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WISC-IV Profiles in Children with Attention Deficit Hyperactivity Disorder and Comorbid Learning Disabilities

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WISC-IV PROFILES IN CHILDREN WITH ATTENTION DEFICIT
HYPERACTIVITY DISORDER AND COMORBID
LEARNING DISABILITIES

by

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Bachelor of Arts in Psychology

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A thesis submitted in partial fulfillment of

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ABSTRACT

WISC-IV Profiles in Children with Attention Deficit Hyperactivity Disorder and Comorbid Learning Disabilities

by

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Attention Deficit Hyperactivity Disorder (ADHD) and learning disabilities (LD), including Reading Disorder (RD), Disorder of Written Expression (DWE), and Developmental Coordination Disorder (DCD) all co-occur at high rates. Previous research indicates increased neurocognitive impairment in ADHD with the presence of comorbid diagnoses. However, few direct comparisons between intellectual profiles of children with one or multiple ADHD and LD diagnoses are available, specifically for the Wechsler Intelligence Scale Fourth Edition (WISC-IV), despite its frequent and historical use with this population. Profile analysis may contribute insights into spared and impaired abilities. Therefore, the present study addressed these matters by comparing WISC-IV profiles of children with ADHD and comorbid LD. Participants included 301 children with ADHD-Inattentive ($n=101$), ADHD-Combined ($n=79$), ADHD-DCD ($n=42$), and ADHD-RD and/or Disorder of Written Expression (ADHD-RD-DWE) ($n=79$). Children were 10.2 years old, 69% male, with a Full Scale IQ of 101.5. Diagnoses of ADHD and learning disorders were established through comprehensive evaluations including behavioral symptom ratings, interviews with parents, and neuropsychological measures. Results indicated a significant group by Index score interaction, which was primarily caused by the ADHD-RD-DWE group performing

significantly worse ($p < .05$) on Verbal Comprehension Index (VCI) and Perceptual Reasoning Index (PRI) than all other groups. This group demonstrated a relatively flat profile, while the ADHD-DCD group demonstrated a sloping profile (VCI > PRI > Working Memory > Processing Speed). Differences in ADHD presentations were also found, with the ADHD-Inattentive group exhibiting slower processing speed than the ADHD-Combined group. Findings indicate differences in intellectual profiles of children with ADHD and LD as well as ADHD presentations. The combination of LD and ADHD results in unique intellectual profiles, indicating clinical and theoretical utility in distinguishing between these disorders. Further investigation is needed to determine the extent to which these profiles are predictive of academic, social, and behavioral outcomes.

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CHAPTER 1

INTRODUCTION

Children with Attention Deficit Hyperactivity Disorder (ADHD) exhibit a number of cognitive and behavioral abnormalities that are the direct result of the disorder itself, but that also result from coexisting learning disabilities (LD), which occur at a high frequency. Research indicates that Reading Disorder (RD) and Developmental Coordination Disorder (DCD) are among the most commonly co-occurring learning disabilities with ADHD (Mayes & Calhoun, 2006). Children with these comorbid conditions exhibit worse outcomes across a number of domains, including academic success, social skills, and occupational outcome in adulthood (Glomb, et al., 2006; Eden & Vaidya, 2008).

Intellectual assessment has been useful in characterizing the cognitive deficits demonstrated by these children for both clinical and research purposes. From a clinical perspective, results of intellectual assessments are commonly used to develop educational assistance plans and intervention methods, as well as measure treatment outcomes. From a research perspective, results of IQ batteries in combination with other neuropsychological and achievement tests have provided a framework for LD taxonomies as well as provided insight into brain regions that are differentially affected by the disorders.

However, currently available information for the commonly used Wechsler Intelligence Scale for Children (WISC) is limited in a number of respects, including limited research examining the impact that co-existing learning disabilities have on index and subtest score profiles. Previous research on the WISC-R and WISC-III indicates

children with comorbid ADHD and RD may demonstrate weaker performance on the Freedom from Distractibility Index (FDI) than children with ADHD alone, but have comparably low scores on the Processing Speed Index (PSI) (Rucklidge et al., 2002). The extent to which verbal deficits independent of reading ability and working memory abilities in children with ADHD and RD are impacted on the WISC-IV is currently ambiguous. Furthermore, research is needed to examine perceptual reasoning and working memory abilities in children with ADHD and DCD. For example, Loh, Piek, and Barrett (2011) found that these children received lower scores on their WISC-IV Perceptual Reasoning Index (PRI), compared to children with ADHD only. However, this study used a small sample and a shortened form of the WISC-IV, not including the Working Memory Index (WMI), which is an ability likely impacted by a diagnosis of DCD (Alloway, 2011).

While there is abundant literature on the WISC-III, there is evidence that revisions made in the development of the WISC-IV have altered some of the characteristics of the test. For example, while the Perceptual Organization (POI) factor has historically been sensitive to brain injury, recent studies of children with traumatic brain injury (TBI) suggest that the WISC-IV Perceptual Reasoning Index (PRI) is no more sensitive to brain injury than the Verbal Comprehension Index (VCI), which has been typically viewed as being resilient in the presence of brain injury (Allen et al., 2010; Donders & Janke, 2008).

Given the limitations apparent in the existing literature and the important role that IQ testing has played in the identification, treatment and research of LD, the current study examines WISC-IV performance in children and adolescents diagnosed with ADHD

only, compared to groups of children diagnosed with both ADHD and learning disorders.

In the following sections, information relevant to ADHD, learning disorders, and

intellectual assessment is discussed.

