A STUDY INVESTIGATING THE EFFECTS OF STIMULANT MEDICATION ON PROCESSING SPEED AND WORKING MEMORY IN AN ADHD POPULATION

By

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(Under the Direction of Linda Campbell, PhD)

ABSTRACT

Attention-Deficit/Hyperactivity Disorder is the most researched pediatric mental health disorder with many interested fields of practice involved in assessment, treatment, and research of this disorder. This study aimed to add to the wealth of research on neurocognitive performance associated with ADHD and ADHD treatment with stimulants specifically within the cognitive domains of working memory and processing speed. Initial analysis was performed with retrospective data to assess novel comparison statistics between similar cognitive domains on common cognitive assessment measures within a clinical comparison population. Both main indices of working memory and processing speed on the WJ IV COG and the WISC-V were assessed to measure similar constructs with large correlations between these measures in these domains. They were also found to be statistically similar to the correlations between the WJ IV COG and WISC-IV even with some significant changes within the working memory index on the Wechsler scale. The perceptual speed cluster on the WJ IV COG produced anomalous results compared to the former stated results and WISC-IV comparative results.

In comparison to these clinical population statistics, a significant stimulant medication impact was not detected within the working memory performance nor the processing speed performance measures. There was, again, an anomalous result found when comparing the

perceptual speed cluster to processing speed in relation to the aforementioned results. However, the working memory comparison indicated a higher correlation, interpreted as more consistent results, within the ADHD group whose performance being compared was linked with active or inactive stimulant medication status between days of assessment; this was compared to the clinical control group who were not on any stimulant medication at any point, although this difference was short of statistical significance.

Taken together, these findings add to the extensive literature involving individuals with ADHD and treatment of such. However, while the results add to the extant data of cognitive performance considerations of the presentation, assessment, and treatment of this diagnosis, perhaps more questions for future research were likewise presented. Specifically ideas are presented that consider alternative outlooks on therapeutic effects of treatment in these domains and methodological nuances within similar future studies.

INDEX WORDS: ADHD, working memory, processing speed, stimulant medications

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DEDICATION

Eight years before his passing, my grandfather, Lieutenant Colonel Jackson G. Thompson, a research chemist at Oak Ridge National Laboratory and World War II veteran, published his personal research and theory on the subject of D20 "heavy water" in a book titled "Aging at a Slower Rate: *Questions, No Answers.*"

My dissertation is dedicated to my grandfather as his subtitle, "*Questions, No Answers*," exemplifies how I view research. While we observe, investigate, and gather information about phenomena and human experience, the "answer" often includes some level of "it depends." Research adds to the wealth of limitless knowledge that exists in the world and allows us to expand what we know and what is considered "truth," but often leads us to more questions along the way. So, here I present my dissertation with the unofficial subtitle: "*Some Answers, but Honestly, More Questions."*

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CHAPTER 1: INTRODUCTION

The assessment of Attention-Deficit/Hyperactivity Disorder (ADHD) is wrought with logistical challenges particularly with the commonly and easily prescribed stimulant medication as a known efficacious treatment. Objective data, self-reports, collateral reports of socio-emotional inventories and anecdotal recounts all have weight in the final determination of an ADHD diagnosis and recommendations. Further, ADHD "is the most extensively studied of the pediatric mental disorders" (Advokat, Comaty, & Julien, 2014, p. 523). Within research among many fields of study, there is much debate as to which assessment tools are most valid, give the most useful and predictive information, and which should be trusted as the most valid and in what contexts, as well as what patterns of deficits or areas of concern may be indicative of ADHD. These many opinions span fields such as psychiatry, neurology, psychology (neuropsychology, school and educational psychology, clinical and counseling psychology), pharmacy, as well as pediatrics and general practice. While the assessment and diagnosis of ADHD may have many interested parties, and the complexity of diagnosis highlights the importance of ADHD research from the perspective of multiple fields, the varying viewpoints make it difficult to fully collaborate and merge information into a cohesive and helpful whole.

ADHD Prevalence & Diagnosis

According to the Center for Disease Control in 2016, approximately 9.4% (6.1 millions) of children in the United States ages 2 to 17 years old were diagnosed with ADHD, according to parent report, at some time in their lives (Danielson et al., 2018). About two-thirds (6 out of 10) of these children were taking medication for their ADHD which represents 1 out of 20 children

in U.S. (Danielson et al., 2018). Studies demonstrating the efficacy of psychostimulants for ADHD symptoms are extensive and psychostimulants have been referred to as "one of the most broadly effective drug therapies of the twenty-first century" (Advokat, Comaty, & Julien, 2014, p. 525). Nonetheless, treatment collaboration with other services and professionals are recommended as adjunct treatment especially with younger children (AAP, 2011). Other efficacious and well-established treatments include parent- or teacher-administered behavior therapy (e.g., AAP, 2011) as well as behavioral parent training, behavioral classroom management, and behavioral peer interventions (e.g., Evans, Owens, & Bunford, 2014). According to Preston, O'Neal, and Talaga (2013), outcomes for stimulants for ADHD have been significantly positive in over 200 "well-controlled studies" (p. 257). While a great deal of evidence supports the efficacy of psychostimulants in the treatment of ADHD, other studies indicate negative aspects as well (e.g., Ragan, Bard, & Singh, 2013). Drawbacks include over-prescription (under-prescription in Europe; Kooij et al., 2019), misuse/abuse in several populations, potential side effects such as serious adverse psychiatric events, seizures, and psychotic disorders (Storebo, Faltinsen, Zwi, Simonsen, & Gluud, 2018), and common side effects such as increased heart rate, decreased appetite and insomnia. There has also been evidence for potential long-term side effects such as decrease is possible height growth (Advokat, Comaty, & Julien, 2014). On the other hand, researchers also have found evidence that stimulants may act as a neuroprotective agent for those with a proper diagnosis of ADHD; one study notes that stimulants "not only reduce symptoms, but also may normalize the chemical microenvironment of the developing brain and ensure more normal brain maturation" (Castellanos et al., 2002 as cited by Preston, O'Neal, and Talaga, 2017, p. 259). The severity of the potential consequences – both negative and positive – make proper diagnosis of ADHD

imperative. However, the many variables and multiple health professionals involved in comprehensive assessment of this disorder represent a complex problem for psychologists, psychiatrists, and other mental and medical health professionals involved in the treatment, health, and wellbeing of children and adolescents.

Within the Clinical Practice Guidelines for the Diagnosis, Evaluation, and Treatment of Attention-Deficit/Hyperactivity Disorder in Children and Adolescents, the American Academy of Pediatrics (AAP, 2011 renewed in 2016) outlines that when diagnosing ADHD, a health professional must verify Diagnostic and Statistical Manual of Mental Disorders (DSM) criteria of the diagnostic impairments including documentation of the impairments within more than one setting. The guidelines also task the clinician with the requirement of ruling out any alternative cause of the behaviors mentioned in the criteria and must include valid assessments to diagnose or exclude other conditions that might be present. Some related causes could involve genetics, environmental etiologies, or rearing practices. Several common differential diagnoses include emotional or behavioral (e.g., anxiety, mood, learning, or language disorders or other neurodevelopmental disorders) as well as some physical conditions. According to Preston, O'Neal, and Talaga (2017), ADHD is "a diagnosis of exclusion" and all other potential disorders must be ruled out as "most psychiatric disorders in childhood present with some degree of motoric restlessness and inattention" (p. 254). Further, it is noted that all related disorders must be considered in a comprehensive evaluation as many of "these outwardly observable behaviors absolutely do not automatically lead to a diagnosis of ADHD" (Preston, O'Neal, & Talaga, 2017, p. 254). The large number of potential etiologies for hyperactive and inattentive symptoms leaves any diagnosing clinician in a challenging position of gaining a wide range of information outside of the ADHD symptom criteria as any diagnosis of exclusion does.

Statement of the Problem

Many medical physicians and psychiatrists (occupations with prescribing rights nation-wide) may and do diagnose ADHD within their own practice, often only using a short screener questionnaires to assess the strict presence of the external and observed symptoms. However, to thoroughly and fully investigate all the potential comorbidities and competing environmental, societal, and interpersonal influences, a more comprehensive psychological evaluation is necessary. More and more physicians are now requiring clients to obtain a full psychological evaluation in order to assess for ADHD properly before they will prescribe psychostimulants for ADHD symptoms. This is partially due to the number of potential clients feigning this disorder in order to obtain psychostimulants. These medications also are widely documented to be misused in many settings, especially in higher education settings to enhance academic performance (e.g., Weyandt et al., 2013). It is noted in the European Consensus statement on diagnosis and treatment of adult ADHD" that "the diagnosis [of ADHD] should not be applied to justify the use of stimulant medication to enhance performance in the absence of a wider range of significant impairments indicating a mental health disorder… [such as] … self-esteem, social interactions and relationships, [and] behavioural problems" (Kooij et al., 2010, p. 8). With all of these implications and intersections of widespread diagnosis and treatment of ADHD, there is a greater need for more comprehensive evaluation of ADHD in clients. As such, the presenting question of potential ADHD is such a common referral to psychologists that much research has been done in the area of assessing ADHD by psychiatrists and psychologists alike.

Purpose of the Study

This study will identify whether or not stimulant medication has significant effects on areas of cognitive functioning in children with ADHD, specifically in the domains of working

memory and processing speed. Existing studies identify varying effects of stimulant medications on the academic, cognitive, and daily functioning of children and adolescents. Few studies have measured the two domains of cognitive functioning with commonly used cognitive measures comparing performance when the participants had taken stimulant medications and when they had not without several common methodological issues present in similar studies. This design allows within-subject comparisons of the cognitive functioning in these two disparate conditions which renders significant information about the effects of stimulants but also the findings between two intellectual measures that does not currently exist in the literature. With this methodological approach and the results indicated, physicians and psychologists alike with have more information on what may be seen or used for assessment of ADHD when stimulant medication is involved in treatment.

Definitions and Operational Terms

The following are explanations of key terms and constructs discussed herewith in:

Attention-Deficit/Hyperactivity Disorder (ADHD): Attention-Deficit/Hyperactivity Disorder (ADHD) is a behavioral/mental health disorder and is characterized as a neurodevelopmental disorder within the DSM-5, (i.e., a condition that onsets within the developmental period). According to the DSM-5 the essential feature of ADHD is "persistent pattern of inattention and/or hyperactivity-impulsivity that interferes with functioning or development" (APA, 2013, p. 61). The symptom criteria then fall into two categories: inattention and hyperactivity/impulsivity. Each symptom is assessed for persistence of at least six months and is required to negatively impact social and academic/occupational activities as well as be inconsistent with the developmental level of the child. Inattention symptoms include often: failing to give close attention to detail/making careless mistakes, difficulty sustaining

attention in tasks, not seeming to listen when spoken to directly (mind elsewhere), not following through on instructions and finishing tasks, having difficulty organizing tasks and activities, avoiding or reluctance to engage in tasks requiring sustained mental effort, losing things, easily distractible, and/or being forgetful in daily activities. The hyperactivity/impulsivity symptoms include often: fidgeting, leaving seat often, running and climbing inappropriately, restlessness, unable to engage quietly, always on the go, talking excessively, impulsive responses, and interrupting or intruding on others. Six of the aforementioned symptoms in each or either category must be present for six months for children up to the age of 17 and then only five are required for age 17 years old and older. There are three types of ADHD including ADHD, Combined Presentation (ADHD-C), ADHD, Predominantly inattentive presentation (ADHD-PI), and ADHD, Predominantly hyperactive/impulsive presentation (ADHD-HI). The first requires six symptoms in each category and the two latter requires six in the specified category. Further, several of the symptoms had to have been present before the age of 12 years old as well as being present in two or more settings (e.g., school, work, and/or home). Lastly, the manifestation of these symptoms must not be the result of another mental health disorder (e.g., mood disorder) (APA, 2013).

