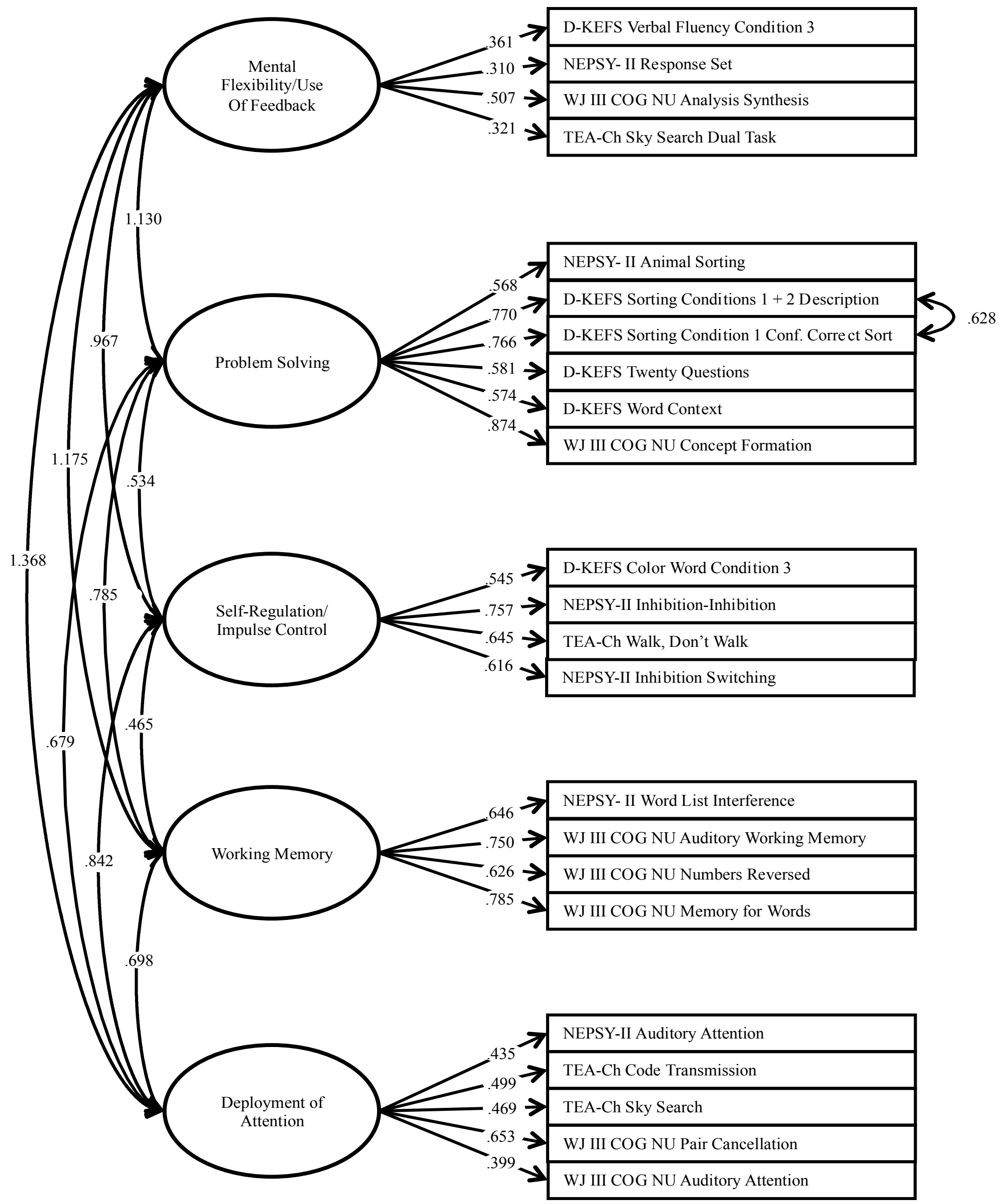

Figure 6. Modified six-factor model proposed by the researcher

Table 31

Comparison of Fit Indices for the Original and Modified Models

	Single-Factor		Integrated SNP/CHC		Proposed Model	
	Original	Modified	Original	Modified	Original	Modified
χ^2	898.40	707.82	799.86	639.82	815.34	342.78
df	377	367	370	293	371	218
χ^2/df	2.38	1.93	2.16	2.18	2.20	1.57
p	< .001	< .001	< .001	< .001	< .001	< .001
CFI	.616	.749	.684	.699	.673	.879
RMSEA	.068	.056	.062	.063	.063	.044
SRMR	.124	.118	.121	.121	.124	.096