CHAPTER 2

LITERATURE REVIEW

Attention Deficit Hyperactivity Disorder

Attention Deficit Hyperactivity Disorder (ADHD) is a neurodevelopmental disorder characterized by poor attention, excessive activity, and impulsivity (APA, 2000). Developmentally inappropriate symptoms typically arise in childhood and may endure throughout adolescence and adulthood (Biederman, 2005). Symptoms manifest across more than one setting, such as home and school. This diagnosis is associated with poor outcomes in academic performance and social functioning (Daley & Birchwood, 2010; Barkley, 1990). ADHD is often the most commonly diagnosed psychological disorder in childhood (Barkley, 1998), with prevalence rates ranging from 3% to 7% (APA, 2000). Male to female ratios vary from 2:1 to 9:1, relative to differences in subtype and clinical setting (APA, 2000; Cuffe et al., 2005).

ADHD is classified into the following subtypes: predominantly hyperactive (ADHD-H), predominately inattentive (ADHD-I), and combined (ADHD-C). The Diagnostic and Statistical Manual of Mental Disorders, 4th Edition (DSM-IV; APA, 2000) defines ADHD-I as evidencing symptoms of inattention, such as poor sustained attention, difficulty attending to detail, and distractibility. Additionally, symptoms of hyperactivity (e.g., squirming) and impulsivity (e.g., difficulty awaiting turn and tendency to interrupt others) must be present for a diagnosis of ADHD-C. The predominantly hyperactive subtype is confined to symptoms of hyperactivity and impulsivity. Research primarily examines ADHD-I and ADHD-C and suggests that ADHD-C is often distinguishable from the other subtypes by increased externalizing

problems and diagnoses (Eiraldi et al., 1997; Morgan, Hynd, Riccio, & Hall, 1996).

These findings are not surprising given the increased symptoms required to meet criteria for ADHD-C.

Comorbid Learning Disorders

Children with ADHD are a highly diverse group with various comorbid conditions, including psychiatric diagnoses such as anxiety, mood, and substance use disorders (Bierdman, Newcorn, & Sprich, 1991; Kessler et al., 2006). Learning disorders co-exist at exceptionally high rates ranging from 25-40% (Barkley, 1998) within the broad category of LD, from 25-40% within Reading Disorder (RD) (August & Garfinkel, 1990; Semrud-Clikeman et al., 1992), and as high as 50% for Developmental Coordination (DCD) (Crawford & Dewey, 2008; Pitcher, Piek, & Hay, 2003). Reading Disorder is defined as deficits in reading achievement in areas such as speed, accuracy, or comprehension, compared to an individual's age, grade level, and general intelligence (APA, 2000). Disorder of Written Expression is characterized by deficits in writing, such as spelling, organization, excessive grammatical errors (APA, 2000). Developmental Coordination Disorder is characterized by deficits in the development of motor coordination, which is unexplained by the child's intelligence, neurological, or psychiatric disorders (APA, 2000). Children with this disorder often show observable behaviors such as poor posture, clumsiness, and difficulties holding a pencil.

The presence of these comorbid conditions are associated with increased cognitive, emotional, and academic impairments (Bonafina, et. al., 2000), as well as overlapping symptoms among the disorders. For example, DCD has been linked to similar psychosocial difficulties found in ADHD, such as emotional problems, behavioral

concerns, poor overall academic performance, and learning difficulties (Tseng, Howe, Chuang, & Hsieh, 2007; Dewey et al., 2002). The combination of RD and ADHD has been associated with poor motor coordination. For example, previous studies found children diagnosed with ADHD and RD exhibited more difficulties with visual motor coordination and planning compared to children only diagnosed with ADHD (August & Garfinkel, 1990; Robins, 1992). Additionally, children with ADHD may show deficits in motor performance and reading skills, yet not meet criteria for either LD diagnosis (Mayes, Calhoun, & Crowell, 2000). Similarly, children with an LD often exhibit symptoms of inattention without meeting criteria for ADHD. Because of the high frequency of comorbidity of ADHD, DCD, RD, and the overlap of symptoms further investigation of these disorders may provide insights into genetic susceptibility and atypical cognitive development.

Although LD research has largely focused on RD, DCD, and math deficits, some studies suggest that disorders of written expression exceed prevalence rates of mathematics or reading disorder (Mayes & Calhoun, 2006). Disorders of Written Expression also commonly co-occur with RD since both diagnoses result in deficiencies in language skills and require similar cognitive abilities (Parodi, 2006; Lindstrom et al., 2007). Writing is commonly understood as expressive language and reading understood as a receptive language skill. However, these psycholinguistic processes are interrelated in that the production of written language depends on comprehension capabilities (Shanahan, 1997). Previous studies found positive correlations between reading and writing performance (Stotsky, 1983; Shanahan & Lomax, 1986; Tierney & Shanahan, 1991), suggesting a common cognitive mechanism underlies both reading and writing

performance (Parodi, 2006; Sadoski & Paivio, 2001). Furthermore, it is relatively rare to receive a diagnosis of Disorder of Writing Expression in the absence of a Reading Disorder (APA, 2000). Research also indicates that this diagnosis may be a direct consequence of language and word decoding deficits resulting in RD (Lindstrom, 2007). Therefore, the present study has included Disorder of Written Expression and combined cases with RD in subsequent theoretical understanding, hypotheses, and analyses.

Etiological Theories

The frequency of comorbidity of symptoms and diagnoses suggests implications for etiology (Crawford & Dewey, 2008). Different theorists have made conjectures about the established overlap in neurodevelopmental disorders. Gilger and Kaplan (2001) proposed a generalized atypical brain development (ABD) framework that emphasizes nonspecific developmental deficits rather than distinct diagnoses. They suggest ABD should be used in conjunction with current diagnostic definitions as a guide to understanding the proposed common etiology of these disorders. However, others have suggested these disorders are independent in etiology and individual differences in symptom profiles should not be overlooked (Crudance & Riddell, 2006).