Working Memory. Working memory is considered a broad cognitive ability within the Cattell-Horn-Carroll (CHC) model of intelligence (Schneider & McGrew, 2018) which is focused on in much of neuropsychological assessment. However, working memory has been defined and theorized in various ways, although with some distinct commonalities. While working memory is a construct common in psychological assessment research, the strict construct validity of each created measure to assess working memory may employ other involved abilities therefore making test error inevitable. Additionally, all tests have a degree of

test error so none can perfectly measure a construct (e.g., McGrew, LaForte, & Shrank, 2014). While the variety of operational definitions that have been proposed, researched, and measured, assessments of particular constructions of working memory are generally assumed to have reasonable convergent validity between those purporting to measure working memory and aspects thereof.

Specifically, working memory has been defined as "the ability to maintain and manipulate information in active attention" (Schneider & McGrew, 2018, p. 97). There are several components of working memory according to Baddeley (2012) that fall into two structures related to two domains of short-term storage (previously "span") which are visual-spatial short-term storage ("visuospatial sketchpad") and auditory short-term storage ("phonological loop"). These are considered the basic initial storage component of these two domains and the "central executive" component of each involves "binding" or finding relationship between or manipulating information of each domain. This then leads to a delineation of a central executive verbal working memory component and a central executive visual or spatial working memory component.

Processing Speed. Processing speed within the CHC model framework, has been defined as "the ability to control attention to automatically, quickly, and fluently perform relatively simple repetitive cognitive tasks" and may also be described as "attentional fluency or attentional speediness" (Schneider & McGrew, 2018, p. 108, italics removed). It is considered an important predictor of performance once people know how to do a task. While the intricacies and theories of what processing speed entails perhaps has not been as debated over as much as working memory, there are still several either narrow or other abilities that are argued to be potentially involved and possible confounding factors within assessment processes. These are

noted to possibly include abilities such as psycho-motor speed, decision speed as well as perceptual speed which can also be separated into comparative perceptual speed and searching perceptual speed. Similar to working memory measures, each test created to assess processing speed may, by nature of the task, employ other involved abilities, therefore, making the strict construct validity impossible due to inevitable test error. As such, while each measure described herein that is stated to measure processing speed, there is the assumption of reasonable convergent validity between them although overlap of other narrow abilities would be unavoidable.

Research Questions:

The following are research questions considered through this study:

1. Are the correlations of scores for processing speed and working memory between the WISC-V and WJ IV COG moderately correlated and measure similar constructs?
2. Is there a significant medication effect on working memory and processing speed abilities in children/adolescents diagnosed with ADHD as measured by the Wechsler Intelligence Scale for Children, Fifth Edition (WISC-V) and the Woodcock-Johnson IV Tests of Cognitive Abilities (WJ IV COG)?

Research Hypotheses:

The purpose of the current study was to assess for the presence of clinically significant impact of stimulant medication on two of the five cognitive domains commonly involved in psychological assessment of ADHD. The cognitive functioning domains of focus in this study are processing speed and working memory. The first research question will be analyzed by comparing the correlations between measures with statistical norms of low, moderate, and high correlations as well as compared to the correlations reported between the previous edition of the

Wechsler Intelligence Scale (WISC-IV) and the WJ IV COG reported in the WJ IV COG Manual.

The following hypotheses are proposed:

1. It is hypothesized that the correlation between the WISC-V Working Memory Index (WMI) and the WJ IV COG Short-term Working Memory (*Gwm*) cluster in the clinical control group not on stimulant medication (Group 2) will not be significantly different than .72 (the correlation between the WISC-IV WMI and WJ IV COG *Gwm*).
2. It is hypothesized that the correlation between the WISC-V Processing Speed Index (PSI) and the WJ IV COG Cognitive Processing Speed (*Gs*) cluster in Group 2 will not be significantly different than .55 (the correlation between the WISC-IV PSI and WJ IV COG *Gs*).
3. It is hypothesized that the correlation between the WISC-V Processing Speed Index (PSI) and the WJ IV COG Perceptual Speed (P) cluster in Group 2 will not be significantly different than .56 (the correlation between the WISC-IV PSI and WJ IV COG *Gs*).

The second research question was addressed by analyzing if the correlations on comparable construct measures between tests are significantly different between groups, and if there is impact by the medication more than typically between these measures in a clinical population.

4. It is hypothesized that the correlation between the WISC-V Working Memory Index (WMI) and the WJ IV COG Short-term Working Memory (*Gwm*) cluster in the participant group with ADHD and on and off stimulant medication (Group 1) will be significantly lower than the correlation between the WISC-V Working Memory Index (WMI) and the WJ IV COG Short-term Working Memory (*Gwm*) cluster in Group 2.

5. It is hypothesized that the correlation between the WISC-V Processing Speed Index (PSI) and the WJ IV COG Cognitive Processing Speed (*Gs*) cluster in Group 1 will be significantly lower than the correlation between the WISC-V Processing Speed Index (PSI) and the WJ IV COG Cognitive Processing Speed (*Gs*) cluster in Group 2.
6. It is hypothesized that the correlation between the WISC-V Processing Speed Index (PSI) and the WJ IV COG Perceptual Speed (P) cluster in Group 1 will be significantly lower than the correlation between the WISC-V Processing Speed Index (PSI) and the WJ IV COG Perceptual Speed (P) cluster in Group 2.

CHAPTER 2: REVIEW OF THE LITERATURE

Psychologists' Assessment for ADHD

Comprehensive psychological assessments for ADHD through Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition (DSM-5) criteria (APA, 2013), involve many facets of information gained from several sources. Assessment of ADHD also often puzzles health providers because of the commonality of ADHD symptoms with other potential etiologies, influences, disorders, or environmental responses. There are many sets of guidelines, suggestions, and/or best practices set out by many organizations, books, researchers, and experts in the fields of psychology and psychiatry regarding specific approaches of assessing ADHD. Many different assessments and domains of functioning are suggested. However, these guidelines and suggestions are very inconsistent. Areas of inquiry are generally suggested to include reviewing of records, clinical interviews, observations, and the use of rating scales (Sparrow & Erhardt, 2014). Cognitive assessments can provide helpful information for intervention planning and specific strengths and weaknesses as well as rule out differential diagnoses (Sparrow & Erhardt, 2014). There is significant debate among psychologists regarding the necessity and validity of almost all assessments used within evaluations for potential diagnosis of ADHD. With this overload of research and information, there is at least agreement that there is no one measure that can definitively diagnose ADHD, i.e., there is no gold standard ADHD measure (e.g., Barkley, 1998; Sparrow & Erhardt, 2014). Otherwise stated, there is not one single comprehensive diagnostically accurate test that is sufficient on its own and/or would delineate and cover the exhaustive list of aspects of ADHD and other

diagnoses that may need to be ruled out. However, Krieger and Amador-Campos (2018), among others, suggested that the combined use of performance-based objective tests and rating scales for ADHD supply "valuable complementary information that can improve the assessment of executive domains in ADHD" (p.1063).

Cognitive Assessment in ADHD

Objective performance data in a comprehensive psychological assessment for ADHD can consist of many different tests assessing various cognitive areas including assessments to evaluate several other domains including intelligence, achievement, executive, attention, and other areas of neuropsychological functioning. Assessing all of these domains can provide essential information to rule out issues such as intellectual disability, specific learning disorders, significant brain damage, and/or language difficulties as well as many other diagnoses. Many assessments used to measure these, especially comprehensive intelligence tests, can also be used as process instruments in that they allow observational data while the child is asked to do various tasks that access a variety of cognitive domains and a variety of a child's abilities (Sparrow & Erhardt, 2014). Further, cognitive assessments can provide targeted areas of intervention and help individualize treatment for children with ADHD whereas a named diagnosis alone may not provide this feature (Sparrow & Erhardt, 2014).

Candidly, the literature is wrought with incongruent information on cognitive, neurological, and/or executive functioning areas that are affected by ADHD but with very little research that comprehensively pulls all the information together cohesively. As Coghill et al. (2014) pointed out regarding ADHD literature especially regarding effects of psychostimulants on cognitive performance, research findings in this area are and "can be selectively quoted to support a particular position." This ambiguity is commensurate with findings in this literature

review in that the heterogeneity of this disorder and its effects contribute to the extensive amount of disparate literature on this topic. The ambiguity is then magnified further with the tendency for researchers to cite other past research that is only confirmatory with their findings and/or their own research and cite old research and disregard updated research when ADHD is one of the most researched pediatric disorders with new data and information in the field constantly. This compilation attempts to provide information from many perspectives as well as to contribute to the research in an unbiased and nonaligned approach. However, there could be nonsignificant findings within unpublished research which cannot be taken into account in this review.

Specific Cognitive Areas Implicated by ADHD Research

There are many assessed areas of cognitive functioning that may be impacted by aspects of ADHD and therefore may provide helpful information to contribute to a diagnosis or provide helpful intervention directions (Sparrow & Erhardt, 2014). Certain cognitive areas have been implicated by some researchers (and contested by others) to be impacted by ADHD and, therefore, have been researched extensively to attempt to identify cognitive "ADHD profiles." Again, the literature in this area is rather inconsistent especially when considering the intricacies of the abilities measured (i.e., the subcategories of functioning within the domains of cognitive functioning), the overlapping and intersecting abilities inherent in each test (i.e., the impossibility of strict, distinct, and separate construct validity), as well as the assumed concurrent validity between tests measuring "same" or at least very similar constructs.

Broadly, Sparrow and Erhardt (2014) offer several cognitive domains that should be considered when evaluating possible ADHD including attention, intelligence, academic achievement, executive functions, executive aspects of visual processing and language skills,

memory/learning involving short- and long-term memory, speed or rate of work, and fine-motor deficits as those may be present as well. More specifically, Hale et al. (2010) noted functional cognitive areas that may manifest impairments in ADHD included inhibitory control, attention regulation, sensory-motor, and executive functions including working memory and processing speed and efficiency. While these abilities are noted as areas of inquiry, no pattern of consistent deficits in ADHD has been identified. For example, within a meta-analysis of executive functioning performance in children and adolescents with ADHD, Willcutt, Doyle, Nigg, Faraone, and Pennington (2005) concluded that the deficits in executive functioning are not universal among individuals with ADHD so they are not "necessary nor sufficient to cause all cases of ADHD" (pg. 1336). This conclusion is echoed by other researchers including Toplak, West, and Stanovich (2017), who propose that no specific domain of executive functioning deficit has been consistently implicated for an ADHD diagnosis and further state "there is more work to be done to establish the clinical validity of these measures" (p. 161).