Summary of Results

This chapter outlined the statistical procedures utilized to test the research question and hypotheses. The theoretical models of a single-factor model, the Integrated SNP/CHC model, and a six-factor model proposed by the researcher were used to determine which model best represented the construct of executive functioning with a clinical sample of children. A full comparison of the fit indices for the original and modified versions of all three models can be found in Table 31. Findings suggested that the single-factor model did not adequately represent the underlying factor structure of executive functioning with the sample data even with some modifications allowing for co-variance between observed variables. All fit indices with the exception of the

RMSEA were considered poor. Similarly, the results of both the initial and modified versions of the Integrated SNP/CHC model demonstrated poor fit for all of the fit indices except the RMSEA. Minor improvements were observed for the modified Integrated SNP/CHC model, particularly regarding a decrease in multicollinearity between the latent factors. Additional changes to improve the overall fit of the model were suggested, such as removing the third level variables of inhibitors/facilitators and executive functions completely. These changes were not made in order to maintain the integrity of the model as they would significantly deviate from Miller's (2013) theoretical structure.

Finally, the six-factor model proposed by the researcher demonstrated poor model fit for most of the fit indices during initial model testing. Modifications were made to remove one latent variable, drop several subtests, and relocate other subtests to new factors. The third-level variable of executive functioning was also removed from the model allowing all of the latent factors to co-vary. Results from the modified proposed model suggested a large improvement in fit with most of the fit indices falling in the good to acceptable range; however, the chi-square value remained significant after modifications indicating either a slight deviation from normality or continued specification errors. The proposed model continued to demonstrate difficulty with the mental flexibility/use of feedback factor as evidenced by low structural coefficients and a high degree of multicollinearity between mental flexibility/use of feedback and the other latent variables. Although none of the three theoretical models appeared to fully represent the factor structure of executive functioning in the study, the updated five-factor model proposed by the researcher demonstrated the best fit out of the three models examined.

CHAPTER V

DISCUSSION

The present study examined which of three theoretical models best represented the construct of executive functioning in a child-clinical sample. Structural equation modeling through a CFA was used to determine whether a single-factor model, the Integrated SNP/CHC model, or a six-factor model proposed by the researcher most appropriately represented the factor structure of executive functioning. This chapter reviews salient findings from the analysis, study limitations, and directions for future research.

Purpose and Goal

The purpose of this study was to better understand the construct of executive functioning by comparing three different theoretical models chosen to represent divergent viewpoints in the field. One common conceptualization of executive functioning is to organize all higher-order processes under one construct (Flanagan & Harrison, 2012; Goldberg, 2001). This perspective decries the difficulty of parsing out separate executive functions due to the high connectivity between skills. In contrast to such a single factor approach, the dominant view in the field of school neuropsychology is that executive functions are comprised of separate and distinct skills. In addition to examining the single-factor model in this study, the researcher investigated two different multidimensional models based on popular theories in the literature. The Integrated SNP/CHC model (Miller, 213) has been previously researched with a clinical population of children and uniquely conceptualizes working memory and attention as facilitators of higher-order executive functions. The third model, a six-factor model proposed by the researcher, expanded Miyake and Friedman's (2012) work by adding three additional variables to their original model of working memory, set shifting, and inhibition. Anderson's (2008) description of executive functions also supports the structure of the six-factor model.

The importance of understanding the presentation of executive functioning in a child-clinical sample is evidenced by the high degree of executive dysfunction in this population and its detrimental effects on academic, social, and emotional functioning both in childhood and adulthood (Brock et al., 2009; McCloskey et al., 2009; Röthlisberger et al., 2013). Information obtained from this study will help clinicians better understand the nature of executive function and dysfunction in children with disabilities. Results of the study can help inform intervention planning and support the development of executive skills in the schools and in the workplace.

Summary of Results

Preliminary Analysis

Multiple preliminary analyses were computed to describe the nature of the clinical sample utilized in the primary analysis. The statistical package SPSS, version 19, was used to calculate descriptive statistics, bivariate correlations, and multivariate and univariate analyses. Preliminary analyses were also used to guide decision making during the model modification phase and to assist in providing an explanation of the findings. During data selection, the researcher selected subtests from a larger dataset to identify participants ranging from 8- to 16-years-old based upon the overlapping age range of the four neuropsychological measures used in the analysis. Participants totaled 300 and the distribution of gender was slightly skewed with more males than females. The higher prevalence of males in the sample was not surprising as it is consistent with higher rates of neuropsychological diagnoses for male children observed in the general population (Boyle et al., 2011). Descriptive statistics also indicated that the sample included a higher percentage of individuals who identified as Caucasian/European compared to the other ethnic groups of Hispanic/Latino, African American, or Asian/Pacific Islander. This trend is consistent with census data confirming that Caucasian is currently the largest ethnic group in the United States (U.S. Department of Commerce, 2011). Families of color may also be less likely to seek testing due to a lack of trust stemming from psychology's history of cultural bias on psychological assessments (Reynolds & Suzuki, 2013).