A substantial body of research has investigated the genetic relationship between ADHD and RD. Willcutt and colleagues (2005) examined four common hypotheses explaining this comorbidity. Founded on population base rates for the respective disorders, the cross-assortment hypothesis suggests an individual with a diagnosis of ADHD is more likely to choose a partner with RD and vice versa. Thus, genetic susceptibility in both parents results in an additive combination of symptoms from each disorder. Faraone and colleagues (1993) found this theory to best explain the

comorbidity rates of ADHD and RD when examining biological relatives of children diagnosed with ADHD. However, following studies (Doyle et al., 2001; Friedman et al., 2003) did not replicate these results indicating the cross-assortment hypothesis may not provide a basis for most cases of comorbidity.

The phenocopy hypothesis proposes that a diagnosis of one disorder results in an increased risk for manifesting symptoms of another disorder (Pennington, Groisser, & Welsh, 1993). For example, a child with reading difficulties may exhibit symptoms of inattention and hyperactivity due to frustration with reading rather than neurocognitive difficulties related to RD. However, subsequent research in larger samples has not supported the phenocopy hypothesis (Rucklidge & Tannock, 2002; Seidman, et al., 2001; Willcutt, et al., 2001).

Another proposal is the cognitive subtype hypothesis suggesting children with both ADHD and RD possess distinct etiological factors from children that develop ADHD or RD alone. Thus, children with comorbid ADHD and RD would have different symptomology and cognitive deficits than individuals with only one disorder. Research regarding this hypothesis is inconclusive and requires further investigation. Rucklidge and Tannock (2002) supported this hypothesis by finding their comorbid group performed significantly worse on color naming measures than the groups with only ADHD or RD. However, other studies found that groups with ADHD and RD exhibited similar cognitive deficits suggesting an additive combination from each individual disorder (Pisecco et al., 2001; Swanson, Mink, & Bocian, 1999; Willcutt, et al., 2001).

Finally, Willcutt and colleagues (2005) examined the common etiology influences hypothesis describing a mutual genetic basis for the high co-occurrence of ADHD and

RD. This hypothesis assumes cognitive deficits in each disorder are partly shared; meaning children with comorbid diagnoses will have similar weaknesses as children with only one diagnosis (Willcutt et al., 2003). Twin studies have implicated that RD and ADHD separately are highly heritable and polygenic (DeFries & Alarcón, 1996; Faraone et al., 2001; Fisher & DeFries, 2002), as well as providing evidence suggesting common genetic influences impacting comorbidity (Stevenson et al., 1993; Willcutt, et al., 2003).

Etiological research on DCD and ADHD has largely resembled the research on co-occurring ADHD and RD. Evidence suggests DCD and ADHD have a shared genetic heritability (Martin, Piek, & Hay, 2006). Others have suggested that there are differences in cognitive symptomology providing evidence against the common etiology influences hypothesis (Loh, Piek, & Barrett, 2011). These etiological theories provide theoretical foundations for examining cognitive similarities and discrepancies in ADHD and LD.

Wechsler Intelligence Scale for Children Profiles

Because ADHD, RD, DWE, and DCD are not only genetically, but also cognitively related (Nigg, Hinshaw, Carte, & Treuting, 1998; Rucklidge & Tannock, 2002; Willcutt, et al., 2005), the existing literature has attempted to distinguish shared and distinct cognitive deficits among these disorders. Research has used a variety of cognitive measures including intelligence, academic achievement, and working memory measures (Alloway, 2011). Particularly, the Wechsler Intelligence Scale for Children (WISC) is widely used for this purpose because of its extensive history of use and sensitivity to cognitive deficits within this population (Loh, Piek, & Barrett, 2011; Mayes & Calhoun, 2006). One of the earliest examples is a study by Nelson and Warrington (1974) that demonstrated children with LD commonly have lower WISC Verbal IQ,

relative to their Performance IQ. WISC profile analysis using composite scores as well as individual subtest performance continues to be a widely used practice in determining cognitive strengths and deficits within each disorder (Hale, Fiorello, Kavanagh, Hoepfner, & Gaither, 2001; Kramer, 1993; Hjelmquist, & Gillberg, 2001).

Despite frequent use of the WISC in clinical populations, more research is needed to examine the newest version of the WISC, the WISC-IV. The structure of the most recent revision of the Wechsler Scales differs in notable aspects from its forerunners. Earlier reorganization was a reaction to evidence supporting alternatives to the original verbal-performance dichotomy of intelligence. Previous research supported three factor latent structures comprised of Verbal Comprehension, Perceptual Organization, and Freedom from Distractibility factors. Further research led to a fourth processing speed factor, which addressed evidence indicating the instability of the Freedom of Distractibility factor (Chan, 1984; Stewart & Moely, 1983). Furthermore, efforts were made to address theoretical considerations and align the WISC indexes with theories, primarily the Cattell-Horn-Carroll (CHC) theory of intelligence (Keith et al., 2006). Thus, the four revised index scores were derived from factor analytic work and theoretical concerns, making the revised test an empirically salient assessment of actual underlying cognitive functions.

Most recently, changes from the WISC-III to the WISC-IV include renaming the FDI to the Working Memory Index (WMI) and replacing Arithmetic with Letter-Number Sequencing within this index. This change is intended to better measure working memory by decreasing the need for mathematical academic knowledge. Three of four subtests on the WISC-III POI and VCI have been retained in the WISC-IV PRI and VCI.