Hale et al., (2010) wrote a chapter regarding ADHD assessment and intervention and provided an overview of information at that time that related to the functional impairments that manifest in ADHD. The authors outline many related constructs and the likely impairment level and the reliability of that impairment. As noted by Hale et al. (2010), the reliability of some areas of impairment are considered "consistent" (e.g., inhibitory control is noted as consistent "moderate to severe" impairment) while more are considered "inconsistent" (e.g., executive functioning/fluid reasoning are indicated as "mild to severe" impairment which is significantly inconsistent across profiles) (Hale et al., 2010, p. 227). Processing speed and working memory are both areas of significant inconsistency in these results on ADHD performance, as they are both noted to range from "mild to severe" impairment across profiles (Hale et al., 2010, p. 227).

However, even with the heterogeneity of ADHD testing performance results as well as the conglomerate of areas tested, working memory and processing speed have been consistent specific areas of inquiry when assessing ADHD. Working memory and processing speed are also specifically implicated as areas of interest when considering the most commonly used assessments in typically diagnostic practice compared to neuropsychological assessments used in research.

Working Memory and Processing Speed in ADHD

Comprehensive intelligence tests are typically a standard basis of most psychological evaluations especially neuropsychological or psychoeducational evaluations. Most commercial intelligence tests provide a baseline for the individual's "expected range of functioning" (Sparrow & Erhardt, 2014, p. 137) for comparison to other measured areas. Some research and meta-analyses have shown ADHD to have negative impacts on overall IQ scores (e.g., Frazier, Demaree, & Youngstrom, 2004) as well as specifically in the areas of working memory and processing speed (e.g., Mayes Calhoun, Chase, Mink, & Stagg, 2009; Fried et al., 2016). Specifically, Mayes et al. (2009) found lower working memory (WMI) and processing speed (PSI) scores using the Wechsler Intelligence Scale for Children, Fourth Edition (WISC-IV) for ADHD children relative to their overall intellectual functioning (FSIQ). This was a robust finding as co-morbid disorders were recorded and included in analysis (therefore a generalizable clinical population) and the presence of a co-morbid anxiety, depression, or oppositional defiant disorder (ODD) diagnosis did not alter performance on working memory or processing speed between groups.

A myriad of methodologies and measures have been used to assess working memory and processing speed related to ADHD as well as various specific aspects of these domains. Several

of these methodologies focused on children and youth will be discussed in more detail separated by each domain: working memory and processing speed.

Working Memory and ADHD

As mentioned, working memory has been implicated in impacts of ADHD within cognitive and executive functioning profiles (e.g., Fried et al., 2009; Martinussen, Hayden, Hogg-Johnson, & Tannock, 2005; Wilcutt et al., 2005). For example in a more recent study, Fried et al. (2016) studied pediatric and psychiatric referred youth with and without ADHD in a between-subjects design. Compared to controls, working memory deficits were higher in youth with ADHD. However, their results were interpreted to "show that WM [working memory] deficits are not universally associated with ADHD" (Fried et al., 2016, p. 493).

Due to the magnitude of research on ADHD, several integral meta-analyses have found notable consistent findings in working memory deficits in ADHD. Martinussen et al. (2005) performed a meta-analysis investigating working memory deficits in children with ADHD analyzing 26 studies from 1997-2003. Across studies, it was found that, independent of comorbidity, children with ADHD demonstrated moderate to large impairments in multiple components of working memory. The components were delineated as: verbal storage and verbal central executive working memory (i.e., verbal control and manipulation) and then spatial storage and spatial central executive working memory (i.e., spatial control and manipulation). These delineations are similarly used by other researchers as well although by different names such as: nonexecutive working memory (storage) and executive working memory (control and manipulation) (e.g., Coghill et al., 2014). Comparison groups, Martinussen et al., (2005) found that both spatial storage and spatial storage/manipulation were more impaired ("large" impairment) in ADHD groups than verbal storage and verbal storage/manipulation ("modest"

impairment). However, within this review, with the exception of verbal storage, the other three working memory domains results (i.e., verbal central executive working memory, spatial storage, and spatial central executive working memory) demonstrated there "was substantial variability in findings between studies that was not due to chance alone" (Martinussen et al., 2005, p. 380) and publication bias was significant for the spatial storage finding but not for the other three areas of working memory functioning.

Other researchers have also found a larger deficit in visuospatial working memory compared to verbal when looking broadly at ADHD deficits. Such as while Hale et al., 2010, noted in their chapter that throughout the literature working memory deficits are noted to range from mild to severe, they specifically note that the visual impairments in working memory are typically greater than the working memory verbal impairments. Similarly, within their meta-analysis, Willcutt et al., (2005) found that groups with ADHD exhibited lower performance compared to control groups on all executive functioning measures including working memory with the added note that relatively consistent group differences were found in spatial working memory specifically with less apparent differences in verbal working memory between groups.

When examining specific working memory deficits in ADHD, it is particularly clinically relevant to then address what the deficits are associated with or how they show up in real-world performance. An interesting and relevant finding among several researchers involved how working memory affects academic performance. As found by multiple resources (e.g., Fried et al., 2016; Tourjman at al., 2019), the extent of these measured deficits in specifically working memory can predict the impact ADHD has on individuals' daily and academic functioning. This is particularly helpful in identifying these deficits to then target as areas of intervention for treatment of ADHD as well as individuals at-risk for more academic difficulties. In a particular

study, Fried et al., (2016) compared working memory abilities among youth with and without ADHD and first found that more youth with ADHD had working deficits than controls. Upon further examination, the amount of working memory deficits detected within the ADHD sample was associated with an increased risk in academic performance and grade retention than ADHD youth without similar working memory deficits. While there were some deficits found within the control group with working memory, it was not clinically significantly present.

Processing Speed and ADHD

Speed or rate of information processing can be affected by ADHD (Sparrow & Erhardt, 2014) due to the amount of time children may take to complete tasks including time on-task and off-task. However, some individuals with ADHD may instead speed through tasks and finish them quickly with many errors – this has at times been attributed to impulsivity or children's compensation for their awareness of short attention span (Sparrow & Erhardt, 2014). Due to both of these presentations (that also may show within the same child), a more consistent result may be variability with their speed of processing (Sparrow & Erhardt, 2014). Similarly as mentioned, Hale et al. (2010) found that overall processing speed deficits show up in ADHD quite inconsistently ranging from mild to severe impairment.

However, there still has been specific research done with measures of processing speed and how they are impacted by ADHD. For example, Zieman (2010) performed a study investigating possible discrepancies among ADHD subtypes within the areas of processing speed and working memory. Overall the findings indicated that "processing speed was reduced for the entire sample providing more evidence of a possible neurological deficit/basis inherent to ADHD" (Zeiman, 2010, p. ix). Similarly, within their study on youth with co-occurring disorders, Mayes et al (2009) found processing speed (PSI on WISC-III and WISC-IV) was

lower relative to overall intelligence (FSIQ) and the inattentive type of ADHD had slower processing speed than the combined group.

Although knowing the literature is variable and inconsistent, given these results, it is important to consider how well-established treatments are able to have impact on these areas of deficits and the meaning of them.

ADHD and Treatment with Psychostimulants

The American Academy of Pediatrics' Clinical Practice Guidelines suggests as first line treatment, both stimulant medication and behavioral therapy for treatment of ADHD in children and adolescents (AAP, 2011). It is specifically recommended that there is strong evidence for treatment with stimulant medication and behavioral therapy is suggested alongside but is less emphasized as a recommendation the older children become. As high as the prevalence of psychostimulant use is, i.e., the two-thirds of children prescribed who are diagnosed with ADHD (Danielson et al., 2018), the 3.5% of children in the U.S. overall that are prescribed a psychostimulant medication (Zuvekas & Vitiello, 2012), and the estimated 5-35% of non-medical use by students (Ragan, Bard, & Singh, 2013), there is no denial that this medication class continues to need as much research as possible.

The most common stimulant medications prescribed for ADHD are formulations of methylphenidate (MPH) or amphetamine, with 90% of the prescribed medications consisting of various preparations (modes of delivery and dosage forms) of methylphenidate (Advokat, Comaty, & Julien, 2014). Within the stimulant class, both methylphenidate and amphetamine products "block the dopamine transporter and amphetamine also promotes release and reverse transport of dopamine" (Faraone et al., 2015, p. 12). Many different stimulant medication formulations have been developed for treatment for ADHD including but not limited to

methylphenidate (trade names: Ritalin, Methylin, Concerta, Daytrana), d-methylphenidate (Focalin), mixed amphetamine salts (Adderall and Adderall XR), and lisdexamfetamine (Vyvanse). Several are immediate release but more recent formulations are long-acting or extended release (e.g., ER, CD, LA, XR's) in order to make up for the short half-life of the active symptom control mechanisms (i.e., "duration of action"). Most stimulant medication's mode of action is to "augment deficient dopaminergic (or norepinephrine) systems" or increase the action of dopamine to optimize the behavior and attention regulation of the prefrontal cortex (Advokat, Comaty, & Julien, 2014, p. 523).

The majority of efficacy research on stimulants for ADHD is performed with questionnaire or survey measures reporting ADHD symptomology by either informants, the client, or a combination of both. This may be partially due to the ease and quick administration of symptom questionnaires compared to administering cognitive assessments or full psychological evaluations. Accordingly, and as mentioned previously, there is a disconnect between psychiatrists or primary care physicians briefly assessing ADHD and then prescribing only part of the first line treatment of psychostimulant medication and separately psychologists diagnosing with full and complete evaluations. As such, some of the children and youth who are being prescribed these psychostimulants have potentially not yet undergone a comprehensive psychological evaluation. Therefore, when ADHD referrals come to psychologists, their job of assessing and interpreting an individual's performance across multiple cognitive areas (among other domains) becomes complicated with the fact that many children are already prescribed psychostimulants. As these medications have been called "cognitive enhancers," (e.g., Ragan, Bard, & Singh, 2013) and are supposed to treat the deficits and difficulties that impair daily performance in individuals with ADHD, it is highly plausible to think these changes in

performance would be detectable through cognitive assessments. Discussion and consultation regarding treatment of ADHD would be incomplete without consideration of medication. Therefore, when discussing the areas of inquiry of deficit in ADHD, it would be negligent to ignore this factor of medication. As Martinussen et al., (2005) pointed out in their meta-analysis on cognitive impairments in ADHD, the majority of the studies they analyzed (26 at the time) requested children discontinue any prescribed stimulant medication at least 24 hours before and only two studies did not indicate medication status. While the research findings of actual cognitive enhancement by psychostimulants in ADHD and healthy individuals is mixed and considered incomplete by some researchers, there is enough evidence to consider impact on client's testing performance if the child or adolescent is taking medications during a psychological evaluation.

Psychostimulants within the Assessment Process

Some evidence supports that cognitive deficits that are involved in ADHD are not present when a client is taking stimulant medication as this type of medication "normalizes executive functioning in ADHD" (Kempton et al., 1999). Gimpel et al., (2005) also showed higher IQ after a year of treatment with stimulant medication and when on medication. With this information, a practitioner would assume that an evaluation with a client while on medication may not show the range of symptoms needed to inform or discount a diagnosis (behaviorally and objectively). Within a meta-analysis of research spanning over about 20 years, Frazier et al., (2004) highlighted how children and adults with ADHD show cognitive deficits on intelligence quotients (IQ) tests when compared to controls not diagnosed with and when not taking ADHD medication. As such, it is noted that for ADHD evaluations, "assessment approaches in which measures of specific functions are compared with overall ability may be insensitive, because

overall ability is also decreased" (Frazier et al., 2004, p. 553). Some practitioners tend to just take all of this information into account and simply note if an individual is taking or not taking psychostimulant medication within an evaluation and use this within the interpretation of the results; e.g., "Joe Smith had not taken his ADHD medication on the day of testing, therefore the results of the WISC-V may be an underrepresentation of his true cognitive abilities."