Numerous disability categories were represented in the sample population. Demographic statistics illustrated that over half of the participants had been diagnosed with more than one disability. This pattern may be explained by the fact that many of the disabilities studied in this research are highly co-morbid (American Psychiatric Association, 2013). It is also likely that the children in the sample were referred for a neuropsychological evaluation because they demonstrated additional complexity beyond what is observed during a traditional school evaluation (Hale & Fiorello, 2004). The single clinical group with the highest number of participants in this study was learning disability, which is expected given that learning disability is the most common disability category identified in special education (Fletcher, Lyon, Fuchs, & Barnes, 2007). The only combination of two disabilities with a consistent pattern in the sample data was 14.60% of children who had been diagnosed with both a learning disability and ADHD. The other three single disability categories of neurological impairment, ADHD, and other single disability (e.g., diabetes) each represented approximately 8 percent of the sample.

Although participants displayed average performance overall on many of the subtests, six mean scores were below the expected mean as outlined in the assessment manuals of each measure. Slight deviations from normality were also observed for many subtest scores, which is consistent with the clinical nature of the sample where children with disabilities might be expected to perform somewhat below average. This pattern is not surprising given that deficits in performance on executive tasks are a common feature of many clinical disorders (Banich, 2009; Hunter & Sparrow, 2012; Wilcutt et al., 2005).

Data were then examined to compare the difference between subtest scores before and after imputation with no major differences in means or standard deviations noted. Preliminary Spearman-rank order correlations were run with non-imputed data in order to be consistent with the modeling procedures. The original versions of the models were compared with both imputed data through MI and non-imputed data using FIML. Results of the models were commensurate. Thus, FIML was chosen for model modification as it was a better representation of the true nature of the data and because it has been shown to be a robust procedure when a high number of values are missing (Enders, 2001). FIML was also the preferred method for handling missing values in this analysis because it is less affected by non-normal data distributions compared to other imputation methods. Finally, FIML decreases researcher error by requiring fewer options for imputation procedures, such as determining how many iterations to run during modeling (Allison, 2003).

Preliminary analyses examining the relationships between variables illustrated that the sample demographics were generally consistent across ethnicity, disability status, and gender. A performance difference was observed for age, which indicated that children with a neurological impairment were significantly older than children diagnosed with other disabilities. One explanation for the difference in age may be that adolescents are more likely to experience a TBI compared to school-aged children, due in part to increased risk-taking behavior during this developmental period (Castillo, 2008). Spearman rank-order correlations were also conducted to determine the degree of relationship between the dependent variables of subtest scores. Many moderate positive correlations were observed between the subtests. Strong positive correlations were documented among several of the WJ III COG NU tests. The only other measure with strong correlations among its own tasks was between the two D-KEFS Sorting subtests of Condition 1 Confirmed Correct Sorts and Sorting Descriptions 1 + 1 Combined. Several other strong correlations were observed between subtests of different measures, although the majority of these relationships were between the WJ III COG NU tests and subtests from other measures. Additionally, strong correlations were noted between the NEPSY-II Animal Sorting and the D-KEFS Sorting tasks. Although many significant moderate and strong positive correlations were documented, other subtests in the analysis displayed negative, albeit non-significant, relationships. This finding may be related to the inability of neuropsychological measures to adequately parse out constructs due to the high degree of task impurity on these items (Banich, 2009). None of these negative correlations were allowed to exist on the same factor in the final models.

Spearman rank-order correlations were also computed between age and subtest scores. Age was significantly and negatively correlated with three subtests, the WJ III COG NU Pair Cancellation, D-KEFS Verbal Fluency Condition 3, and D-KEFS Color Word Condition 3, indicating that older participants scored significantly more poorly on these items compared to younger children. Significant positive correlations were documented for the TEA-Ch Sky Search and WJ III COG NU Auditory Attention; older participants tended to perform better on these tasks.

Additional results from MANOVAs and univariate ANOVAs were obtained to understand the impact of the demographic variables of age, gender, disability status, and ethnicity on subtest performance. An imputed version of the data was utilized for these analyses because the statistics could not be run with the high amount of missing data. Males and females displayed consistent performance across subtests with the exception of three subtests. Males obtained significantly lower scores on the NEPSY-II Word List Interference and NEPSY-II Animal Sorting subtests. In contrast, male participants scored significantly higher on the TEA-Ch Sky Search DT subtest.