Two timed visual-motor subtests (Picture Arrangement and Object Assembly) were removed from the POI and replaced with two motor-free visual reasoning subtests (Picture Concepts and Matrix Reasoning). Thus, there is less emphasis on motor coordination and speediness on the PRI, which may be an advantage to groups with limitations in these skills. On the VCI, the Information subtest was changed from a core to supplemental subtest, increasing emphasis on verbal reasoning rather than verbal academic abilities. Despite alterations to subtests and indexes the WISC-III and IV have a high correlation (0.88) on Full Scale Intelligence Quotient (FSIQ) and Indexes ranging from 0.72 to 0.88 (Wechsler, 2003). However, the extent to which alterations in the WISC-IV impact scores in clinical populations is not yet fully understood.

Attention Deficit Hyperactivity Disorder

Extensive research has examined WISC-R and WISC-III profiles for clinical cases. Various studies have demonstrated that children with ADHD have characteristically lower FDI and PSI, relative to their scores on the POI and VRI (Calhoun & Mayes, 2005; Naglieri, Goldstein, Iseman, & Schwebach, 2003; Wechsler, 1991). Additionally, children with ADHD demonstrate significantly worse performance on the Coding subtest compared to Symbol Search subtest even though these are the two primary measures contributing to the PSI (Calhoun & Mayes, 2005; Mayes & Calhoun, 2003; Naglieri et al., 2003; Snow & Sapp, 2000; Wechsler, 1991). Extensive research has shown that poor performance on the Coding subtest is strongly associated with neurological dysfunction (Fiedorowicz et al., 2001; Hooper & Tramontana, 1997; Light, Pennington, Gilger, & DeFries, 1995), which provides some support for neurobiological theories of ADHD.

While considerable research has validated these WISC-III profiles, revisions to the WISC-IV may affect their generalizability for children with ADHD and learning disabilities. Currently, limited data are available regarding the effects of WISC-IV revisions to profile analysis. The technical manual for the WISC-IV reported similar patterns of performance as on the WISC-III for a small sample of children with ADHD. This sample performed poorest on the WMI and PSI, indicating difficulties with short-term storage and the manipulation of information (working memory), as well as quickly performing simple clerical tasks (processing speed) (Wechsler, 2003). The highest scores for this sample were for subtests comprising the VCI and PRI. The only study to date comparing WISC-III and WISC-IV profiles in children with ADHD found that they produced comparable results in that the lowest scores were obtained on subtests that composed the FDI/WMI and PSI (Mayes & Calhoun, 2006). Furthermore, the WISC-IV results demonstrated larger index discrepancies, indicating the new version might have increased sensitivity to ADHD.

Furthermore, other measures confirm WISC findings of weaknesses in processing speed and working in children with ADHD. For example, measures such as the Trail Making tests (Shanahan et al., 2006), Stroop color word naming (Willcutt, 2010), and reaction time on continuous performance tasks have also provided evidence for processing speed deficits in ADHD (Wodka et al., 2007). Additionally, working memory tasks such as the verbal working memory (VWM) test from the WRAML-2 (Sheslow & Adams, 2003), spatial span (Alloway, 2011), and Corsi blocks have demonstrated weaknesses in verbal and visuospatial working memory (Martinussen, Hayden, Hogg-Johnson, & Tannock, 2005). These findings are relevant to understanding deficits in

children with ADHD, because processing speed and working memory abilities have important implications for academic achievement. For example, decreased processing speed can lead to poor reading fluency, which consequently impacts other cognitive processes (Jacobson et al., 2011). Furthermore, working memory scores predict reading achievement separate from phonological abilities in normal children (Swanson & Beebe-Frankenberger, 2004). Difficulties with working memory have also been associated with worse performance on mathematical computation and story problem solving (Bull & Scerif, 2001; Geary, Hoard, & Hamson, 1999; Swanson & Sachse-Lee, 2001), and reading (Alloway et al., 2009). Thus, working memory deficits present in children with ADHD may also result in further academic difficulties, beyond symptoms directly related to their diagnosis. These problems with working memory may stem from a lack of behavioral inhibition within this population (Barkley, 1997; Pennington & Ozonoff, 1996).

Past research has also investigated differences between ADHD subtypes, but found less consistent evidence for distinct neuropsychological profiles among these groups. Numerous studies found no significant cognitive differences across ADHD subtypes, which may call into question the validity of the subtypes (Chhabildas, Pennington, & Willcutt, 2001; Hinshaw et al., 2002; Huang-Pollock, Nigg, & Carr, 2005). However, studies that found differences suggest children ADHD-I often exhibit a sluggish cognitive tempo and slower processing speed than children diagnosed with ADHD-C (Barkley, Grodzinsky, & DuPaul, 1992; Calhoun & Mayes, 2005; Hartman, Willcutt, Rhee, & Pennington, 2004). Mayes and colleagues (2009) reported that the WISC-III and WISC-IV captured this distinction by finding significantly lower PSI

scores in the ADHD-I group compared to the ADHD-C groups. However, other studies do not find differences between ADHD subtypes on IQ and processing speed measures (Chhabildas, Pennington, & Willcutt, 2001; Farone et al., 1998). Thus, further research is required to determine whether profile differences do exist between the ADHD subtypes.

Reading Disorder

Because little research has investigated comorbid ADHD with RD and DWE, research examining deficits in children with only RD may be useful in predicting performance in comorbid groups. For instance, Kaufman (1981) suggests dyslexia, a specific reading disability, is associated with poor performance on Arithmetic, Coding, Information, and Digit Span subtests (ACID profile). Kaufman (1994) later altered the profile with Symbol Search rather than Information appearing among the weakest subtest in children with RD (SCAD profile). These profiles indicate that Verbal IQ (VIQ) will be lower compared to Performance IQ (PIQ) in this population. However, this pattern of performance is sometimes reversed, which may be due to the variability within children with dyslexia (Thomson, 2003). Furthermore, studies on the WISC-R and WISC-III indicate that children with RD perform significant worse on the FDI and PSI compared to their VCI and POI (Thomson, 2003). Kaufman suggests that the Freedom from Distractibility factor may “hold the key to competent LD assessment” (1981, p. 521).