However, Frazier et al. (2004) suggested approaches that actually compare an individual's intact functions "to those thought to show greater impairment may provide more accurate detection" (p. 553), i.e., their highest potential of cognitive abilities compared to problems in other areas of functioning. Otherwise stated, when comparing other abilities such as academic or adaptive functioning, the baseline of comparison (typically IQ) needs to be the individual's true highest potential or their deficits may not be detected. Therefore, assessing IQ when an individual with ADHD is on their prescribed stimulant medication should be that baseline. With all this in mind, it brings in the logistical concerns within evaluations of needing cognitive information in several areas while also needing a baseline of accurate cognitive potential with the presence of any deficits to compare. As such, as Sparrow and Erhardt (2014) suggest the best option is to gain performance data on multiple days and possibly when on and off their stimulant medication or for dosage comparison. However, this is not always possible in real-world practice and subsequently is followed with the practitioner's question of if the client should be tested when on or off their stimulant medication. Accordingly, it is important to know what patterns or impacts psychostimulant medications have on some areas assessed most commonly, namely as the focus of this study: working memory and processing speed. Much neuropsychological and psychiatric research has shown specific aspects of working memory or

processing speed to be impacted by psychostimulants in those with ADHD, but there are mixed results.

Working Memory and Processing Speed impacted by Stimulant Medication

There has been significant amounts of research done on the neuropsychological impacts of psychostimulants but results and methodologies significantly vary. While many of the following studies encompass many areas of cognitive and executive functioning, working memory and processing speed results will be the focus.

As an example, Gimpel et al. (2005) used the Wechsler Intelligence Scale for Children, Third Edition (WISC-III) in a within-subject design of children diagnosed with ADHD. After initial baseline testing, the majority of the population was then treated with stimulant medication and was re-tested a year later when on this medication. There were significant increases on all index scores of the WISC-III with large increases on the Processing Speed Index specifically and moderate effect on the Freedom from Distractibility Index. The Freedom from Distractibility index at that time consisted of subtests that are considered to measure working memory. However, there were also small non-significantly but clinically meaningful increases over that year in the few children in sample who were not treated with medication.

The span of fields of disciplines that these involve studying the effects of stimulant medications on individuals with ADHD is quite wide. For example, Wong and Stevens (2012) performed fMRI tasks with youth (ages 11-17) with ADHD to assess stimulant effects on neurological brain processes as it affected working memory performance. They found improved working memory reaction time as well as identified some functional connectivity that may underlie this benefit. The working memory task used was a "Sternberg working memory fMRI task" where they had to learn a visually presented set of letters.

In a meta-analysis in 2014, Coghill et al. (2014) examined only placebo-controlled studies investigating the effect of specifically methylphenidate (MPH) in children and adolescents with ADHD. Overall, they found a small but statistically significant positive effect from MPH on the executive component of working memory. A moderate effect was found for the non-executive component of working memory (span). They did not differentiate between verbal/auditory and visual-spatial working memory abilities. It was pointed out however, that these cognitive constructs were measured with "a wide range of tasks, each of which might be more or less sensitive to change" (Coghill et al., 2014, p. 612).

When considering the aforementioned more pronounced deficits in visual/spatial working memory compared to verbal, there have been several studies investigating the specific effects of psychostimulants on visual or spatial working memory in particular. Bedard, Martinussen, Ichowicz, and Tannock (2004) found that methylphenidate improved visual-spatial working memory in a clinically referred population with ADHD. Using the Cambridge Neuropsychological Testing Automated Battery (CANTAB), a research oriented instrument that has become commercial, researchers performed a double-blind placebo controlled within subject experiment. While parallel versions of other tasks were used across the 5 days of testing, there was not parallel versions available for the working memory task. While this study was purported as robust and the CANTAB has frequently been used in research, it has been found to have potential practice effects when used as a repeat measure; Cacciamani et al., (2018) showed there was marked improvement of practice effects on the CANTAB spatial working memory task specifically at six months after baseline in a population with mild cognitive impairment.

It is important to consider stimulant treatment for ADHD when compared to other treatments as well and not just placebo. Geladé et al., (2016) compared between three groups for

treatment of ADHD with optimally titrated methylphenidate, treatment with neurofeedback, and then a third "semi-active control condition" of physical activity (p. 459). It was a randomized control trial with Dutch speaking children aged 7-13 years old. Several areas of neurocognitive functioning were measured including visual-spatial working memory specifying two aspects of the task as: "short-term storage or maintenance of visual-spatial information (forward condition) and visuospatial working memory (backward condition)" using a visual computer task with shapes that has been used in past research (Geladé et al., 2016, pg 460). Visual-spatial working memory was shown to improve overtime similarly among all three conditions. However, it was noted that stimulant medication showed superior effects over neurofeedback to improve neurocognitive functioning overall.

When considering any improvements seen in working memory due to stimulant medication effects, the impact on subsequent clinical or real-world performance is optimal to examine as well. For example, Hawk et al. (2018) performed a study within a week-long summer research camp with 9- to 12-year-old children with a DSM-IV diagnosis of ADHD. They implemented a randomized double-blind placebo-controlled study evaluating the effects of methylphenidate (MPH) treatment specifically and measuring if dosage had an effect of children's classroom behavior and if this was mediated by improved cognitive functioning. The researchers performed within-subject trials at different doses of MPH and a placebo control condition. They used a visual computer task used in past research with a forward span and a backwards mental manipulation condition. The study concluded overall that "specific cognitive processes (namely working memory and inhibitory control) actually account for, or partially mediate, individual differences in clinical response to stimulants" (Hawk et al., 2018, p. 1279). More specifically, the working memory task that involved mental manipulation, versus the

simpler visuo-spatial working memory task, actually mediated both classroom productivity and teacher-reported classroom behavior.

Some studies have shown less effects of stimulants on cognitive processes such as processing speed and working memory. In a sample of 15- to 25-year-olds, Biederman et al., (2008) performed a between-subject study using several neuropsychological assessments targeting specifically executive functioning, memory, and learning processes. Their findings overall highlighted that subjects with ADHD (diagnosed with DSM-III-R criteria) that were not on stimulant medications during testing, had significantly lower total overall scores than the control group without an ADHD diagnosis or medication as well as specifically in the domains of working memory and processing speed among other domains. The group of subjects with ADHD that had taken stimulant medication at time of testing also had lower total scores, inference control, and processing speed scores than the control group with no ADHD or medications. This was interpreted to demonstrate that the ADHD group with no stimulant medication exhibited more neuropsychological deficits than those with ADHD on medication. However, when comparing the ADHD groups directly to each other, while there were improvements in a few executive functioning areas (sustained attention and verbal learning) than those who abstained from medication but there were no significant differences in other executive function measures including processing speed with the weakest effects shown in working memory (measured with WAIS/WISC-III Arithmetic & Digit Span), organization/planning, and set shifting. Overall, Biederman et al., (2008) concluded that "stimulants may have a limited effect on EFDs [Executive Functioning Deficits] in individuals with ADHD" (p. 1154). Other evidence also has shown variable differences in different components of the domains being discussed. Swanson, Baler, and Volkow (2011) performed a meta-analysis and found that in

well-controlled studies using different batteries, "stimulant-related cognitive enhancements were more prominent on tasks without an executive function component (complex reaction time, spatial recognition memory reaction time, and delayed matching-to-sample) than on tasks with an executive function component (inhibition, working memory, strategy formation, planning, and set-shifting)" (Swanson et al., 2011, p. 211).

Methodological Flaws in Research Studies

While the above described studies illustrate some more recent samples of studies investigating the impact of stimulants on neuropsychological functioning (e.g., executive memory including working memory and processing speed), it cannot be purported to encompass the entirety of the debate and various results within this realm of research. As mentioned previously, Coghill et al. (2014) stated research findings on psychostimulants on cognitive performance "can be selectively quoted to support a particular position." Additionally, some research (e.g., Storebo et al., 2018) points out the methodological flaws in much of the efficacious evidential research on psychostimulants for ADHD, naming that there is publication bias as well as need to reduce vested interest. Although the actual evidence of cognitive enhancement by psychostimulants is quite ambiguous, their non-medical use by students is significant due to the storied effects on concentration and academic enhancement – enough so that many call for more regulation of these medications (Ragan, Bard, & Singh, 2013).

Stimulant medication typically has impact on cognitive areas but there are inconsistent results in areas of functioning including in working memory and processing speed. As such, it is cautioned by Sparrow and Erhardt (2014) not to assume psychostimulant treatment for ADHD will create a positive enhancement of performance or that this should be used in diagnosis. However, as concluded by Coghill et al., (2014) the evidence does "suggest that it might be

appropriate to measure cognitive as well as clinical outcomes when treating ADHD" to measure "the effects of medication on these distinct aspects of functioning" (p. 612).

To add to the current literature, this study will be able to present nominal data into what these differences look like on cognitive assessment measures going forward in the field of psychological assessment on current and commonly used assessments. While some of these past methodologies are subject to limitations such as practice effects, publication bias, between instead of within subject, and uncommonly used assessments, this study will add what patterns may be present in medication response or non-response in those with ADHD. This study will, in the end, provide practitioners with important information to evaluate and understand how ADHD treatment works and how well it works.

CHAPTER 3: METHOD

Institutional Review Board Approval

Before analyses were conducted, the study was reviewed and approved by the Institutional Review Board at University of Georgia. In keeping with requirements of the IRB, before analysis, the data was de-identified and assigned code numbers that did not correspond to any identifying information. See Appendix A for approval letter.

Participants

Demographic information taken from records included age, ethnicity, and gender, as well as other information including length of time between testing days, medication type and dosage, and any comorbid diagnoses. Selection criteria for the present study included children and adolescents ranging from the ages of six years old to 16 years and eleven months old (age range for WISC-V). Sample characteristics of participants are show in Table 1 as well as sample characteristics of each group. The total sample (N = 101) consisted of 42 females and 59 males. The majority were Caucasian (70.3%) and the mean age was 11.61 (SD = 3.21).

The sample included two groups:

Group 1) 23 children and adolescents diagnosed with ADHD (any type) that were currently prescribed stimulant medication (e.g., methylphenidate, dextroamphetamine-amphetamine) for symptoms related to ADHD

Group 2) 78 children and adolescents in a clinical control sample who were not currently prescribed stimulant medication.