Although gender differences were noted on these three subtests, research in the field of neuropsychology has found inconclusive and minimal data on gender performance overall (Seidman et al., 2005), suggesting caution in generalizing these findings.

Preliminary results also confirmed that participants differed in their level of performance on 10 of the 29 subtests in the analysis, depending on their ethnicity. In general, children who identified as a race or ethnicity other than Caucasian/European performed more poorly on several subtests including the WJ III COG NU Memory for Words, Auditory Working Memory, Concept Formation, and Planning tests. Individuals who did not identify as Caucasian/European also generally demonstrated lower scores on the NEPSY-II Word List Interference and Animal Sorting as well as the D-KEFS Twenty Questions and Word Context tasks. There were some exceptions to this pattern. On the WJ III COG NU Numbers Reversed subtest, Caucasian/European children performed more poorly than those from a Latino(a)/Hispanic background. Additionally, both African American/Other and Caucasian/European children scored lower than Hispanic children on the TEA-Ch Code Transmission. Most of the performance differences were expected given that differential performance has been documented previously in the assessment literature and neuropsychological batteries continue to struggle with cultural bias (Flanagan, Ortiz, & Alfonso, 2013). Importantly, the TEA-Ch Code Transmission and WJ III COG NU Numbers Reversed may have less cultural loading as they are only based on repeating or listening to numbers.

Primary Analysis

Single-factor model. Results from the primary analysis were obtained through SEM, specifically individual CFAs testing the factor structure of executive functioning to determine the model fit of the three theoretical models under examination. The single-factor model was first investigated to determine if a one-factor model was the most appropriate way of conceptualizing executive functions in a clinical group of data. The single-factor theory was included as executive functions have historically been conceptualized as one overarching and unitary construct (Anderson, 2008; Jurado & Rosselli, 2007). This model was also included as a comparison to the other two multiple-factor theories represented: the Integrated SNP/CHC model and the six-factor model proposed by the researcher.

Findings from the original single-factor model confirmed that while all paths were significant, most of the model fit indices were unacceptable. The single-factor model was modified to allow for co-variance between certain observed variables; however, fit of the model did not improve and the single-factor model continued to be a poor representation of the sample data. This result was consistent with the researcher's hypothesis that the single-factor model would represent the poorest fit of all three models, and was not surprising given that most researchers support a multidimensional approach to understanding executive functioning (Banich, 2009; Blair & Ursache, 2011). In fact, current research on brain localization and neuropsychological research has highlighted that certain discriminant processes exist during higher-order thinking and contribute to differential performance on executive tasks (Hale & Fiorello, 2004).

Integrated SNP/CHC model. The second model analyzed in the study was the Integrated SNP/CHC model. This theory was hypothesized to best represent the factor structure of executive functioning due to previous factor analytic research with a clinical sample of children utilizing this model (Miller, 2013). The Integrated SNP/CHC model separates the more traditional executive functions of problem solving, cognitive flexibility, response inhibition, and concept recognition and generation from the facilitators and inhibitors of attention and working memory. In the Integrated SNP/CHC model, the inhibitors/facilitators support the executive functions by either improving or diminishing performance depending on the strength of one's attention and working memory abilities. In the current study, the inhibitors/facilitators and executive functions were third-level factors and were allowed to co-vary to represent their relationship. The second-level factors (e.g., attention, cognitive flexibility) were represented by neuropsychological subtests based on Miller's (2013) model. Subtests were removed before the analysis if they did not belong to one of the four neuropsychological measures or had poor psychometric properties. See Table 5 in Chapter 3 for a full list of subtests removed before the original model was analyzed.

The original Integrated SNP/CHC model adequately converged during model estimation with no errors noted. All standardized coefficients were significant. The original version of the model demonstrated poor fit indices with the exception of the RMSEA, which was considered acceptable. In order to increase the overall fit and remove all possible specification error, model modifications were conducted during the second phase of the primary analysis. Modifications also focused on decreasing the high level of multicollinearity observed between latent factors. The Integrated SNP/CHC model was modified by collapsing the cognitive flexibility and response inhibition factors at the second-level of latent variables. Three other subtests were dropped from the second analysis. The WJ III COG NU Memory for Words, WJ III COG NU Auditory Working Memory, and NEPSY-II Narrative Memory Free Recall subtests were removed due to either poor factor loadings or the modification index produced by laaven in R suggesting it would increase specification.