Research investigating the WISC-IV demonstrated similar results for the WMI and PSI. For example, De Clercq-Quegebeur and colleagues (2010) found children with dyslexia performed significantly worse on the WMI with weaker performance on the PSI compared to their VCI and PRI. Similarly, Wechsler (2003) found that children with RD performed poorest on the WMI. These findings relate to the cognitive deficits of

phonological processing already associated with RD (Swanson, 1999). Specifically, Digit Span and Letter Number Sequencing subtests require information to be processed in the phonological loop of the working memory system (Baddeley, 2001).

In contrast to WMI and PSI findings, De Clerq-Quegebeur and colleagues (2010) did not show significant impairment on the WISC-IV VCI and PRI measures. This result also supports research showing advanced language abilities can develop in children with RD (Vellutino et al., 2004). Despite these findings, Wechsler (2003) found that Vocabulary was among the lowest scored subtests in children with RD. This population has limited reading development, which may suppress their ability to gather and retain verbal information (Stanovich, 1986).

Research on both ADHD and RD individually demonstrate deficits in working memory and processing speed. While there is considerably less research investigating WISC profiles in children with comorbid ADHD and RD, some studies have demonstrated a distinct cognitive profile. For example, Rucklidge and colleagues (2002) used a shortened version of the WISC-III (Vocabulary, Block Design, Arithmetic, Digit Span, Symbol Search, and Coding subtests) to examine a group with ADHD, RD, and comorbid ADHD and RD. Results indicated that children with ADHD showed impairment on the PSI, while the children with only RD performed worse on FDI. The group with comorbid conditions reflected the RD group and performed significantly worse on FDI than the ADHD and control groups.

Further research found similar results using some subtests from the WISC-R and WISC-III as part of a comprehensive battery examining processing speed and working memory (Wilcutt et al., 2005). The results indicated that the comorbid groups performed

significantly lower on the working memory measures (Digit Span and Arithmetic), than the ADHD only group. Although, each clinical group performed significantly lower on PSI than the controls, there were not significant differences among the clinical groups. Thus, the research suggests children with comorbid ADHD and RD exhibit worse performance on the WISC-R and WISC-III FDI than children with ADHD (Rucklidge et al., 2002; Wilcutt et al., 2005), yet have comparably low scores on the PSI (Shanahan et al., 2006; Wilcutt et al., 2005). Furthermore, Wilcutt and colleagues (2010) found that children with comorbid ADHD and RD performed worse on WISC-R subtests than children with ADHD only, indicating verbal reasoning deficits were present and detected by the previous WISC. However, it has yet to be determined if the WISC-IV is sensitive to these verbal reasoning deficits in children with ADHD and RD.

Developmental Coordination Disorder

While DCD is primarily characterized by fine and gross motor deficits, some research suggests children with DCD also exhibit deficits in visual perception independent of motor functioning (Tsai, Wilson, & Wu, 2008; Piek and Pitcher 2004). For instance, Tsai, Wilson, and Wu (2008) found this population performed worse than a control group on a motor-free visual discrimination task as part of the Beery-Buktenica Developmental Test of Visual–Motor Integration (VMI; Beery 1997) evaluating perceptual abilities. This measure is of particular interest to the current study because of its correlation (0.66) with the WISC (VMI Manual), indicating a similar cognitive element in the VMI.

Although evidence suggests deficits in visual perceptual reasoning in DCD, some studies indicate this ability might be partially or fully preserved as well as independent of

visual motor difficulties in children with DCD (Schoemaker et al., 2001; Bonifacci, 2004; Henderson et al., 1994). For example, children with visual motor integration difficulties performed significantly worse on gross motor tasks, yet there were no significant differences in perceptual abilities (Bonifacci, 2004). Furthermore, previous studies indicate visual perceptual deficits in children with DCD may be accounted for by the presence of comorbid conditions (Crawford & Dewey; 2008; Jongmans et al., 2003) and the motor component frequently within perceptual measures (Schoemaker et al., 2001).

Studies using previous Wechsler scales found worse performance on the PIQ (Coleman, Piek, & Livesey, 2001; Piek & Coleman-Carman, 1995; Henderson & Hall, 1982), and PSI (Smyth & Glencross, 1986; vanDellen & Geuze, 1988). However, these findings may be due to the motor component in the subtests composing the PIQ (Coleman et al., 2001). Studies examining co-occurring DCD and ADHD found comparable results for visuoperceptual abilities, processing speed, and working memory. For example, Loh, Piek, and Barrett (2011) found evidence that children with DCD and comorbid ADHD demonstrated significantly worse perceptual reasoning abilities than a sample of children with only ADHD on the WISC-IV. This result suggests visuospatial difficulties present in DCD, which are not apparent in ADHD. Additionally, this study found that the comorbid group performed significantly lower on PSI than the comparison group, but not significantly different from the ADHD group. This finding resonates with other studies indicating children with DCD generally work slower than typically developing children (Piek & Skinner, 1999).