Table 1

Descriptive Statistics for Demographic Information

Variable	Group 1	Group 2	Total
	N = 23	*N* = 78	*N* = 101
	M (SD)	*M (SD)*	*M (SD)*
Age	13.15 (2.72)	11.16 (3.23)	11.61 (3.21)
	N (%)	*N* (%)	*N* (%)
Gender			
Female	8 (34.8%)	34 (43.6%)	42 (41.6%)
Male	15 (65.2%)	44 (56.4%)	59 (58.4%)
Race/Ethnicity			
White/Caucasian	17 (73.9%)	54 (69.2%)	71 (70.3%)
Black/African American	5 (21.7%)	12 (15.4%)	17 (16.83%)
Latinx/Hispanic	1 (4.3%)	3 (3.8%)	4 (3.96%)
Asian	0	1 (1.3%)	1 (0.99%)
Indian-American	0	1 (1.3%)	1 (0.99%)
Multi-Racial/Biracial	0	5 (6.4%)	5 (4.95%)
Other	0	2 (2.6%)	2 (1.98%)

Demographically, Group 1 was slightly higher in percentage of males (65.2%) than the overall sample (58.4%). The mean age of Group 1 was also slightly higher (13.15) than Group 2 (11.16) or the total sample (11.61). Group 1 were all diagnosed by a doctoral student in counseling psychology under the supervision of a licensed psychologist as having ADHD (two participants were taken out even though they were previously diagnosed with ADHD but an ADHD diagnosis was not confirmed by our clinicians). Some participants came in with previous psychological evaluations that lead to a diagnosis of ADHD or had been screened and diagnosed by a primary care physician and prescribed a medication. Due to the significant number of comorbidities common in clinical samples with ADHD, i.e., it is more common than not (e.g., Larson et al., 2011), it was clinically relevant to include those participants with any comorbid diagnosis. Further, there has been evidence that the presence of the most common co-

morbidities among children with ADHD, (i.e., anxiety, depression, and ODD) did not alter performance on the WMI or PSI on the WISC-IV. (e.g., Mayes et al., 2009). Group 2 were a comparative control sample not diagnosed with ADHD within the clinically referred population at the same testing clinic.

While all the participants were administered a whole battery of various assessments, for the purposes of the current study, test data was only collected from the variables in question on the WISC-V and the WJ IV COG. Further, while some subtests may have been left out for specific clinical reasons for some participants, all data points available for each analysis were used and that information is provided in Results section Tables.

Instruments

The Wechsler Intelligence Scale for Children, Fifth Edition (WISC-V). The WISC-V (Wechsler, 2014) is an individually administered, norm-referenced assessment that measures a child/adolescent's overall intellectual ability including five distinct cognitive domains. The WISC-V has 21 total subtests, 10 primary subtests of which are used in a standard battery in practice to assess an overall Intelligence Quotient (IQ) score as well as the five domains including: Verbal Comprehension Index (VCI), Visual-Spatial Reasoning Index (VSI), Fluid Reasoning Index (FRI), Working Memory Index (WMI), and Processing Speed Index (PSI). The WISC-V was updated in 2014 from the WISC-IV to adhere more closely to the CHC model of intelligence theory. Revision of WISC-V from the fourth edition included replacing an index measuring "Perpetual Reasoning" with the Visual-Spatial Index and the Fluid Reasoning Index as two separate domains. The WISC-V also updated theoretical foundations regarding working memory and the clinical utility of the processing speed tasks. One addition was expanding the

construct coverage of the Working Memory Index from solely auditory working memory tasks to include visual and auditory working memory subtests.

The WISC-V was standardized on 2,200 children aged 6 years to 16 years and 11 months old. The sample was approximated on key demographic variables matching the October 2012 U.S. census. The WISC-V been shown to have appropriate psychometric properties by experts, examiners, and the research team that evaluated the standardization studies with extensive evidence within the WISC-V manual (Wechsler, 2014). Several studies provide evidence of the scale's reliability and validity including concurrent validity studies with other measures and factor analytic studies. Convergent and discriminant validity was evidenced with correlational studies with other major assessments at the time as well as with 13 special and matching sample groups. The average subtest reliability ranges from good to excellent and for primary index scores were .88 to .93 (Wechsler, 2014). Additionally, interscorer agreement for most subtests ranged from .98 to .99. All of these provide strong support for the validity, reliability, and clinical utility of WISC-V (Wechsler, 2014).

Working Memory Index (WMI). The WISC-V WMI is described to measure a child's ability "to register, maintain, and manipulate visual and auditory information in conscious awareness" requiring attention, discrimination, and concentration (Wechsler, 2014, p. 159). The internal reliability of the WMI is .92 overall and each subtest has reliabilities as follows: Picture Span = .85; Digit Span = .91; and Letter-Number Sequencing = .86 (Wechsler, 2014).

Digit Span (DS). The Digit Span subtest measures working memory and mental manipulation as well as brief focused attention, auditory discrimination, and auditory rehearsal. This subtest consists of three tasks including: Digit Span: Forward, Backwards, and Sequencing. Digit Span: Forward specifically measures auditory rehearsal and working memory capacity.

Digit Span – Backwards measures transformation of information with mental manipulation. Digit Span: Sequencing measures mental manipulation with increased cognitive complexity.

Picture Span (PS). The Picture Span subtest measures "visual working memory and working memory capacity" involving attention, visual processing, visual immediate memory, and response inhibition (Wechsler, 2014, p. 11).

Letter-Number Sequencing (LN). The Letter-Number Sequencing subtest is a supplemental subtest that can substitute DS or PS within the WMI if needed. It measures auditory discrimination, brief focused attention, concentration, registration, auditory rehearsal, sequential processing, working memory capacity, and mental manipulation (Wechsler, 2014).

Processing Speed Index (PSI). The WISC-V PSI is noted to measure a child's "speed and accuracy of visual identification, decision making, and decision implementation" (Wechsler, 2014, p. 159). The internal reliability coefficient of PSI overall was .88 which was considered in a good range although noted to be lower than the other composite scores. For each subtest within the PSI, the reliabilities are as follows: Coding = .82 and Symbol Search = .81; and Cancellation = .82.

Coding (CD). The Coding subtest measures processing speed, "short-term visual memory, procedural and incidental learning ability, psychomotor speed, visual perception, visual-motor coordination, visual scanning ability, cognitive flexibility, attention, concentration, and motivation" (Wechsler, 2014, p. 11).

Symbol Search (SS). The Symbol Search subtest measures visual-perceptual and decision making speed involving "short-term visual memory, visual-motor coordination, inhibitory control, visual discrimination, psychomotor speed, sustained attention, and concentration" (Wechsler, 2014, p. 12).

Cancellation (CA). The Cancellation subtest is a supplemental subtest that can substitute for CD or SS within the PSI when needed. It measures "rate of test taking, speed of visual-perceptual processing and decision making, visual scanning ability, and visual-perceptual recognition and discrimination" also involving attention, concentration, and visual recall (Wechsler, 2014, p. 12).

Woodcock-Johnson IV Tests of Cognitive Abilities (WJ IV COG). The WJ IV COG (Shrank, McGrew, & Mather, 2014) is an individually administered co-normed test of intelligence for the age-ranges of two years old to over 80 years old. The WJ IV COG includes 18 subtests, of which 10 are in the Standard Battery and 8 in the Extended Battery but 1-7 are considered the core subtests which derive the General Intellectual Ability Index (GIA). The Standard Battery measures seven broad CHC factors delineated into the clusters: "fluid reasoning (Gf), comprehension-knowledge (Gc), short-term working memory (Gwm), cognitive processing speed (Gs), auditory processing (Ga), long-term retrieval (Glr), and visual processing (Gv)" (McGrew, LaForte, & Shrank, 2014, p. 120-121).

The WJ IV COG is a revised version of the WJ III COG with renorming, new narrow ability clusters, and new subtests including a new working memory (Verbal Attention) and new perceptual speed subtest (Letter-Pattern Matching). The WJ IV COG was normed from 2009-2012 with 3,891 individuals from kindergarten to 12th grade. The sample was stratified to represent the United States population at that time and examinee weighting was used when it did not match.

The WJ IV COG is noted to have extensive validity due to content validity within construction specifically to match the CHC model of intelligence and research as it continually develops as well as measured internal structure validity within and between the Woodcock-

Johnson IV tests. Further, multivariate statistical procedures showed appropriate convergent and divergent associations (McGrew, LaForte, & Shrank, 2014). Construct validity was also shown when divergent and convergent validity was compared to other cognitive measures such as the Wechsler Intelligence Scale for Children, Fourth Edition (WISC-IV), Kaufman Assessment Battery for Children, Second Edition (KABC-II), and the Standford-Binet, Fifth Edition (SB5).

Short-Term Working Memory cluster (Gwm). The WJ IV COG defined the CHC domain of short-term working memory as "the ability to apprehend and hold information in immediate awareness and then use or manipulate it to carry out a goal" involving efficiency of attentional control in this process (Mather & Wendling, 2014, p. 23). In the 5 to 18-year-old range, this cluster has a median reliability of .91 (Mather & Wendling, 2014). The subtests included in this cluster are Verbal Attention and Numbers Reversed.

Verbal Attention. The Verbal Attention subtest measures verbal working memory and attentional control and considered an aspect of executive functioning.

Numbers Reversed. The Numbers Reversed subtest measures auditory short-term working memory and attentional capacity.

Cognitive Processing Speed (Gs). The WJ IV COG defines cognitive processing speed as "the ability to quickly perform both simple and complex cognitive tasks, particularly when measured under pressure to sustain controlled attention and concentration" and "is an aspect of cognitive efficiency" (Mather & Wendling, 2014, p. 23). For ages 5 to 19 years old, the cluster has a median reliability of .94. The *Gs* cluster on the WJ IV COG includes the subtests: Letter-Pattern Matching and Pair Cancellation.

Letter-Pattern Matching. The Letter-Pattern Matching subtest measures the speed at which an individual can make visual symbol discriminations and identify common orthographic patterns and is considered a perceptual speed task as aspect of processing speed.

Pair Cancellation. The Pair Cancellation subtest measures executive processing, attention/concentration, and processing speed abilities.

Perceptual Speed (P). Perceptual Speed is considered a "narrow ability cluster" within the *Gs* ability (*Gs*-P) and is defined as "the ability to rapidly perform simple clerical tasks that use symbols, such as matching letters or numbers" and is related to orthographic processing. This cluster has a median reliability of .93 and includes the Letter-Pattern Matching subtest and the Number-Pattern Matching subtests, both of which are included as *Gs* subtests.

Number-Pattern Matching. The Number-Pattern Matching subtest measures perceptual speed (i.e., the speed at which an individual can make visual symbol discriminations).

Data Collection/Procedures

Data was gathered retroactively from archival data from 2016 to 2019 within the records kept by a department clinic at a southeastern University and de-identified. Within procedures of the testing site, each client/participant was administered a comprehensive psychological evaluation by a graduate doctoral student enrolled in a doctoral counseling psychology program in the southeast United States. The evaluation procedures included a clinical interview with the client's parents as well as the client and various psychological assessments including cognitive, achievement, and social-emotional measures. Each client was administered a typical battery of assessments over a two-day period, several of which will be the target analysis of this study (WISC-V and WJ IV COG) as well as additional measures included given referral information and preliminary assessment results. Each client in Group 1 was asked to take their prescribed

stimulant medication in the morning of the first day of assessment (which included administration of the WISC-V) and then abstain from taking their stimulant medication on the second day of testing (which included administration of the WJ IV COG).

All doctoral student evaluators had completed introductory coursework in psychological assessment and could be in the second, third, or fourth of four required courses. The student test administrators worked with and were supervised by an upper-level graduate assistant assessment coordinator and assessment procedures were overseen by this individual and a licensed psychologist supervisor. Accuracy in administration and scoring procedures were attempted to be checked and correct. All assessments were taped and were completed in optimal testing conditions at the testing center.