Results from the modification phase suggested that the model was not drastically improved and several fit indices were still unacceptable. Further, the path between the third-level variables of executive functions and inhibitors/facilitators remained over 1, while the attention and working memory paths from the inhibitors/facilitators factor were over .90. These findings suggest that a high degree of multicollinearity remained. Overall, the Integrated SNP/CHC model continued to produce low fit for the sample data and did not confirm the researcher's hypothesis that it would best represent the factor structure of executive functioning. Additional modifications were suggested, such as removing the third-level distinctions between facilitators/inhibitors and executive functions. However, these changes were not made in order to maintain the theoretical integrity of Miller's (2013) model.

Six-factor model proposed by the researcher. The third model analyzed in this study was a six-factor model proposed by the researcher. This model was loosely based on Anderson's (2008) description of what comprises executive functions in the literature. It also intentionally incorporated Miyake and Friedman's (2012) three-factor model, which has been highly researched in the field. The six-factor model expanded Miyake and Friedman's three factors of working memory/updating, inhibition, and set shifting to include the three additional factors of initiation, planning, and organization; problem solving; and deployment of attention. These three factors were added to determine if additional factors better represented the factor structure of executive functions and to allow for comparison between the six-factor model and the Integrated SNP/CHC model.

The original six-factor model included paths from the six latent variables to an overarching third-level factor titled executive functions. The organization of observed variables onto their latent factors was determined through previous research on the construct and data obtained from the test manual outlining which constructs subtests were produced to measure. The original findings from the six-factor model indicated that all paths were significant and the model adequately converged with no errors. Most of the standardized coefficients for the paths were appropriate, but several remained below the cutoff of .40. Specifically, problems were observed for the subtests of NEPSY-II Clocks, WJ III COG NU Planning, and D-KEFS Tower on the initiation, planning, and organization factor. Model fit indices highlighted that while the RMSEA was appropriate, all of the other fit indices were poor and deemed that the model did not have good fit.

Because of the poor model fit, model modifications were also conducted on the six-factor model proposed by the researcher. The initiation, planning, and organization factor was removed from the analysis completely, resulting in a five-factor model. Additional subtests were removed or moved to another factor, particularly focusing on improving the mental flexibility/use of feedback variable due to its latent path over 1. The TEA-Ch Creature Counting, D-KEFS Trail Making Condition 4, and NEPSY-II Narrative Memory subtests were removed completely. The NEPSY-II Inhibition Switching task was moved from mental flexibility/use of feedback to self-regulation/impulse control, while the WJ III COG NU Analysis/Synthesis test was relocated from problem solving to mental flexibility/use of feedback. Previous research comparing the WJ III COG NU tests with the D-KEFS indicated that Analysis/Synthesis did not factor on the fluid reasoning construct as expected (Floyd et al., 2010). The suggestion to move WJ II COG NU Analysis/Synthesis to cognitive flexibility/use of feedback was allowed due to theoretical understanding that the same cognitive flexibility skills are needed for both set shifting and problem solving tasks (Ionescu, 2012). Finally, the D-KEFS Sorting subtests were allowed to co-vary, which decreased their factor loadings to more acceptable estimates.

Overall, the modifications made to the proposed model improved several fit indices and resulted in the best overall fit of the three models. Most of the latent variables of the proposed model had good structural paths to observed variables with all paths being statistically significant. Consistent with the Integrated SNP/CHC model, continued problems with multicollinearity were observed for the updated five-factor model proposed by the researcher. The mental flexibility/use of feedback factor still displayed low structural coefficients and had co-variances with the other latent variables over 1. These findings indicate that the mental flexibility/use of feedback factor continued to be problematic and may not discriminate well between the other remaining four latent variables.

Overall Findings and Hypotheses

While the structural paths were statistically significant for the three models, several of the fit indices indicated that none of the original proposed models demonstrated strong fit for all indices using the sample data. Of the models, the Integrated SNP/CHC model and the six-factor model were more appropriate for model modification compared to the single-factor model. These models continued to have poor fit and structural coefficients that varied from adequate to good depending on the specific factor. Model modifications occurred using knowledge of theory of executive functions as well as modification indices generated by laaven in R. After the model modification phase, the updated five-factor model proposed by the researcher demonstrated best fit of the clinical data. Several of the fit indices were considered good and all paths were significant.