However, Loh and colleagues (2011) had small samples of children and used a prorated version of the WISC, which did not include the WMI that may provide further

insights into working memory deficits detected by other measures (Alloway, Rajendran, and Archibald, 2009; Piek, Dyck, Francis, & Conwell, 2007). For example, Alloway (2011) found decreased performance on all working memory tasks in the Automated Working Memory Assessment (AWMA; Alloway, 2007) in children with DCD. Particularly, this group received lower scores on measures targeting visuospatial working memory, while the group with ADHD performed poorly on both verbal and visuospatial working memory measures. The author suggests that while ADHD and DCD share a common deficit in working memory, the cognitive processes in each condition may be different. Perceptual difficulties in children with DCD may result in worse working memory performance by impacting the visuospatial sketchpad (visual storage system) theorized to be a component of the working memory system (Piek, et al., 2007; Baddeley, 2003). Whereas, working memory deficits exhibited in ADHD may be a consequence of the attention component required to perceive and manipulate information (Chhabildas Pennington, Willcutt, 2001; Piek et al., 2007).

Affected Brain Regions

Some insight into cognitive profiles in these groups is provided by research indicating that ADHD subtypes, RD/DWE, and DCD have distinct underlying biological substrates and core behavioral symptoms. For example, neuroimaging and animal studies indicate that the symptoms of ADHD are associated with the prefrontal cortex (PFC) (Dalley et al., 2008; Seidmen et al., 2005; Dalley et al., 1999, & Whishaw et al., 1992), caudate nucleus (Krain & Castellanos, 2006; Castellanos et al., 2002), and primary motor cortex (Buchmann et al., 2006; Moll et al., 2000). The prefrontal lobes are implicated in working memory abilities within this disorder (Klingberg, Forssberg, & Westerberg,

2002), while premotor circuits are more associated with slower processing speed in ADHD (Jacobson et al., 2011). Furthermore, neuroimaging and neurophysiological data provide evidence for neurobiological differences between ADHD subtypes (Mayes et al., 2009; Barry et al., 2006; Clarke, Barry, McCarthy, & Selikowitz, 2001; Johnstone, Barry, & Dimoska, 2003). Reading disabilities are characterized as a language-based disorder, which results in pervasive symptoms of poor phonological processing, writing, working memory, and processing speed (Bruck, 1992; Denckla, 1993; Maughan & Carroll, 2006). Research indicates that cognitive symptoms in RD are a result of unique morphological differences in the planum temporale and perisylvian cortex (Galaburda, 1994) that are not prevalent in children with only ADHD (Hynd et al., 1990). Furthermore, fMRI studies indicate disruptions in specific left-parieto-temporal and occipito-temporal circuits, which are thought to be unique to reading disorders (Shaywitz & Shaywitz, 2005). In contrast to ADHD, verbal working memory (Zayed et al., 2013), processing auditory information (Desroches et al., 2013), and processing speed deficits (Breznitz, 2003) in RD are related to brain circuits involved in phonological processing. Finally, writing requires coordination between multiple brain regions coordinating the neuropsychological abilities of executive functioning, language development, and motor output (Berninger, 1996). In DWE, the network functioning of these regions is disrupted, meaning that multiple regions, including Broca and Wernicke's areas for language processing are affected (Bennett, McHale, & Soper, 2011). Furthermore, DWE may be a direct consequence of language, phonological processing, and word decoding deficits resulting in RD (Lindstrom, 2007; Hale & Fiorello, 2004). Thus, similar neurological mechanisms involved in RD are likely disrupted in DWE. Finally, research indicates that

motor deficits in DCD are associated with cerebellar (Cantin et al., 2007; Zwicker, Missiuna, & Boyd, 2009) and parietal lobe (Zwicker, Missiuna, & Boyd, 2009; Peters et al., 2013) dysfunction, which may also account for poor perceptual abilities observed in this population. Thus, there is both biological and clinical evidence supporting distinct brain regions associated with ADHD and comorbid LD, which may result in distinct cognitive profiles. Additionally, when a child has comorbid disorders, there may be multiple dysfunctional circuits compounding deficits, resulting in lower scores on IQ indexes.

Conclusion

Research indicates working memory and processing speed are both impacted by separate diagnoses of ADHD, RD, and DCD. However, the current literature suggests these deficits are due to distinct underlying causes of each disorder, which may result in varying degrees of impairment. The degree to which these cognitive processes are impacted by comorbid diagnoses is currently ambiguous in certain respects. For example, consistent findings have shown children with ADHD perform worse on the WMI and PSI compared to their VCI and PRI (Calhoun & Mayes, 2005). However, distinct differences in ADHD-I and ADHD-C subtypes are currently unclear. Whereas Mayes and colleagues (2006) found children with ADHD-I demonstrated a sluggish cognitive tempo and consequently a slower WISC PSI, children with anxiety and depression were included, which may impact performance. Furthermore, many studies found no differences between subtypes on other cognitive assessments (Huang-Pollock, Nigg, & Carr, 2005).

With regard to children with ADHD and RD, Rucklidge and colleagues (2002) found that these children appear to perform poorly on the FDI, compared to children with ADHD only. Thus, it is expected that this finding may translate into the WMI on the updated WISC-IV. While it might be anticipated that children with RD would perform worse on the VCI due to the reading capacities required for verbal development, some research indicates otherwise (De Clerq-Quegebeur et al., 2010; Eckert et al., 2003). However, few studies have investigated this phenomenon in children with both RD and ADHD. Finally, Loh and colleagues (2011) found children with DCD demonstrated lower PRI, compared to children with ADHD only. However, it is unclear the magnitude to which perceptual reasoning is impacted in DCD, because other evidence suggests this disorder is primarily confined to motor dysfunction rather than perceptual abilities (Bonifacci, 2004).

Because of the limitations in the current research, it is imperative to examine differences in IQ profiles across neurodevelopmental comorbid condition. This analysis may provide a unique perspective into specific deficits related to each diagnosis, thus offering evidence for distinct cognitive deficits as a result of each disorder.