Research Method and Statistical Method

The IBM SPSS Statistics 27 was utilized to analyze the data for this current study. First, descriptive statistics were found for all variables in both groups. Then, scatterplots of all variables (WMI and PSI on WISC-V and *Gwm*, *Gs*, and P on WJ IV COG) were conducted to examine for any nonlinearities of the relationships among each variable. Then normality was assessed by screening for skewness and kurtosis.

To test hypotheses and research questions within this study, the performance of all participants was analyzed by comparing their performance on each comparative construct of each assessment (WISC-V and WJ IV COG) between the days of testing. Due the inability to utilize a test-retest design for intelligence testing as practice effects would have interfered with valid results for these type of assessments, a correlational comparison was used. While there is not current research or normative correlations between the currently used WISC-V and WJ IV COG tests (as both came out in 2014), this will be subverted by comparing the on/off medication

group to our own sample of clinically referred children not on medication and their typical correlations. Correlations between the following were measured within each participant group:

Group 1: ADHD prescribed medication

1) WISC-V: WMI (taking medication) & WJ IV COG *Gwm* (not taking medication)

2) WISC-V: PSI (taking medication) & WJ IV COG *Gs* (not taking medication)

3) WISC-V: PSI (taking medication) & WJ IV COG Perceptual Speed (not taking medication)

Group 2: clinical control group (not prescribed stimulant medication)

1) WISC-V: WMI & WJ IV COG *Gwm*

2) WISC-V: PSI & WJ IV COG *Gs*

3) WISC-V: PSI & WJ IV COG Perceptual Speed

To evaluate the main hypotheses, all of the correlations coefficients values were transformed into z scores with the Fisher's r to z transformation. To assess the first research question, the correlations of group 2 will be assessed for size of correlations and then using the fisher's r transformation to z-scores, they will be compared to correlations in hypotheses from the WISC-IV and WJ IV COG normative statistics.

Then for the second research question, the z scores were then compared between groups for each matching construct comparison and analyzed for statistical significance by determining the observed z test statistic. This was done to compare to correlations between comparable indices (as delineated above) in the clinical control group. We will then examine if the z scores are more significantly different with the group who were prescribed medications compared to the group where medications were not a part of the picture. If the correlations between groups are not significantly different, then that will be interpreted as no significant decipherable impact

considered from stimulant medication on these cognitive measures purported to measure similar constructs in commercially used assessments. If there were significant differences between any of the correlations between groups, the magnitudes of the differences will be examined to see which was larger. The lesser correlation will be interpreted to be a more significant difference between testing days (e.g., if WISC-V WMI vs. WJ IV COG *Gwm* in Group 1 is significantly different and lower than the correlation between the same in Group 2, then the medication had an impact on performance).

CHAPTER 4: RESULTS

The purpose of the present study was to examine differences in cognitive performance when on vs off prescribed stimulant medication in an ADHD children and adolescent population compared to a control comparative clinical sample. First, some preliminary analysis of the sample and data are presented as relevant to the results. Then, descriptive statistics of targeted variables are presented, followed by analysis of all hypotheses.

Preliminary Analyses

As diagnosis was a salient aspect of this study, the diagnoses of each group and combined were analyzed and are presented in Table 2 below.

Table 2

Diagnostic Information of Samples

Primary Diagnosis	Group 1	Group 2	Total
	N = 23	*N* = 78	*N* = 101
	N (%)	N (%)	N (%)
ADHD, Combined Presentation	13 (56.5%)	17 (21.8%)	30 (29.7%)
ADHD, Inattentive Presentation	8 (34.8%)	25 (32.1%)	33 (32.7%)
ADHD, Hyperactive/Impulsive	1 (4.3%)	3 (3.8%)	4 (3.96%)
Other Specified/Unspecified ADHD	1 (4.3%)	0	1 (0.99%)
Specific Learning Disorder: Math	0	4 (5.1%)	4 (3.96%)
Specific Learning Disorder: Writing	0	1 (1.3%)	1 (0.99%)
Specific Learning Disorder: Reading	0	4 (5.1%)	4 (3.96%)
SLD: Reading specifically dyslexia*	0	7 (9%)	7 (6.93%)
Adjustment Disorder	0	1 (1.3%)	1 (0.99%)
Generalized Anxiety Disorder	0	6 (7.7%)	6 (5.94%)
Major Depressive Disorder	0	1 (1.3%)	1 (0.99%)
Other Specified/Unspecified Depressive Disorder	0	2 (2.6%)	2 (1.98%)
Other DSM Diagnosis	0	4 (5.1%)	4 (3.96%)

V Code or ICD Code	0	1 (1.3%)	1 (0.99%)
No diagnosis	0	2 (2.6%)	2 (1.98%)
Presence of Comorbid Disorder	13 (56.5%)	35 (44.9%)	48 (47.5%)
Anxiety-related disorder	2 (8.7%)		
Mood-related disorder	1 (4.3%)		
Learning-related disorder	9 (39.1%)		
Other Disorder	1 (4.3%)		
Absence of Comorbid Disorder	10 (43.5%)	43 (55.1%)	53 (52.5%)

*Note = This category is NOT subsumed in the above SLD: Reading category but separate.

To assess for comparability of samples from an overall cognitive ability standpoint, FSIQ scores were compared between groups and were found to not have significant differences nor significant differences from the mean overall. There was not a significant difference between means of FSIQ or GAI between Groups 1 and 2 or significant deviation from the normative average of 100. Tests of normality for FSIQ were acceptable. Further, time was assessed between testing days. The average days between testing for Group 1 was 13.87 days, (SD = 10.02), Group 2 was 10.62 days (SD = 7.32).

Descriptive Data

See Table 3 for means and standard deviations for all indices included in this study for both groups. T-tests were performed to highlight any significant differences between group means, all of which were non-significant. Tests of normality for all indices were performed, all of which fell in the acceptable range for normality.

Table 3

Descriptive Statistics of Variables

	Group 1			Group 2			Sig diff?
	N	*M*	*SD*	*N*	*M*	*SD*	
WISC-V WMI	23	103.39	16.73	77	101.00	15.43	Not sig diff
WISC-V PSI	22	91.68	13.21	75	93.83	15.65	Not sig diff
WJ IV COG *Gwm*	22	101.05	13.69	73	97.70	15.53	Not sig diff
WJ IV COG *Gs*	22	86.36	15.66	75	88.31	14.25	Not sig diff
WJ IV COG P	19	80.63	17.82	70	88.04	17.98	Not sig diff

*Tinted grey highlight = While on stimulant medication

Study Analyses

To test hypotheses and research questions within this study, the performance of all participants was analyzed by comparing their performance on each comparative construct of each assessment (WISC-V and WJ IV COG) between the days of testing. Due the inability to utilize a test-retest design for intelligence testing as practice effects would interfere with valid results for these type of assessments, a correlational comparison was used. While there is not current research or normative correlations between the currently used WISC-V and WJ IV COG tests (as both came out in 2014), this was subverted by finding correlations of each variable within groups and then comparing Group 1 (on/off medication ADHD group) to Group 2 (our own sample of clinically referred children not on stimulant medication).

Research Question 1. Regarding the first research question, the correlations of scores for Group 2 on processing speed and working memory variables between the WISC-V and WJ IV COG were all moderately correlated and therefore assumed to measure similar constructs. The score comparisons from day 1 (WISC-V) and Day 2 (WJ IV COG) were compared just in Group 2 as there was not medication differentiation between days in this group. Therefore, the correlations represent a clinical sample similar to the sample used for the WISC-IV vs WJ IV COG. The following hypotheses were tested specifically with results listed in Table 4:

Table 4

Comparison of Correlations between WISC-IV & WJ IV COG versus WISC-V & WJ IV COG

Indices Comparison	WISC-IV vs WJ IV COG		Group 2 WISC-V vs WJ IV COG		Z-score
	N	*r*	*N*	*r*	
WMI vs *Gwm*	174	.72	73	.626**	-1.22
PSI vs *Gs*	174	.55	73	.648**	1.09
PSI vs P	174	.56	69	.733**	2.08°

** Correlation is significant at the 0.01 level (2-tailed)

° Z-score indicating significantly different correlations

Hypotheses one. It was hypothesized that the correlation between the scores on the WISC-V Working Memory Index (WMI) and the WJ IV COG Short-term Working Memory (*Gwm*) cluster in Group 2 would not be significantly different than .72 (the correlation between the WISC-IV WMI and WJ IV COG *Gwm*). A Pearson correlation was computed to compare the scores of performances of Group 2 subjects with results yielding a large significant correlation, $r(73) = .626$, $p < .01$. Fisher's r to z transformation was used to determine if there was a statistically significant difference between the observed correlation and the null hypothesis value of .72. Results supported the hypothesis, indicating the observed correlation did not differ significantly from the previous tests correlation of similar composites ($z = -1.219$, $p = 0.05$).

Hypothesis two. It was hypothesized that the correlation between the WISC-V Processing Speed Index (PSI) and the WJ IV COG Cognitive Processing Speed (*Gs*) cluster in Group 2 would not be significantly different than .55 (the correlation between the WISC-IV PSI and WJ IV COG *Gs*). A Pearson correlation was computed to compare the scores between composites with the results yielding a large significant correlation, $r(73) = .626$, $p < .01$. Fisher's r to z transformation was used to determine if there was a significant difference between the observed correlation and the null hypothesis value of .55. Results supported the hypothesis, indicating the observed correlation did not differ significantly from the previous correlation of similar composites of previous edition of WISC-IV ($z = 1.09$, $p = 0.05$).

Hypothesis Three. It was hypothesized that the correlation between the WISC-V Processing Speed Index (PSI) and the WJ IV COG Perceptual Speed (P) cluster in Group 2 will not significantly differ from .56 (the correlation between the WISC-IV PSI and WJ IV COG P). A Pearson correlation was computed to compare the scores between composites yielding a large significant correlation, $r(69) = .733$, $p < .01$. Fisher's r to z transformation was used to

determine if there was a significant difference between the observed correlation and the null hypothesis value of .56. Results did not support the hypothesis, indicating the observed correlation was significantly different from the previous correlation of similar composites from the WISC-IV PSI and WJ IV COG P ($z = 2.08$, $p = 0.05$).

Research Question 2. The second research question addressed the main purpose of the study, to test for the presence of a significant medication effect on subjects' performance on working memory and processing speed tasks.

Table 5

Comparison of Correlations between on/off med group (Group 1) vs no meds (Group 2)

Indices Comparison	Group 1		Group 2		
	N	*r*	*N*	*r*	Z-score
WMI vs Gwm	22	.801**	73	.626**	1.41
PSI vs Gs	21	.644**	73	.648**	-0.026
PSI vs P	19	.341	69	.733**	-2.08º

** Correlation is significant at the 0.01 level (2-tailed)
º Z-score indicating significantly different correlations at the 0.05 level

Hypothesis four. It was hypothesized that the correlation between the WISC-V Working Memory Index (WMI) and the WJ IV COG Short-term Working Memory (*Gwm*) cluster in Group 1 (on and off meds) will be significantly lower than the correlation between the WISC-V Working Memory Index (WMI) and the WJ IV COG Short-term Working Memory (*Gwm*) cluster in Group 2; indicating a medication effect on performance. A Pearson correlation was computed within each group between the WISC-V: WMI (while on medication) & WJ IV COG *Gwm* (while not on medication). In Group 1, a large and statistically significant correlation was yielded, $r(22) = .801$, $p < .01$. In Group 2, a large and statistically significant correlation was found, $r(73) = .626$, $p < .01$. Fisher's r to z transformation was used to determine if there was a statistically significant difference between the observed correlations between groups (null = no

difference). Results did not support the hypothesis, indicating the observed correlations did not differ significantly ($z = 1.41$, $p = 0.05$), suggesting there was not a significant effect on performance from status of taking stimulant medication or not.