Overall, the research findings did not support the study hypothesis as the Integrated SNP/CHC model did not demonstrate stronger fit than the other two models. Instead, the modified five-factor model showed the best fit, followed by the Integrated SNP/CHC, and lastly the single-factor model. This finding is surprising given the previous research using a clinical sample of children utilized in the development of

Miller's (2013) model. It is possible that additional issues, such as task impurity, best explain these results as the construct of executive functioning may be even more difficult to clearly distinguish in a clinical sample of children. Similarly, the modified five-factor model proposed by the researcher allowed for overlap in constructs through covariance and therefore may have produced stronger fit indices.

Other modification suggestions were made through the modification index but were not included due to lack of theoretical support. For instance, it was noted that removal of the mental flexibility factor in the six-factor model would increase fit. However mental or cognitive flexibility is a historically strong construct in the executive functioning literature (Ionescu, 2012) and its removal would represent a drastic change in the construct. Although the mental flexibility factor was not removed, problems with this construct were a consistent finding for both multidimensional models. The response inhibition and cognitive flexibility factors in the Integrated SNP/CHC model were collapsed due to problematic observed variables. These findings suggest that tasks that traditionally measure set shifting and cognitive flexibility may have a higher degree of task impurity, and may not adequately discriminate between executive skills in a mixed-clinical sample of children. Further, this pattern could be explained by the younger age of the sample. Although researchers using Miyake and Friedman's (2012) model have documented the presence of a three-factor structure of set shifting, inhibition, and updating/working memory as early as 7 years of age, these studies were predominantly conducted on a typically developing population. In contrast, Zelazo and Müller (2010) noted that a two-factor structure of working memory and set shifting best fit a sample of children ages 9 to 12. Thus, the executive functions traditionally conceptualized as mental flexibility or response inhibition may be more impacted by disability and developmental trends than some other executive functions.

Further, cognitive control and flexibility may continue to be more complex than originally thought (Wiebe, Morton, Buss, & Spencer, 2014). Other researchers have noted set shifting and problem solving are fragmented versions of the overarching cognitive flexibility concept (Ionescu, 2012). These findings suggest that another non-tested model may better represent the construct or that significant modifications may need to occur to adjust for task impurity. One emerging construct beginning to be included in the neuropsychological research is theory of mind and perspective taking (Wiebe et al., 2014). Weiebe and colleagues (2014) noted that perspective taking requires an individual inhibit his or her dominant feelings or thoughts, and then shift to a new perspective considering the other person. The three examined models did not incorporate all elements of executive functions, such as social and emotional control, because it was not feasible given the limitations of the data set and a lack of direct observable tests for these variables (Banich, 2009). Thus, it is possible that the models may have not been appropriately specified due to missing elements that were not included in the present study.

Research Implications

The findings from this study have important implications for both researchers and clinical practitioners. Results indicated that differential performance among the neuropsychological measures was observed for disability type as well as ethnicity. Further, none of the models demonstrated strong fit and both multidimensional theories exhibited problems with multicollinearity. This pattern suggests that clinicians should be cautious when using tests of executive functions to diagnose different disabilities. Thus, these tests should not be used in isolation and multiple sources of data should be used to reach diagnostic conclusions. Issues related to task impurity and difficulty directly measuring higher-level executive skills continue to be highly problematic, particularly when testing children with disabilities. Results from this study suggest that the latent constructs often measured in neuropsychological tests may be even more related in a clinical sample of children than in a typically developing one. Similarly, intervention planning should be based on observations of the multiple skills required for a task on a measure of executive functioning and clinicians are cautioned not to over-rely on the main executive skill the subtest is intending to measure.

Another important finding from this research is the complex nature of cognitive or mental flexibility and its relationship with other executive skills, specifically inhibition. The results of this study suggest that cognitive flexibility, or set shifting, may be more related to other executive functions than previously thought. School neuropsychologists may need to re-evaluate how they assess for these functions. It may be helpful to incorporate other forms of assessments, such as rating scales and observations, to help differentiate between inhibition and flexibility.

Methodological Issues/Limitations

As with all research, this study is not without its limitations, which should be considered during interpretation and noted before generalizing findings to any population. General limitations are always considered during use of advanced statistical techniques like SEM. Other more specific limitations exist relating to the nature of archival data and the focus of the study on children with various disabilities. Additional limitations were encountered due to the complex nature of the construct of executive functioning and previously documented difficulties measuring this construct with traditional neuropsychological batteries.

Archival Data

The use of archival data produced inherent limitations (Meyers et al., 2006). First, an archival data set did not allow the researcher to control or monitor how the data was collected in the field. Individuals providing evaluations as part of the KIDS, Inc. program are well trained and supervised by experienced neuropsychologists; however, administration error or report entry mistakes were still possible. The use of archival data also limited the number and types of variables that could be analyzed in the proposed study. For instance, certain assessment instruments were excluded from the study because they were not well represented in the data set. A final limitation of using an archival data set was that data entry errors were possible during data coding, entry, and cleaning. To decrease the chance of this occurring, graduate students entering and managing the data set received specialized training and regularly checked the work of their peers on the research team.