Research Aims and Study Hypotheses

Given the limited research examining distinct comorbid learning disorders on cognitive function in ADHD, research is needed to disambiguate cognitive profiles within these populations. Thus, the aim of the current study is to examine the effect of comorbid learning conditions on WISC-IV performance in children with ADHD. If distinct learning disorders have a unique impact on WISC-IV profiles in ADHD, it is predicted that:

Hypothesis 1

Children in the ADHD-Inattentive and ADHD-Combined subtypes will demonstrate lower scores on the WISC-IV PSI and WMI compared to their VCI and PRI scores, with the ADHD-I group exhibiting worse performance on the PSI, than the ADHD-C group.

Hypothesis 2

The ADHD-RD group will exhibit worse performance on the WMI and VCI, with comparable scores on the other Indexes, when compared to the ADHD only groups.

Hypothesis 3

The ADHD-DCD group will demonstrate worse performance on the PRI and comparable scores on the other Indexes when compared to the ADHD only groups.

CHAPTER 3
METHODOLOGY

Participants

Children will be included in this study if 1) they had a diagnosis of ADHD-C, ADHD-I, comorbid ADHD and DCD, or comorbid ADHD and Reading Disorder and/or Written Expression Learning Disorder; 2) they had no comorbid pervasive developmental disorder, traumatic brain injury, or other neurological conditions; 3) they were administered the WISC-IV as part of a clinical evaluation. Participants included 301 children with ADHD-Inattentive ($n=101$), ADHD-Combined ($n=79$), ADHD-DCD ($n=42$), and ADHD, RD, and/or Writing Disorder ($n=79$). The sample was 69.1% male, 10.17 years of age on average, and 64.5% attended a private school. Information regarding ethnicity was not available for this sample.

Measures

The WISC-IV is designed to assess cognitive abilities in children 6 to 16 years of age, including verbal and perceptual reasoning abilities as well as working memory and processing speed. These abilities are reflected in four index scores, including a Verbal Comprehension Index (VCI), Perceptual Reasoning Index (PRI), Working Memory Index (WMI), and Processing Speed Index (PSI). A Full Scale IQ (FSIQ) score may also be calculated by combining these indexes, and serves as an estimate of general intellectual ability. The Indexes and the Full Scale IQ are standard scores with means of 100 and a standard deviation of 15. Index scores are measured using 15 subtests, 10 of which are considered core subtests and 5 considered supplemental. These subtests have a mean of

10 and a standard deviation of 3. In the following sections a detailed description is provided for each index score and its corresponding subtests.

WISC-IV Verbal Comprehension Index (VCI). This index involves the expression of verbal concepts, application of previously acquired verbal knowledge, and academic aptitude. These skills are greatly impacted by a child's education and familiarity with U.S. culture. The VCI is composed of the following subtests:

Vocabulary. This subtest requires a child to define words with increasingly difficult vocabulary.

Similarities. This task assesses a child's ability to recognize conceptual similarities between words.

Comprehension. Children must answer questions related to their knowledge of general information and social situations.

WISC-IV Perceptual Reasoning Index (PRI). The PRI assesses nonverbal reasoning abilities requiring attention to visual elements, spatial skills, and forming abstract concepts without words. This index is composed of the following subtests:

Block Design. This task involves arranging blocks to match a designated pattern within a specified time limit.

Picture Concepts. The subtest asks children to choose pictures based upon their abstract relationship to one another.

Matrix Reasoning. Participants choose pictures to complete a visual and conceptual pattern.

WISC-IV Working Memory Index (WMI). The WISC-IV WMI assesses auditory short-term memory, the ability to hold and manipulate information, and the effectiveness of encoding strategies a participant may use. This index also requires good attention and concentration. The WMI is composed of the following subtests:

Digit Span. Participants are asked to repeat an increasing series of numbers forward and backwards.

Letter-Number Sequencing. Children mentally manipulate an auditory list of letters and numbers and say them in ascending numerical and alphabetical order.

WISC-IV Processing Speed Index (PSI). This composite score measures the ability to perform simple, clerical-type tasks quickly and efficiently.

Coding. Participants quickly copy geometric symbols or numbers that are paired with numbers according to a key.

Symbol Search. Children identify the presence or absence of a target symbol in a row of geometric symbols.

The WISC-IV was standardized on a nationally stratified sample of 2,200 children, who were selected based on the 2002 U.S. census data to provide a representative sample of age, sex, race/ethnicity, geographic region, and socioeconomic status (parental educational attainment) within the United States population. Samples were obtained from states that represented each of the four major U.S. geographic regions used in the 2000 U.S. census (Northeast, South, Midwest, and West). Categories for race and ethnicity included White, African American, Hispanic, Asian, and Other.

The sample was divided into 11 age groups, which allows for calculation of age corrected standard for subtest, Index and IQ scores. Across all age groups, the reliability (internal consistency) of the Composite Indexes ranged from .88 to .97, and the reliability for the subtests ranged from .79 to .89 (The Psychological Corporation, 2003, Table 4.1, p. 34). Test-retest reliability ranged from .86 to .93 across indexes establishing stability of the measure (The Psychological Corporation. 2003, Table 4.4, p. 40). Evidence for the strong validity of the test scores was based on test content, response processes, internal structure, and intercorrelation studies. Additionally, there is strong evidence indicating the WISC-IV is a reliable and valid measure for children with ADHD and LD (The Psychological Corporation. 2003, Table 5.29 & 5.30, p. 87-88).