Hypotheses five. It was hypothesized that the correlation between the WISC-V Processing Speed Index (PSI) and the WJ IV COG Cognitive Processing Speed (*Gs*) cluster in Group 1 will be significantly lower than the correlation between the WISC-V Processing Speed Index (PSI) and the WJ IV COG Cognitive Processing Speed (*Gs*) cluster in Group 2, indicating a medication effect on performance. A Pearson correlation was computed within each group between the WISC-V: PSI (while on medication) & WJ IV COG *Gs* (while not on medication). In Group 1, a large and statistically significant correlation was yielded, $r (21) = .644$, $p < .01$. In Group 2, a large and statistically significant correlation was found, $r (73) = .648$, $p < .01$. Fisher's r to z transformation was used to determine if there was a statistically significant difference between the observed correlations between groups (null = no difference). Results did not support the hypothesis, indicating the observed correlations did not differ significantly ($z = 0.026$, $p = 0.05$), suggesting there was not a significant effect on performance by status of taking stimulant medication or not.

Hypothesis six. It is hypothesized that the correlation between the WISC-V Processing Speed Index (PSI) and the WJ IV COG Perceptual Speed (P) cluster in Group 1 will be significantly lower than the correlation between the WISC-V Processing Speed Index (PSI) and the WJ IV COG Perceptual Speed (P) cluster in Group 2, indicating a medication effect on performance. A Pearson correlation was computed within each group between the WISC-V: PSI (while on medication) & WJ IV COG P (while not on medication). In Group 1, a moderate and non-statistically significant correlation was yielded, $r (19) = .341$, $p = .01$. In Group 2, a large

and statistically significant correlation was found, r (69) = .733, p < .01. Fisher's r to z transformation was used to determine if there was a statistically significant difference between the observed correlations between groups (null = no difference). Results did support the hypothesis, indicating the observed correlations did differ significantly (z = 2.08, p = 0.05), suggesting there was a significant effect on performance by status of taking stimulant medication or not.

Follow Up Analyses

Several follow up analyses were performed and results are shown in Table 6 below. Upon further analysis, when comparing the working memory correlation of Group 1 (all ADHD and again the more consistent even when on/off medication; r = .801) with the correlation of performance of the 45 participants in Group 2A who were diagnosed with a type of ADHD by our clinic (r = .470), there was a significant difference statistically (z = 2.14, p = 0.05) and considerably MORE variance within the ADHD group not on medication at all. When considering the 22 participants not diagnosed with ADHD of any type within Group 2, their correlation was more similar to the on and off medicated ADHD group (r = .807).

Table 6

Comparison of Correlations in consideration of Medication Status and ADHD diagnoses

Indices Comparison	Group 1: ADHD On/off Medication		Group 2A: No stim meds Diagnosed ADHD		Group 2B: No stim meds Not Diagnosed ADHD	
	N	*r*	*N*	*r*	*N*	*r*
WMI vs *Gwm*	22	.801**	45	.470**	22	.807**
PSI vs *Gs*	21	.644**	43	.603**	30	.639**
PSI vs P	19	.341	39	.693**	30	.708**

** Correlation is significant at the 0.01 level (2-tailed)
° Z-score indicating significantly different correlations

To follow up on the results for hypothesis five, when comparing processing speed correlations of Group 1 (all ADHD and on/off medication) with the correlation of performance

of the 43 participants in Group 2 who were diagnosed with a type of ADHD by our clinic, there was no significant difference between these correlations; i.e., the amount of variance seen on processing speed performance across days for the participants diagnosed with ADHD but not on any stimulant medications is similar to the variance seen in the ADHD population who on stimulant medications on day 1 and off stimulant medications for day 2. Similarly, when considering the 30 participants not diagnosed with a type of ADHD within Group 2, their correlation was also similar to the on and off medicated ADHD group ($r = .639$).

Finally regarding information from hypothesis six, when comparing the WISC-V PSI to the WJ IV COG P correlations of Group 1 ($N = 19$; all ADHD and on/off medication) with the correlation of performance of the 39 participants in Group 2 who were diagnosed with a type of ADHD by our clinic, again, there was a significant medication effect found within the on and off medication. However, when comparing this to the 30 participants not diagnosed with ADHD and not on stimulant medications in Group 2 their correlation was similar to Group 1 (ADHD on/off meds).

CHAPTER 5: DISCUSSION

Summary

The current study provided evidence that the constructs of the main indices that measure working memory and processing speed measured by both the WJ IV COG and the WISC-V have acceptable and similar construct validity to the previous edition of the WISC-IV and the WJ IV COG. However, the Perceptual Speed index on the WJ IV COG was significantly more correlated to the PSI on the WISC-V than the PSI on the WISC-IV. There was not a significant difference found between performance on working memory indices and processing speed indices when comparing the Group 1 performance (those with ADHD and on/off stimulant medication) to our clinical control sample not on stimulant medication, therefore indicating no significant medication effect. However, there was a significant difference when considering the WJ IV COG Perceptual Speed cluster performance compared between the two clinical groups and therefore a significant medication effect found within this construct compared to processing speed performance on stimulant medication.

Conclusions

Research Question 1. While all measured correlations between the WJ IV COG and the WISC-V domains were found to be large significant correlations, implying valid measurement of similar constructs, there were several particular implications of this information. First, between the working memory measures, a large significant correlation was found between the WJ IV COG Short Term Working Memory (Gwm) cluster and the WISC-V Working Memory Index

between Group 2's performance across days (i.e., no medication status differentiation and within a clinical sample). Even though the confirmation of construct validity of measures of working memory is a promising finding, there was a major change within the construct measurement itself within the new version of the Wechsler test. The Working Memory Index (WMI) from the WISC-IV to the WISC-V added in a visual working memory subtest (Picture Span) which replaced Letter-Number Sequencing as a core subtest for the WMI. The WISC-V introduced this additional working memory subtest to measure visual working memory, a cognitive area of functioning not present within the last edition of the WISC. As discussed previously, working memory is considered a multidimensional construct by many theories, many of which differentiate visual (or spatial) from auditory (or verbal) working memory as well as differentiating central executive working memory compared to a simple memory span capacity of each. Therefore, both subtests within the WMI on the WISC-IV consisted of auditory working memory tasks which was more similar to the two auditory working memory tasks within the *Gwm* cluster on the WJ IV COG. Given the results of the large correlation found in this study between the WISC-V WMI and WJ IV COG *Gwm*, the introduction of the visual working memory task did not seem to present a significantly different aggregated construct of working memory that would be performatively different from the WISC-IV WMI that was solely based on auditory working memory tasks.

Second, between the indices measuring processing speed as an aggregated domain, a large significant correlation was found between the WJ IV COG Cognitive Processing Speed cluster (*Gs*) and the WISC-V Processing Speed Index (PSI) between days of Group 2's performance (i.e., no medication status differentiation within a clinical sample). The WISC-V PSI did not significantly change the subtests or the subtests' content from the previous version.

The only noted changes involved were new symbols added to the Symbol Search subtest and the Coding subtest had been adjusted to create more consistency in item difficulty across rows (Wechsler, 2014a). Therefore within both versions, abilities measured included aspects of processing speed, procedural and incidental learning ability, psychomotor speed, visual-motor coordination, cognitive flexibility, attention, motivation, visual-perceptual and decision making speed involving inhibitory control, visual discrimination, sustained attention, and concentration. Similarly, the two subtests within the *Gs* cluster on the WJ IV COG (Letter-Pattern Matching and Pair Cancellation) are noted to measure perceptual speed involving visual discrimination, executive processing, attention/concentration, and broad processing speed abilities. As such, a large correlation between the two, confirmed similar construct validity of the WISC-V PSI and WJ IV COG *Gs*.

Perceptual speed is considered a narrow ability subsumed within the broad CHC ability of processing speed. Some consider it at the core of the *Gs* ability (McGrew, LaForte, & Schrank, 2014). While the Perceptual Speed (P) cluster measuring the narrow ability of perceptual speed on the WJ IV COG does not purport to measure the broad CHC factor of processing speed, there was still a large correlation between the WISC-IV PSI and the WJ IV COG P composites found within the WJ IV COG manual (McGrew, LaForte, & Schrank, 2014). Therefore, this relationship was used for comparison within this study's hypothesis and results. There was a significantly higher correlation between the WJ IV COG P and the WISC-V PSI compared to the WISC-IV PSI. Given that the WJ IV COG P cluster was the same cluster between comparisons, and the only change would be the changes to the Coding and Symbol Search subtests from the WISC-IV to the WISC-V previously mentioned. For that reason, this could be an area of further inquiry in considering the constructs being measured by the subtests

within these clusters on the WJ IV COG, as there does not appear to be any discernable explanation for this result at this time. The larger number of ADHD diagnoses within our sample compared to the WISC-IV sample may be related to this difference in some way (although given ADHD diagnoses typically might have more inconsistent results, this may be a counterintuitive explanation).

Research Question 2. Overall, a significant medication effect (i.e., a significant impact of performance difference due to medication status) was not found within the analyses of the broad CHC ability of working memory performance. There was also no significant medication effect found within performance measures of processing speed. These results were shown by comparison of the computed correlation within the clinical comparison group (Group 2) with the ADHD group that had taken their medication on Day 1 performance of these measures and not on day 2 (Group 1). Other intricacies also can be drawn from the data and the results will be discussed more specifically within each cognitive domain studied.

Working Memory. There was no significant difference between the correlation of the WISC-V WMI (Day 1 on stimulant medication) and WJ IV COG Gwm (Day 2 off stimulant medication) in the ADHD group already prescribed stimulant medication compared to the clinical control group in which medication status was not a differentiating factor between days of testing performances. Interestingly however, the correlation between the working memory measures within the ADHD group, who were on their medication for day 1 and off their stimulant medication for day 2 of testing, was a higher correlation (albeit not statistically significant), meaning there was lesser variance of working memory performance in this sample when on and off medication compared to when no stimulant medication is involved within a group with a mixed sample of diagnoses being considered. Therefore, to break this result down

further, Group 2 was divided up into Group 2A (Diagnosed with ADHD; no meds) and Group 2B (Not Diagnosed with ADHD; no meds) and more analysis was completed. When comparing the working memory correlations of Group 1 (all ADHD and again the more consistent even when on/off medication) with the correlation of performance of those in Group 2 who were diagnosed with a type of ADHD by our clinic (Group 2A), there was considerable MORE variance within the ADHD group not currently treated with stimulant medication at all. When considering the participant group without an ADHD diagnosis within Group 2B, the correlation between working memory performance was highly correlated and more similar to the on and off medicated ADHD group. Therefore, these results show significantly MORE variance within ADHD performance when there is no medication treatment involved and decreased variance even when on medication and off medication. While the latter implies no significant medication impact (i.e., no significantly discernable impact from medication status) on this area of cognitive performance, the difference between variance within these groups should be investigated further.