Incomplete Data and Imputation Limitations

Another significant limitation to the proposed study involved missing data and imputation limitations. Because practitioners initially administering assessments chose subtests based upon the referral question, there was significant variability in the number of subtests given in each case. This process resulted in a higher amount of incomplete data than would exist in an experimental study. Similarly, using imputed data limited the interpretability of the research findings, particularly given that some items displayed slight deviations from normality. The researcher determined model fit with data produced by a computer algorithm and not direct observation from the sample (Meyers et al., 2006). This limitation was decreased as much as possible by using complex estimation formulas in FIML and numerous indices to measure model fit.

SEM Limitations

SEM is one of the most advanced statistical procedures in the field of psychology and is touted as a powerful multivariate analysis to represent complex theoretical models (Schumacker & Lomax, 2010); however, all analytic procedures have associated limitations. First, the five steps of SEM are highly dependent on utilizing models with strong theoretical backing. Model fit indices may have been skewed or biased if the models were not appropriately specified and identified. SEM is also limited because it produces numerous output measures to assess both the overall model fit and specific paths. All of the indices are vulnerable to misinterpretation and may produce Type 1 or Type 2 error. Further, it is possible that model alterations may influence the generalizability of the findings. To decrease the magnitude of this limitation, all adjustments of the model were supported by research and consistent with theoretical knowledge of the construct.

Clinical Population

While it is a significant strength of the study, using a mixed-clinical sample of children with a wide variety of diagnoses was also a limitation. Children and adolescents included in the study had been previously diagnosed by outside professionals and the researcher did not confirm diagnostic classifications independently. Individuals in the sample also had multiple diagnoses that did not clearly fit into clinical categories. Frequency counts were completed to ensure that the sample represented a diverse range of children and adolescents. The clinical nature of the sample was in contrast to the normative groups used for standardization for the four chosen neuropsychological assessments. Thus, findings should be interpreted with caution as they may not generalize to the overall population.

Age Limitation

The combined administration procedures of the measures limited the age range of the sample to individuals ages 8 to 16. Therefore, conclusions based on the model fit of the sample may not generalize well to younger children, older adolescents, or the adult population. Statistical procedures, such as frequency counts, were computed to ensure that a broad range of ages were included in the sample; however, participant age was not stratified to be representative of the general population and the sample was skewed toward a higher number of children aged 8 compared to other ages.

Modeling Limitations

Another potential limitation of the current study stemmed from difficulty conceptualizing theories of executive functioning. This problem pervades all research on executive function and results in an extreme lack of consensus in the field (Hunter & Sparrow, 2012; Packwood et al., 2011). The complex nature of the construct also increased the difficulty in producing a model that accurately represented the latent variable of executive function because of task impurity and the need to oversimplify what the assessments actually measure. These issues were particularly salient for the six-factor model, which aimed to consolidate multiple perspectives in the field and provide additional information on the role of attention and working memory in higher-order cognition. The fact that the model was a creation of the researcher was a limitation because only the three aspects of working memory, set shifting, and inhibition have been confirmed with previous factor analytic studies. Similarly, both the Integrated SNP/CHC model and the six-factor model needed to be simplified in order to be testable with the archival data set.

Assessment limitations exist due to the types of scores included in the analysis. For example, several of the subtests in the models were represented by the higher-order version or component of the task, though decreased performance on this task may be produced by a basic neurocognitive deficit. For instance, Verbal Fluency Condition 3 on the D-KEFS was theorized to measure set-shifting/flexibility. However, low scores in the data may have been the result of an associated deficit, such as impaired long-term retrieval in word finding. Furthermore, some of the NEPSY-II scores chosen for this study were combined scores, which represented multiple aspects of the task. While this was helpful for providing an overall indicator of performance, the scores may have been skewed by high variation between the components of the score (i.e., time and accuracy).

Directions for Future Research

Based upon the aforementioned research limitations, future research would benefit from further breaking down the sample into distinguishable characteristics to better understand how models of executive functioning present with more specific populations. In particular, current research continues to support the notion that executive functions are developmental in nature and may come online at different ages (Banich, 2009; Jurado & Rosselli, 2007). Although some of the variability of development is accounted for by standardizing measures by age, it would be useful for additional research to divide and compare the sample by narrow age ranges. Controlling for age may help highlight how model structure changes or evolves as individuals age. One explanation for the findings involves the skewed distribution of age range, with a larger amount of the sample belonging in the 8- to 9-year-old age range compared to other ages. As mentioned, executive functions are developmental in nature and the sample variability may have presented differently if it were comprised of a higher number of adolescents. The discrepancy between expected and actual performance on executive tasks may be even more extreme for an older clinical population compared to the younger sample utilized in this study.