Procedure

Participants in this study were selected from a consecutive series of 619 cases that were referred for neuropsychological evaluation over a period of 11 years. Children were primarily referred to the neuropsychologist primarily because they were experiencing academic problems, but presented with multiple complaints, such as learning difficulties, attentional deficits, mood and anxiety symptoms, and behavior disturbances in the home and at school, among others. Children were assessed by a neuropsychologist in private practice, in which only cash reimbursement was accepted. The neuropsychologist diagnosed children with ADHD and learning disorders according to DSM-IV diagnostic criteria based on parent and child interviews, neuropsychological testing, behavioral assessment, and other relevant information from medical and educational records. The WISC-IV was administered as part of larger battery, which included the Behavior Assessment System for Children (BASC), DSM-IV ADHD Symptoms Rating Scale,

Woodcock Johnson Achievement-Third Edition (WJ-ACH-III), and Wide Range Assessment of Memory and Learning (WRAML).

All assessments were administered according to standardized procedures, as indicated in testing manuals, by a neuropsychologist or clinical psychology doctoral candidates under supervision of the neuropsychologist. All measures were scored according to standardized procedures by a pediatric neuropsychologist or clinical psychology doctoral candidates under supervision of the neuropsychologist. Children were individually assessed in a quiet room in a private practice setting. Assessments took place within one day with total assessment times ranging from 3-6 hours. Children were given short breaks throughout the assessment to maintain their effort and attention toward testing materials.

Data Analyses

Data Entry and Screening

Data were double entered into a database and analyzed by SPSS version 19.0. During the preliminary data screening process, frequency distributions for all variables were inspected for out of range variables, which would indicate the presence of a data entry error. Also, all variables were evaluated as potential outliers to guarantee proper scoring and entry into the database. Outliers were defined as having a score ± 3.0 standard deviations above or below the mean. There were no outliers identified in the initial screening of the data. Skewness and kurtosis were also evaluated to ensure normal distribution of the data and were within accepted limits (skewness $< +/1$, kurtosis $< +/- 1.5$). Given the absence of outliers and the normal distribution of the data, parametric analyses were used to test the main study hypotheses.

Preliminary analyses

Prior to analyses on the primary hypotheses, descriptive statistics were calculated for each group on demographic variables, including age, gender, type of school (public or private), and current full-scale intelligence quotient (FSIQ). ANOVA and chi-square analyses were used to determine whether the four groups significantly differ on these variables.

Primary Analyses

The general approach to the analysis was to evaluate the study hypotheses using a mixed model ANOVA that contains group as a between subjects factor, and index score as a within subjects factor (repeated measure). Given that WISC-IV profiles differences are hypothesized for each of the groups, it was anticipated that the results of this analysis will produce a significant main effect for group, a significant main effect for WISC-IV Index, as well as a significant Group X WISC-IV Index interaction effect. Following a significant result for these initial analyses, ANOVAs and other appropriate procedures were used to test the specific predictions made in each hypothesis, by comparing index score differences within and between groups as appropriate.

CHAPTER 4

RESULTS

Descriptive statistics for the ADHD and LD groups are presented in Table 1.

Table 1

Demographic and Clinical Information of the Sample

Variable	Mean	SD	Range
Age (years)	10.2	2.8	6.0-16.4
Grade	4.5	2.7	K-10
FSIQ	101.5	11.9	61-142
VCI	104.8	13.7	67-148
PRI	103.4	12.1	71-137
WMI	97.6	12.4	62-144
PSI	95.9	12.6	70-136
	Frequency		
Diagnosis (%)			
ADHD-I	33.6%		
ADHD-C	26.2%		
ADHD-RD/DWE	26.2%		
ADHD-DCD	14.0%		
Gender (%)			
Male	69.1%		
Female	30.9%		
School (%)			
Public	64.5%		
Private	35.5%		
Comorbid Diagnoses			
ODD (<i>n</i> = 16)	5.3%		
Anxiety Disorder (<i>n</i> =21)	7.0%		
Mood Disorder (<i>n</i> = 11)	3.7%		
Adjustment Disorder (<i>n</i> = 70)	24.3%		

Note. FSIQ = Wechsler Intelligence Scale for Children Fourth Edition (WISC-IV) Full scale IQ. VCI = Verbal Comprehension Index; PRI = Perceptual Reasoning Index; WMI = Working Memory Index; PSI = Processing Speed Index ADHD-I = Attention Deficit Hyperactivity Disorder Predominantly Inattentive Type. ADHD-C = Attention Deficit Hyperactivity Disorder Combined Type. ADHD-DCD = Attention Deficit Hyperactivity Disorder and Developmental Coordination Disorder; ADHD-RD/DWE = Attention Deficit Hyperactivity Disorder and Reading Disorder and/or Disorder of Written Expression; ODD = Oppositional Defiant Disorder.

Chi-square analyses indicated significant differences among the ADHD-I, ADHD-C, ADHD-RD/DWE, and ADHD-DCD groups with regard to gender, $\chi^2(3) = 14.33, p < .01$. Post hoc analyses indicated that the ADHD-DCD group had significantly fewer females than the other groups. There were no significant differences among groups with regard to type of school (public/private), $\chi^2(3) = 2.18, p = .54$. One-way ANOVAs indicated that the groups differed significantly with regard to age, $F(3,297) = 10.66, p < .01$. Post hoc comparisons indicated that the ADHD-C group was significantly younger than the ADHD-I and ADHD-RD/DWE groups. Because the scores used in the main analyses were corrected for age and gender differences are not present on the WISC-IV scores, these differences were not considered in the main analyses.

Descriptive statistics for the ADHD and LD groups on the WISC-IV Index scores are presented in Table 2, as are the results for the mixed-model ANOVA examining potential differences between the groups on the WISC-IV Index scores.