There could be several explanations for the greater variability of working memory performance of a population of not medicated ADHD children and adolescents compared to a sample of ADHD children and adolescents on and off their stimulant medication. However, due to the scope and limitations of this study, there could be many confounding factors that impact these results and were not assessed at this time. One simple explanation is that the children/adolescents who were prescribed stimulant medications for an ADHD diagnosis, may ALSO have the resources to have had other treatments for ADHD and other educational or extra support in school or at home. A second explanation could be attributed to lingering effects of stimulant medications lasting past their typical duration of action (i.e., duration of the active effect of medication). Most short-term formulations of stimulant medications last approximately

3-4 hours (most immediate acting formulations) and long-term formulations (most extended release) are made to work for up to 10-12 hours. Both types of daily stimulant medication are no longer considered active over night until the child takes another dose the following morning. All of these speculated ideas present several questions for follow up that cannot be inferred nor even conjectured by the present data but may be interesting areas of follow up:

A) Would a larger sample size confirm or negate these specific findings?

B) Would different time-dependent formulations of stimulant medications have different results?

C) Does continuous treatment with stimulant medication stabilize working memory performance over time? And/or is amount of time having taken the medication a mediating effect on this relationship?

Processing Speed. Interestingly, the above pattern discussed was NOT found in regard to processing speed performance results. Within an area of research with such a broad range of possible confirmatory and equally contradictory results available, this may not be particularly unexpected. However, the focus on the present study was actually more on the consistency in performance across testing days, NOT higher or lower performance. Therefore, a particular more global implication from this research may be that consistency of cognitive ability performance should and could be more of a focus of future research when considering efficacy or impact of treatments. Consistency in performance may be qualitatively and practically more beneficial to measure as a positive indicator of treatment instead of a focus on "improvement" or higher ("strengths") or lower ("deficits") abilities as measured by one assessment at one point in time especially when considering working memory and processing speed.

Perceptual Speed. Lastly, when considering the results comparing Day 1 processing speed performance versus Day 2 perceptual speed performance, there is less of a correlation (i.e., less consistency in performance) found in Group 1 when the participants' medication status changed by day. By design of the study and hypotheses presented, this was purported to indicate a significant medication effect present from use of stimulant medication compared to the clinical control group with no medication status differential. However, while this is concordant with the hypothesis that the related area of functioning would be impacted by status of stimulant medication, this result presents an interesting anomaly that is particularly puzzling since this effect was NOT seen within the processing speed comparative results. This is somewhat perplexing because of the commonality of most subtests that aggregate to form most of the indices/clusters involved in both analyses. As mentioned previously, the results from Hypothesis 3 within Research Question 1 comparing the WISC-IV and WISC-V correlations to the WJ IV COG clusters, there was a higher correlation between the WJ IV COG P and then WISC-V PSI than the previous WISC version, with the only discernable difference of previously mentioned minor changes within the Coding and Symbol Search subtests. This could have made them more accurate of a measure perhaps but this difference did not show in Hypothesis 2 when comparing directly to the Cognitive Processing Speed cluster on the WJ IV COG. Hence, the only difference between the Perceptual Speed cluster and the Cognitive Processing Speed cluster on the WJ IV COG is the Number Pattern Matching subtest instead of the Pair Cancellation subtest, respectively. As such, the question exists: Would that mean the medication effect lies more within the performance on the Number-Pattern Matching subtest and NOT Pair Cancellation subtest? Unfortunately, the same analysis cannot be used to address this question in the same

way as the hypothesis presents the indices due the manner the subtests standard scores are calculated and presented between measures.

Additional Areas of Implications

Several other areas of focus within this study address problems mentioned within the literature review and will be discussed below.

Addressing Methodological Issues. One aim of this study outside of the direct research questions was to attempt to provide some alternative methodological solutions to common sources of limitations present in past similar studies. Past related studies include comparisons of cognitive "abilities" (i.e., "performance") or effects of stimulant medications or other treatments on areas of cognitive functioning. As mentioned within the literature review, common limitations present in such studies include practice effects, between instead of within subject designed comparisons, use of uncommon neurocognitive measures, and publication bias from journals and those invested in the results (e.g., pharmaceutical companies). The main endeavor of this study was to find patterns identifiable in ADHD diagnostic assessments especially in relation to stimulant medication use on commonly purported impacted areas of cognitive functioning. In the end, this study aspired to provide practitioners with important questions to consider when interpreting results of ADHD diagnostic performance on these measures especially in regard to simulant use, some of which include intriguing ways of assessing these abilities. The method used to answer the second research question specifically attempted to address methodological issues within the research of comparing performance of specific cognitive abilities impacted by stimulant medication use. A within design research method was used to address impacts of individual variability in between-subjects research. No pattern of deficits is agreed upon within working memory and processing speed performance for those diagnosed with ADHD and these

are actually noted as areas of significant variance in ADHD overall. In other words, one individual with ADHD may have high processing speed and low working memory abilities while another individual may have the opposite but either could comment on that particular individual's areas of growth or variability of performance within that area. Hence, the within comparison by correlational design of similar measures may present an alternative way to assess these areas for more or less variance in performance to target these areas for intervention or areas of strength for those with an ADHD diagnosis.

Another common issue to address was any performance bias related to practice effects when administering same or very similar measures to assess within performance. Therefore, a comparison between constructs on measures purporting to measure almost identical constructs was used. However, the comparison statistics needed to assess medication impact though were correlations within a normative population that were not present at the time both WISC-V and WJ IV COG tests were published. A lengthy literature review as well as inquiries with well-known authors in the field did not produce any leads to this data in the current literature.

Normative Correlations for Comparison. The first research question provided some useful information in the form of correlations of same/similar domains between the WISC-V and WJ IV COG, for future comparison that is not available in manuals or the literature at this time. However, the statistics produced in this study would not be as generalizable as a national purposive sample typically used in manual studies. As mentioned previously, this sample is not population-matched for demographics, age or other variables, and may represent a more clinically referred population with more ADHD diagnoses and learning disorders present than the populations used within manual studies. Further, the specific results related the Perceptual

Speed comparisons, as discussed, are particularly hard to decipher and interpret so may be in need of further scrutiny overall.

Implications for Efficacy of Treatment Indicators. As previously mentioned, the particular methods and subsequent results within this study may point to an alternative way of assessing if, how, and what indicators represent therapeutically efficacious results within these areas of cognitive functioning. The goal of many treatments has seemed to exclusively focus on an INCREASE in cognitive abilities. There is a high amount of evidence regarding efficacy of observed or reported decrease in behavioral symptoms with treatment for ADHD. However, when discussing treatment effects on cognitive abilities, the outcome measure is always about ameliorating deficits in these areas or increasing the higher limits of individuals' performance. Therefore, the methods and results of this study present another interesting area of questioning:

> Would it be more therapeutically beneficial to focus on the goal of more consistent performance in these neurocognitive areas, instead of just higher performance? In regard to applicability, would it be more therapeutically indicated for an individual to have a better idea of what to expect of themselves within an area of cognitive functioning on a regular basis and then be able to accommodate and provide themselves more regular, dependable assistance as needed?

There may be societal and cultural implications of broadening or even straying away from the focus on strict betterment or increase of cognitive performance. Perhaps a focus on more applicable and functional consistency in these abilities would encourage less culturally-biased promoted ideas of success. This would align with Counseling Psychology values of promoting multiculturalism and equitable focus of psychological research, intervention, treatments, and eliminating societal, cultural, and systemic bias as we continue to become more aware and able.

Limitations

There are several limitations in regards to the results of this study. One easily recognizable and problematic limitation is the small sample sizes for the analyses performed. While correlations performed within Group 2 may have adequate power, the comparisons used to answer the second research question and follow-up analyses were reliant on Group 1 statistics within a significantly small sample size. It was hoped by this researcher, to gain more participants within this group throughout the 2020-2021 year, however this was stymied by the COVID-19 pandemic in several ways.

Further, the convenience sample in this study presented several limitations associated with either lack of information available upon extracting past data or the common characteristics of the population that typically was referred to the counseling center of use in this study. There were limits of information able to be extracted from the records because the questions and assessment procedures varied somewhat by clinician and the evolution of testing procedures over the time period data was collected from. One particular area of interest that did not have uniform information was the specifics about the medications being taken by the participants. While name and dosage was typically indicated, there was a) no uniformity in dosage comparisons between different stimulant medications, and b) not enough data to compare between particular formulations of stimulant medications. Additionally, information regarding how long each participant had been on medication was not always indicated; this data could have presented additional information regarding long-term medication effect on more consistent or more variable performance. Typically, when participants were involved in other interventions such as tutoring, this information was included within reports although not in a uniform fashion and

including all possible interventions as a measurable variable. Further, any other behavioral interventions or accommodations at home or school were not often noted either.

The other area of limitation regarding the convenience sample, involves the particular clinical population who commonly are referred to the center. The counseling center does not accept insurance and therefore all clients who receive services at the center pay out of pocket. However, the price of a full psychological assessment is still a fraction of the price of community psychoeducation evaluations. Additionally, this group could have consisted of a larger number of participants with ADHD diagnoses than present in typical population as well as just a clinical population and not a population-compared normative population sample and therefore may produce particularly weighted or skewed results.

Recommendations for Future Research

Several suggested questions for further investigation have already been presented and discussed throughout analysis and discussion of the results of this study as they became applicable. Several more worth mentioning may be indicated by the present research. Broadly, the current research should be replicated and the results should be confirmed or negated with a larger sample. The samples should be more generalizable and population matched. As mentioned, the design and focus on consistency of performance when considering treatment impact may be an interesting formulation to integrate into efficacy testing protocols. Accordingly overall, there is a need of similar studies on larger scales with consistent information about medications and dosages, longevity of medication treatment. It also may also be useful for further investigation to break groups down into smaller age groups especially when considering cognitive areas that may be more or less impacted by developmental trajectory.

Conclusion

In conclusion, this study presents nominal data, methods, and areas of questioning within the realm of ADHD assessment and areas of potential impact of this diagnosis and intervention and treatments. It also presents alternative viewpoints of measuring cognitive performance that is in accordance with less bias on ideals of success within these areas.

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APPENDIX A: IRB APPROVAL LETTER

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Human Research Protection Program

EXEMPT DETERMINATION

May 1, 2020

Dear Linda Campbell:

On 5/1/2020, the Human Subjects Office reviewed the following submission:

Title of Study:	A STUDY INVESTIGATING THE EFFECTS OF STIMULANT MEDICATION ON PROCESSING SPEED AND WORKING MEMORY IN AN ADHD POPULATION
Investigator:	Linda Campbell
Co-Investigator:	Katherine Ellis
IRB ID:	PROJECT00001551
Review Category:	Exempt 4ii

We have determined that the proposed research is Exempt. The research activities may begin 5/1/2020.

Since this study was determined to be exempt, please be aware that not all future modifications will require review by the IRB. For more information please see Appendix C of the Exempt Research Policy (https://research.uga.edu/docs/policies/compliance/hso/IRB-Exempt-Review.pdf). As noted in Section C.2., you can simply notify us of modifications that will not require review via the "Add Public Comment" activity.

A progress report will be requested prior to 5/1/2025. Before or within 30 days of the progress report due date, please submit a progress report or study closure request. Submit a progress report by navigating to the active study and selecting Progress Report. The study may be closed by selecting Create Version and choosing Close Study as the submission purpose.

In conducting this study, you are required to follow the requirements listed in the Investigator Manual (HRP-103).

Sincerely,

Jennifer Freeman, IRB Analyst
Human Subjects Office, University of Georgia