Furthermore, results from this study illustrated that specific differences may exist between the different categories of disabilities in the clinical sample. Due to limitations in the dataset, several disability categories were combined to allow for more equal representation between groups during the statistical analyses. It is imperative that future research explore and control for differences between disability types as interventions are often determined based upon disability criteria. Although it was not feasible for this study, future research would benefit from comparing modeling approaches with more equal disability categories or with a sample with only single disability categories. As noted in the literature review, slight differences have been illustrated between disability types (Hunter & Sparrow, 2012), such as children with ASD demonstrating different performance on the WCST (Broadbent & Stokes, 2013). Thus, focusing in on one disability type may better highlight how executive functions present in a mixed-clinical sample of children.

While model modifications improved fit, particularly for the six-factor model proposed by the researcher, future studies may benefit from conducting an exploratory factor analysis (EFA) to determine if other patterns exist in the data. A larger analysis incorporating additional factors may also help parse out issues related to task impurity and ensure that the theoretical model is appropriately specified by including all constructs. For the current study, popular tests of executive functions, such as the WCST (Davis, 2011), could not be included. Some subtests were excluded from the study for their technical properties or for lack of representation in the data set. Further, observable variables are not available for certain constructs in neuropsychology, such as a way to directly measure emotional regulation. These issues may have contributed to a specification error where important predictor variables were left out of the factor structure (Kline, 2010). Thus, it would be beneficial to expand this research study to incorporate both additional cognitive variables (e.g., verbal comprehension, visual-spatial processing) and other popular tasks to determine if different combinations of subtests commonly thought to measure executive function actually measure more primary abilities. Future research can also expand Miller's (2013) model to include processing speed as a cognitive facilitator/inhibitor, which may help explain why the Integrated SNP/CHC model did not better fit the data in this study. Incorporating behavioral rating scales or scores from CPTs to expand the theoretical structure to include additional types of data outside of traditional neuropsychological measures may also be useful.

Another possible explanation for the findings in this study is that a different theoretical model better represents the factor structure of executive functions in a clinical sample of children. As previously noted, numerous theories exist in the literature and a full comparison of them was beyond the scope of this study. It is possible that a different theory, such Barkley's (1997) model of self-regulation or hot and cold executive functions (Zelazo & Carlson, 2012), may have stronger fit than any of the three models examined in this research study.

A final direction for future research is to expand the five-factor model of executive functioning proposed in this study to include the construct of theory of mind and perspective taking. It is possible that measures of emotional regulation require a person to inhibit their response and then shift to a different function or perspective (Wiebe et al., 2014). Similarly, research on creativity indicates that it is highly linked to cognitive flexibility (Ionescu, 2012). Although it is difficult to measure theory of mind and creativity, future research and neuropsychological assessments may expand to add these constructs. Adding in additional facets may more fully represent mental flexibility and the construct of executive functioning overall.

Conclusion

This study aimed to use the aforementioned methodology and statistical analyses to better understand the factor structure of executive functioning in a child-clinical sample. The current research study utilized three models specifically chosen to represent divergent theoretical perspectives commonly found in the literature that were still testable using standardized neuropsychological measures. These three models were a single-factor model, the Integrated SNP/CHC model, and a six-factor model proposed by the researcher. Findings indicated that none of the three models strongly represented the factor structure of executive functioning. In contrast with the researcher's hypothesis, the Integrated SNP/CHC model did not demonstrate the strongest model fit as measured by multiple fit indices used in SEM. All three initial models displayed poor fit of the data and required modifications to increase specification. After modification, the updated five-factor model proposed by the researcher demonstrated best fit compared to the other two models. Findings highlighted the high degree of task impurity as evidenced by frequent multicollinearity between constructs. This study also illustrated that the construct of mental flexibility or set shifting may present differently in a clinical sample of children as it continued to demonstrate poor fit in both the Integrated SNP/CHC model and five-factor model proposed by the researcher. Continued research on the factor structure of executive function is warranted based on the significant disagreement in the field concurrent with an increased interest in identifying executive deficits with neuropsychological assessments. Findings obtained from this research help to inform both assessment practices and potential interventions for executive dysfunction in children.

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